# Leveraging Conjunctive Use to Develop a Cost-Effective Regional Alternative Water Supply Project

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Central Florida has historically utilized fresh groundwater as its primary potable water supply source. Over the past decade, the South Florida Water Management District (SFWMD), the St. Johns River Water Management District (SJRWMD), and Southwest Florida Water Management District (SWFWMD), whose boundaries meet in central Florida, have individually and collectively determined that fresh groundwater from the Floridan aquifer is a limited resource and cannot meet all future public water supply needs of the region. Surface water and groundwater levels, and spring flows, are some of the environmental measures the water management districts use to assess the environmental effects associated with groundwater withdrawals.

Local utilities have been developing plans and implementing projects to address the potential limitations on fresh groundwater supplies being identified by the water management districts. Utilities have implemented robust conservation programs and extensive reclaimed water reuse systems, including public-access reuse irrigation and aquifer recharge (among other programs). However, as growth continues in the central Florida region, conservation and beneficial reclaimed water reuse will not be able to keep up with increases in future water demands before the sustainable limits on traditional fresh groundwater supplies are reached in some areas. Due to this, the implementation of alternative water supply (AWS) projects will be needed to meet a portion of central Florida's future water demands.

To meet these future water supply needs in an environmentally sustainable manner, the City of St. Cloud (STC), Toho Water Authority (TWA), Orange County Utilities (OCU) and Polk County Utilities (PCU), comprising the Water Cooperative of Central Florida and Reedy Creek Improvement District (RCID), are cooperatively implementing the Cypress Lake AWS Project, a 37.5-mil-gal-per-day (mgd) annual average daily flow (AADF) Lower Floridan aquifer (LFA) brackish groundwater supply project. These utilities were issued a 30-year, 37.5-mgd AADF water use permit (WUP) by SFWMD to withdraw groundwater from the Cypress Lake wellfield in 2011.

Considering the anticipated use of membrane treatment technology, and the estimated recovery associated with lowering the dissolved solids of the brackish groundwater supply, the Cypress Lake project is anticipated to deliver at least 30 mgd of finished (potable) water. Once a WUP for the project was obtained, the utilities developed a preliminary design report for the raw water system and water treatment plant, and a conceptual design report for the finished water transmission system and integration of Cypress Lake Project finished water supplies into the utilities' existing potable water distribution systems. This article summarizes the conjunctive-use modeling performed in support of the development of a conceptual design report for the finished water transmission system.

## Conjunctive Use

The term "conjunctive use" is commonly applied to mean the use and management of multiple water supply sources to increase the available supplies while reducing the potential adverse effects associated with their use. The term is commonly applied to systems that utilize both surface water and groundwater sources where the surface water source may be seasonally unavailable and groundwater sources are overutilized to meet demands when surface water supplies are not available. However, the conjunctive use can apply to the management of many different types of water supplies.

For the Cypress Lake project, brackish groundwater from the LFA is the AWS source being implemented by the utilities. As a groundwater supply source, water from the Cypress Lake wellfield is available from a resource perspective to meet both average and daily peak demands of the utilities (unlike surface water sources that are sometimes seasonally unavailable). However, the utilities' WUP for the Cypress Lake project includes a maximum month allocation that is equal to the annual average allocation for the project. This limitation will cause it to be more challenging for the utilities to meet peak demands from the Cypress Lake project, while staying in compliance with current WUP conditions.

In addition, the Cypress Lake project requires advanced treatment to reduce chlorides, total dissolved solids, and other constituents present in the raw water to meet drinking water standards. Through a parallel project to develop the preliminary design of the Cypress Lake water treatment plant, it was determined that membrane treatment was the preferred technology for the Cypress Lake project and that it would not be cost-effective to design the facility to meet peak daily demands. Instead, the Cypress Lake water treatment plant is being designed to provide a constant supply of finished water (i.e., base-loaded supply).

These regulatory and cost considerations will result in the water treatment plant for the

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project being designed to not fully meet the utilities' peak demands associated with the Cypress Lake project. Conjunctive use in this case would include developing a plan to utilize existing fresh groundwater supplies, storage, or other sources to meet peak demands associated with the Cypress Lake project.

## Conjunctive Use Model Overview

Though one of the primary objectives of the overall project was to develop a plan for implementing the Cypress Lake project, the initial phase of this project (Phase I) entailed development of a plan to interconnect the utilities' distribution systems prior to the implementation of the Cypress Lake project (Phase II). One benefit of these interconnects would be to allow the utilities to convey water among their individual systems to meet demands, thereby increasing operational flexibility; this concept is referred to herein as "water wheeling." Conjunctive use in Phase I included developing a plan for interconnecting the utilities' distribution systems to allow them to convey finished potable water to one another to meet the demands of the group as a whole.

In order to facilitate conjunctive use among the utilities, the Coop-RCID Water Supply (CRWS) Model was developed. The CRWS model is a time-series or continuous-simulation model based on 121 years of climatic conditions that allows for the statistical evaluation of the water balance between the utilities' demands and water supplies throughout the planning period. The CRWS model was developed to simulate the utilities' overall water supply system, including the conjunctive-use needs being assessed as part of this project.

For Phase I of the Cypress Lake project, the CRWS model was developed to simulate the following:

1. Daily customer demands for each utility
2. Fresh groundwater supplies for each utility (including WUP limitations)
3. Service area transfers of water conveyed through interconnects among the utilities

The magnitude, frequency, and timing of the need to transfer existing water supplies among utilities was developed using the CRWS model. The model results facilitated the conceptual design of the interconnects among the utilities and indicated the need to consider notably higher peaking factors than typically used in facility design to meet the conjunctive-use needs of Phase I of the project.

As part of Phase II of this project, the CRWS model was expanded to incorporate the use of water from the Cypress Lake water treatment plant. Based on the results of the water supply modeling, it was determined that leveraging the use of the utilities' existing fresh groundwater supplies to meet the peak demands associated with the Cypress Lake project was the preferred conjunctive-use method for the group to implement. The results of the Phase II water supply modeling were also used to:

1. Estimate the design peak flows to use for transmission pipelines associated with the project.
2. Refine the capacity of the interconnects identified in Phase I to accommodate the required transfer of water from the Cypress Lake project among the utilities as part of Phase II.
3. Identify the magnitude, frequency, and timing of projected water supply needs resulting from supply and regulatory constraints.
4. Estimate potential increased capacity required in the utilities' existing potable water system facilities (e.g., fresh groundwater treatment plants, diurnal storage, etc.) to meet the conjunctive-use needs of the project.

The water supply modeling demonstrated how, by working together, the members of the Water Cooperative of Central Florida and RCID reduced the overall costs associated with implementing the Cypress Lake project by fully utilizing existing resources and infrastructure in a cooperative manner.

Table 1. Water Use Permit Allocation Summary

| Entity | Service Area | WUP # | Average (MGD AADF) | Maximum Month (MGM) |
|---|---|---|---|---|
| STC | Entire | SF #49-00084-W | 9.70 | 412.80 |
| TWA | Main | SF #49-00103-W | 36.50 | 1,555.90 |
| | Poinciana | SF #49-00069-W | 6.25 | 283.10 |
| | O&S | SF #49-01207-W | 0.66 | 27.28 |
| OCU | South, Southwest | SF #48-00134-W | 32.40 | 1,674.43 |
| | and West | SF #48-00059-W | 3.00 | 7.14 (max day) |
| PCU | Northeast | SF#53-00126-W SW#6509 | 13.95 | N/A |
| RCID | Entire | SF #48-00009-W | 22.20 | 933.89 |

## Phase I Model Development

The CRWS model has been developed to simulate the utilities' overall water supply system, including the conjunctive-use needs being assessed as part of this project. A brief discussion of the Phase I version of the CRWS model follows.

**Annual Demands**

The potable water demand projections used for the CRWS model were based on the demand projections developed for the overall project. Demands were projected through 2045 and represent demands associated with long-term average climatic conditions.

**Rainfall**

Potable water demands are directly correlated to rainfall, particularly outdoor or landscape irrigation demands met with potable water sources. During periods of below-average rainfall, demands tend to be above average, and vice versa. In fact, climatic conditions tend to be one of the greatest drivers contributing to the variation in water demands. To account for the effect of rainfall on demand variability, the demand modules for each utility were developed to account for variations in rainfall. Rainfall data were collected from the utilities, National Oceanic and Atmospheric Administration (NOAA) rain gauges, United States Geologic Survey (USGS) rain gauges, and SFWMD rain gauges.

For the calibration of the demand module of the CRWS model, the selection of a rain gauge was based on the proximity of it to each utility's potable water distribution system and existing fresh groundwater treatment plants, and on the available period-of-record associated with each gauge. Rain gauges located within or near each utility's service area were given priority. Rain gauges with period-of-records coincident with each utility's available fresh groundwater pumping data (typically 10 to 15 years through 2012) were also given priority. Composite rainfall series were developed where necessary using data from the next closest gauge (e.g., gap filling).

The CRWS model was developed to use NOAA rainfall data for Orlando from 1892 through 2012 as the basis for the predictive simulations. Using historical rainfall data to perform predictive (future) simulations as-

*Continued on page 44*

*Continued from page 43*
sumes that the wide range of rainfall conditions observed over the past 121 years encompasses potential future conditions. Sensitivity analyses to assess changes in rainfall magnitude or variability associated with climate change or other factors were not performed as part of the Phase I analysis.

**Daily Demands**

The CRWS model calculates a normalized daily demand series considering multiple factors that affect water demand for each utility's service areas. Individual demand models were developed to generate the normalized demand series for each service area. These models were based on the following factors:

- *Seasonal Variation by Day-of-Year*: Deterministically represents seasonal variations in demand resulting from causative factors, such as seasonally variable rainfall, evaporation/evapotranspiration, temperature, and water use (e.g., seasonal customers).
- *Cross-Correlation with Rainfall (varying lags by service area)*: Deterministically defines the direct relationship between daily demand and rainfall.
- *Autocorrelation (varying lags by service area)*: Autocorrelation is the cross-correlation of a signal (e.g., a time series of data) with itself. It is a statistical method used to identify repeating patterns within a time series of data.
- *Statistical Noise*: Represents the portion of the time series of data that could not be represented with other deterministic or statistical factors.

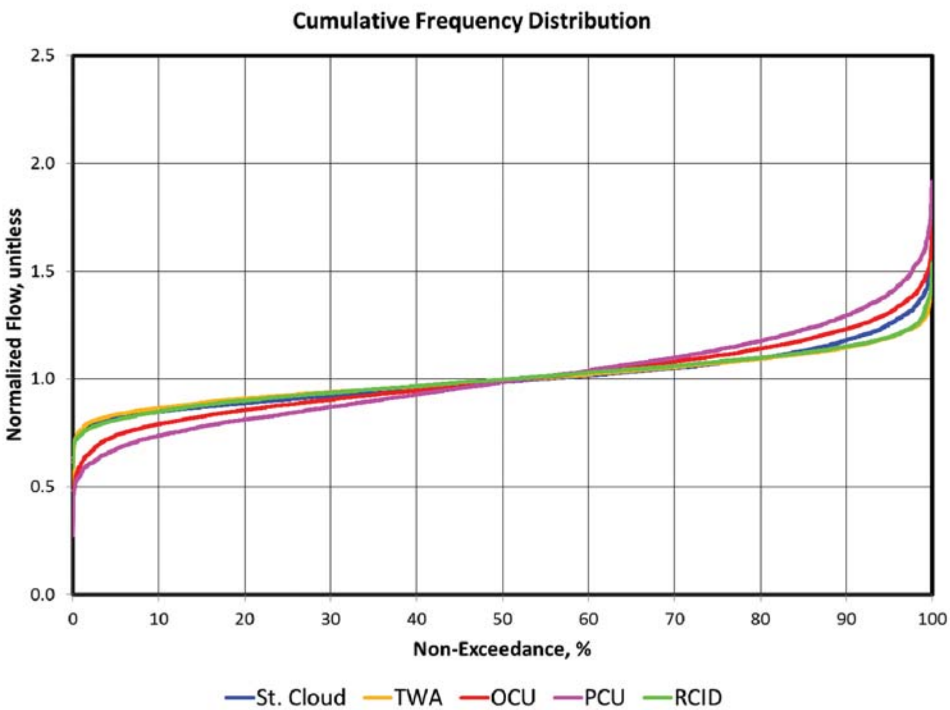


Figure 1. Historical Normalized Daily Peaking Factors

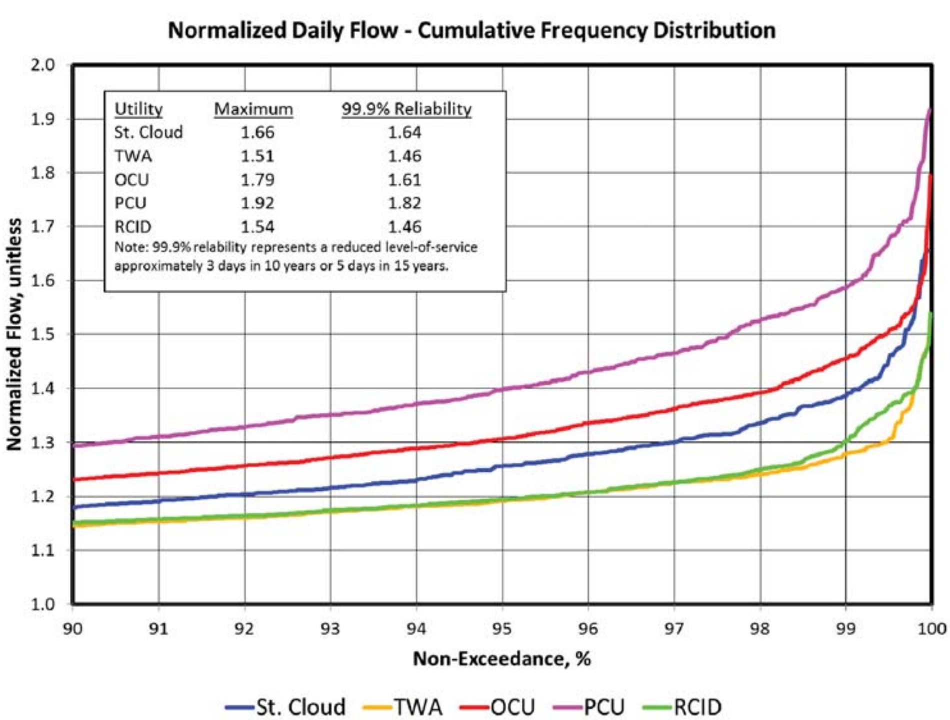


Figure 2. Historical Normalized Daily Peaking Factors (Top 10 Percentile)

Observed daily potable water demand data for each utility and a rainfall data series selected for each utility (typically 10 to 15 years through 2012) were used to calibrate the utility demand models. These models were used to generate a normalized daily potable water demand that could be used to generate a daily potable water demand series for any annual average demand condition.

Once the daily demand models were calibrated, they were used to predict 121 years of daily normalized potable water demands for each service area; daily rainfall in Orlando for 1892 through 2012 was used as the basis for the predictive simulations. The predictive normalized demand series were multiplied by the future annual average demand for each service area. The result is a long-term prediction of potential daily demands for each utility's service area for a selected annual average demand condition (e.g., year). The results of the demand models are presented in Figures 1 and 2.

**Fresh Groundwater Water Use Permit Allocations**

The CRWS model was developed to include a fresh groundwater module. This module was developed to represent each utility's fresh groundwater supplies within the conditions specified in each utility's WUP. A summary of the WUP allocation limitations is provided in Table 1. The CRWS model compares the daily demand series developed for each utility to that utility's WUP allocation to calculate a deficit in fresh groundwater supplies.

**Interconnects**

The CRWS model compares the utilities' fresh groundwater supply surpluses and deficits to determine if available surplus supplies could be transferred among the utilities to meet demand deficits. If surplus supplies are available to meet demand deficits, the CRWS model quantifies the magnitude, frequency, and timing of these potential transfers.

**Phase I Model Summary**

The predicted flows transferred through potential interconnects among the utilities as predicted by the Phase I CRWS model can be used to facilitate the utilities developing a potential plan to wheel water to maximize the use of existing available fresh groundwater sources. Phase I water wheeling results in the deferment of capital expenditures associated with implementing the Cypress Lake project.

The results can be used to develop potential agreements among utilities for the interim purchase of bulk fresh groundwater supplies to meet potential supply deficits that some utilities may experience in the short term before the Cypress Lake project is implemented. It can also be used to develop preliminary pipe sizes for the potential interconnects among utilities. However, it should be noted that Phase I is an interim step in the overall plan to implement the Cypress Lake project. As part of Phase II, water from the Cypress Lake water treatment plant will be conveyed to the utilities. This water may also be "wheeled" or conveyed among the utilities in lieu of each utility having a direct connection to the Cypress Lake delivery system. As a result, the magnitude, frequency, timing, and direction of flows through the potential interconnects among utilities may change. This will affect the design of the interconnect systems.

Table 2. Finished Water Supply from Cypress Lake Water Treatment Plant

| Finished Water Supply Variability | Maximum Daily Flow[1], MGD | Average Flow, MGD AADF |
|---|---|---|
| Base-loaded | 30 | 30 |
| Variable | 38.1 | 30 |

Note: Represents maximum daily flow associated with 99 percent frequency of occurrence for simulations performed.

Table 3. Range of Finished Water Supply Delivered to Utilities

| Utility | Capacity Share, MGD AADF | Range of Maximum Daily Flow[1], MGD | Range of Average Flow, MGD AADF |
|---|---|---|---|
| STC | 5.0 | 1.8 to 6.6 | 1.8 to 5.0 |
| TWA | 12.0 | 12.0 to 18.0 | 12.0 to 14.7 |
| OCU | 9.0 | 9.0 to 16.1 | 9.0 to 11.7 |
| PCU | 3.0 | 0.8 to 4.5 | 0.8 to 3.0 |
| RCID | 1.0 | 0.95 to 1.3 | 0.95 to 1.0 |

Note: Represents maximum daily flow associated with 99 percent frequency of occurrence for simulations performed.

Table 4. Range of Fresh Groundwater Use by Utilities

| Utility | WUP Allocation, MGD AADF | Range of Maximum Daily Flow[1], MGD |
|---|---|---|
| STC | 9.7 | 8.0 to 18.5 |
| TWA | 43.4 | 50.3 to 84.2 |
| OCU | 35.4 | 45.0 to 65.2 |
| PCU | 14.0 | 21.9 to 28.7 |
| RCID | 22.2 | 31.3 to 33.3 |

Note: Represents maximum daily flow associated with second highest daily groundwater use for simulations performed.

## Phase I Modeling Results

**Planning Increments**

The intent of Phase I is to develop a plan for water wheeling among the utilities before the Cypress Lake project is needed. The utilities' WUP allocations sum to approximately 125 mgd average annual daily demand (AADD). This represents the maximum annual average demand that can currently be met with the utilities' combined fresh groundwater supplies. Potable water demands in excess of 125 mgd AADD will need to be met by other sources, including water from the Cypress Lake project. Since the intent of Phase I is to develop a plan to wheel water before the Cypress Lake project is implemented, the 125-mgd demand condition was selected as the final Phase I planning condition.

A 110-mgd AADD condition was selected as the second or interim Phase I planning increment. A demand of 110 mgd represents the initial stages at which Phase I water wheeling could be required according to preliminary conjunctive-use modeling.

**Deficit Analysis**

Based on the previous information, 110-mgd and 125-mgd demand conditions were evaluated using the CRWS model to identify the quantity of water that may need to be transferred through potential utility interconnects as part of Phase 1 of the project. The CRWS model simulates a demand condition, such as 110-mgd average demand, but allows the demands to vary based on climatic conditions and other factors affecting utility demands over a 121-year simulation period. The result is 121 years of predicted daily demands and supply surpluses/deficits (44,196 days). It was determined that up to 4-mgd maximum daily flow may need transferred among the utilities by the 110-mgd demand condition. However, this corresponds to an annual aver-

*Continued on page 46*

*Continued from page 45*
age transfer of up to 0.2 mgd, resulting in a much higher peaking factor than pipes are typically designed for. By the 125-mgd demand condition, the flow transfers among the utilities increased to up to 13-mgd maximum daily flow and 5.2-mgd annual average daily flow, which more closely resembles a standard pipeline design peaking factor.

It's important to note that these results are based on the demand projections assumed for this project. As previously noted, many factors can change, depending on the growth that occurs within a utility's service area. Utilities can implement other projects, such as additional conservation efforts and nonpotable water projects beyond those currently planned for, including retrofitting, and implementing additional water supply projects sooner than previously anticipated.

The water supply modeling results were provided as input and evaluation in the regional hydraulic model. The model, which contains a spatial distribution of demands, was used to evaluate the adequacy of existing interconnects to convey potential flow transfers among utilities, refine the distribution of flows transferred among utilities in order to better address the spatial distribution of potential supply deficits, and develop preliminary interconnect concepts for new Phase I interconnects among utilities.

## Phase II Modeling Results

The CRWS model developed as part of Phase I of this project was expanded as part of Phase II to integrate the use of water from the Cypress Lake project. Simulations were performed on a wide array of potential project supply and demand configurations, termed "scenarios" herein, using the CRWS model. The intent of performing multiple scenarios was to evaluate varying project configurations and their potential effect on the following components of the project:

- Maximum daily flows from the Cypress Lake Water Treatment Plant (WTP).
- Maximum daily flows delivered to the utilities through transmission piping or interconnects.
- Maximum daily fresh groundwater supply required to meet the conjunctive-use needs of the project. Conjunctive use for this project is considered the use of fresh groundwater to meet the peak demands potentially not met by the Cypress Lake project.

The results of the scenarios are presented in Table 2, Table 3, and Table 4. The results of the water supply modeling as presented in the tables were incorporated into the hydraulic model to determine the infrastructure required to convey flows to and among the utilities.

## Facility Capacity Deficit Identification

The intent of the facility capacity deficit task was to determine if the utilities' existing fresh groundwater facilities were of sufficient capacity to meet the potential increase in fresh groundwater use that could occur once the Cypress Lake project is implemented. A macrolevel comparison of the potential peak daily groundwater use calculated for the 12 water supply scenarios evaluated using the CRWS model (Table 4) and the existing Florida Department of Environmental Protection (FDEP)-permitted capacity of the utilities' fresh groundwater treatment plants are presented in Table 5.

The results of the CRWS model indicate that RCID currently has sufficient existing fresh groundwater permitted WTP capacity to meet anticipated future peak groundwater demands.

The OCU currently has sufficient existing fresh groundwater capacity under all but one scenario evaluated. An additional 1.1-mgd of treatment would be required to meet all predicted daily peak groundwater uses.

The results of the CRWS model simulation indicate that PCU's fresh groundwater demands may be in excess of its FDEP permitted capacity in three of the 12 simulations performed. However, PCU currently has capital improvement projects planned that would likely accommodate this additional capacity need.

The results of the CRWS model simulations indicate STC's predicted daily fresh groundwater use was in excess of its FDEP-permitted capacity in five of 12 simulations performed. Based on a review of STC's WTP infrastructure, its FDEP-permitted capacity appears to be constrained primarily by treatment capacity. The STC may consider increasing the treatment capacity at its existing fresh groundwater facilities to address potential future conjunctive-use needs associated with the Cypress Lake project.

Similarly, the results of the CRWS model simulation indicate that TWA's fresh groundwater demands may be in excess of its FDEP permitted capacity in seven of the 12 simulations performed. However, TWA's existing well capacity at its WTPs is sufficient to meet predicted daily fresh groundwater needs. Based on this, TWA may consider increasing the treatment capacity at its existing fresh groundwater facilities to address potential future conjunctive-use needs associated with the Cypress Lake project.

In addition to daily treatment and well capacity, the peak-hour, high-service pumping capacity at the utilities' fresh groundwater

Table 5. Daily Fresh Groundwater Use by Utilities versus Florida Department of Environmental Protection Permitted Capacity

| Utility | FDEP Permitted WTP Capacity, MGD | Maximum Daily Groundwater Use, MGD |
|---|---|---|
| STC | 15.8 | 18.5 |
| TWA | 70.4 | 84.2 |
| OCU | 64.1 | 65.2 |
| PCU | 26.2 | 28.7 |
| RCID | 35.4 | 33.3 |

Table 6. Estimated Peak Hour Fresh Groundwater Use Versus Existing High-Service Pumping Capacity

| Utility | Total High Service Pumping Capacity, MGD | Peak Hour Flow[1], MGD |
|---|---|---|
| STC | 25.6 | 33.2 |
| TWA | 137.6 | 168.2 |
| OCU | 106.3 | 126.6 |
| PCU | 49.1 | 47.6 |
| RCID | 76.2 | 41.6 |

facilities was evaluated for adequacy to meet future demands associated with the Cypress Lake project (Table 6). Based on the results of the peak-hour flows listed in Table 6, STC, TWA, and OCU may need additional high-service pumping capacity in the future at their WTPs to address the predicted conjunctive-use needs associated with implementing the Cypress Lake project.

## Summary

The Water Cooperative of Central Florida and RCID are meeting future water supply challenges through regional cooperation. One of their key initiatives, the Cypress Lake project, will provide an additional 30 to 36 mgd of alternative water supply to the group. Challenges associated with planning a Cypress Lake transmission system were met by providing a detailed water supply evaluation using a water supply model (the CRWS model) and a detailed hydraulic evaluation using a combined regional hydraulic model to develop the conceptual design. Based on the preliminary findings of the WTP project and the 37.5-mgd WUP to withdraw water from the brackish groundwater wellfield, the utilities made the following consensus water supply decisions to maximize utilization and flexibility of the Cypress Lake project transmission design:

- Utilize water wheeling, prior to the implementation of the Cypress Lake project, to leverage the use of existing groundwater supplies and potentially forestall Cypress Lake project capital costs.
- The Cypress Lake project supply is to be analyzed as base-loaded or supplied at a constant rate equal to the AADD associated with the project.
- The utilities' existing fresh groundwater facilities are planned to conjunctively supply maximum day demands (MDD) and peak hourly demands (PHD). Leveraging the use of the utilities' existing fresh groundwater facilities to meet projected peak demands and conjunctive-use needs associated with the Cypress Lake project was determined to be more cost-effective than implementing seasonal storage
- The Phase II (build-out) Cypress Lake transmission was analyzed to accommodate a design flow of up to 36.6 mgd AADD, with defined allocations for each utility.

Through regional cooperation, the utilities are cost-efficiently implementing the Cypress Lake project, one of the largest AWS projects in central Florida, in an environmentally sustainable manner.