Optimizing Existing Facilities: Finding another 3 MGD at Cape Coral's RO Plant

Shawn Kopko, Andy Fenske, Ron Cass, and Gert-Jan Schers

In 1976, the city of Cape Coral put into operation a drinking water supply system containing production wells up to 700 feet deep into the Floridan Aquifer System and a reverse-osmosis (RO) treatment plant with an initial capacity of 3 million gallons per day (MGD). In 1985, the city expanded this system to 15 MGD.

Like other communities in Florida, Cape Coral is undergoing rapid population growth. To ensure that current and future generations will have a safe, reliable drinking water supply, the city has embarked on a sizeable utility extension and facility expansion program to meet these needs. The current population exceeds 160,000 and the city's revised growth model indicates that this will increase to 272,000 in 2015 and to 361,000 at 83 percent build-out in 2050.

The extension of utilities will also increase the percentage of population served with drinking water and sewer collection. Currently 71 percent of the population is served; this figure will increase from 85 percent in 2015 to near 100 percent in 2020.

To support growing population and utility extension plans, a facility expansion program was undertaken in 2005 to expand three existing facilities:

- Everest Water Reclamation Facility (WRF)
- Southwest WRF
- Southwest Reverse-Osmosis (RP) Water Treatment Plant (WTP) and Wellfield

The program will also create three additional treatment facilities:

- North Cape RO WTP and Wellfield
- North Cape WRF
- Southwest Biosolids Processing Facility

Project Overview

The population growth will increase the drinking water demand significantly. The potable demand is anticipated to increase from the current 14 MGD to 29 MGD in 2015 (Figure 2). To address this growth in demand, the expansion of the existing Southwest Reverse Osmosis Water Treatment Plant (SWRO WTP) from 15 to 18 MGD is currently under way to meet short-term needs. Also, the construction of the first 12 MGD phase (of 36 MGD ultimate) of the new North Reverse Osmosis Water Treatment Plant (NRO WTP) has also commenced.

The immediate water demand growth focused the program efforts on providing an interim increase in production at the existing Southwest RO WTP. The interim increase in production was necessary to satisfy demand until such time as the new North Cape RO WTP could be completed. To meet the planned capacity increase at the Southwest RO WTP, additional wells would also be necessary.

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The Existing Wellfield System

The existing wellfield supply system is segmented, in that 11 existing wells supply Plant 1 and 15 wells supply Plant 2. Both Plants 1 and 2 combine production as the Southwest RO WTP. In accordance with regulatory restrictions, the wells are distributed at least 500 feet from each other and are equipped with remote telemetry for operation from the plant site.

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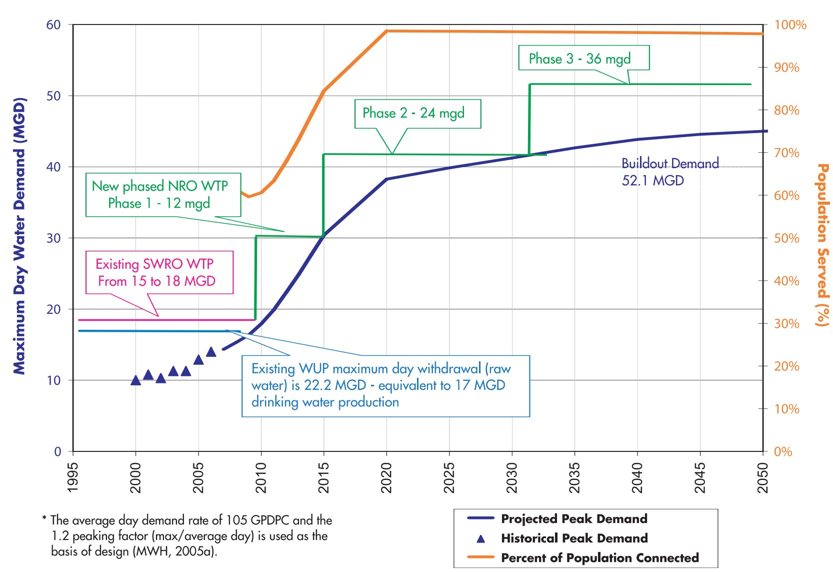
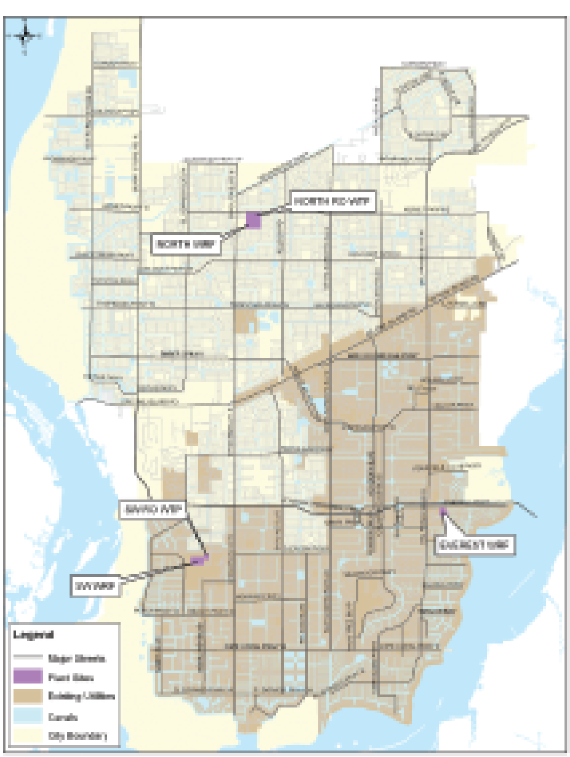


Above: Figure 2 – Drinking Water Demand Forecast



Left: Figure 1 – Cape Coral, Florida

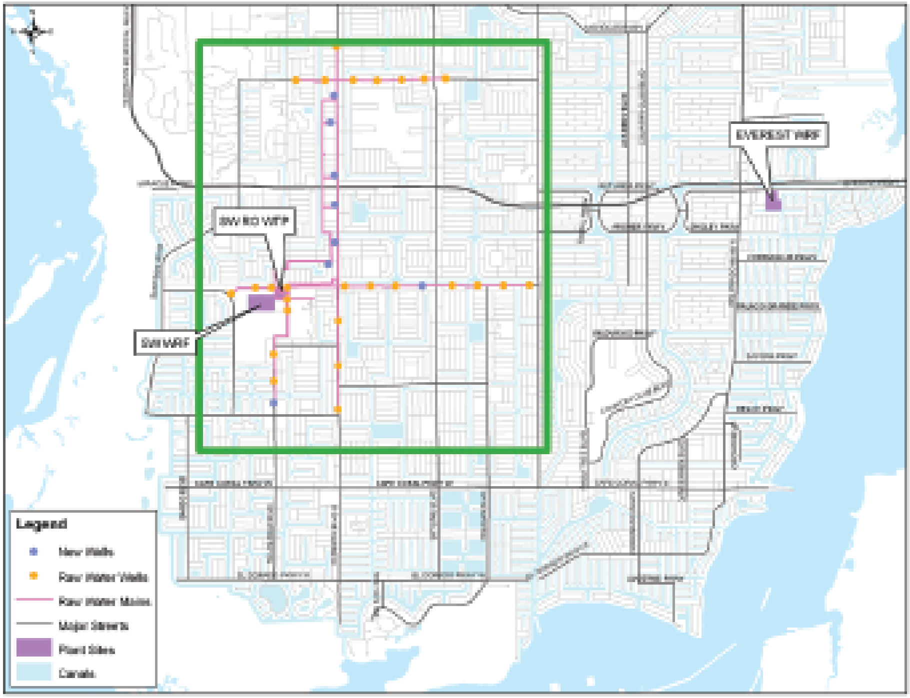


Figure 3 – Southwest Wellfield

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The Lower Hawthorn Aquifer is the shallowest aquifer of the Upper Floridan Aquifer system and provides the bulk of withdrawals currently supplying the city's raw-water needs. All of the city's wells are currently completed into the Lower Hawthorne Aquifer and portions of the Upper Suwannee Aquifer. The city's water use permit currently allows maximum monthly withdrawals of 674 MG (22.2 MGD equivalent maximum day) from this aquifer, with a total yearly allocation of 6180 MG.

These 26 wells are distributed across the southwest portion of Cape Coral. Water quality from these wells has deteriorated only slightly over time, but due to increased demands on the Floridan Aquifer System, a further degradation in water quality is anticipated.

The Existing Southwest RO WTP Facility

The existing RO production trains within the Southwest RO WTP can be summarized as in Figures 4 and 5. The treatment trains are traditional low-pressure, reverse osmosis: groundwater supply treated to reduce pH and prevent inorganic scaling, cartridge filtration at 5 microns to capture residual particulate, multi-stage membrane treatment for chloride removal, degas for hydrogen sulfide reduction, chemical addition for water stabilization, disinfection, then transfer to ground storage tanks for pumping to the distribution system. Concentrate disposal is via a permitted surface discharge, limited in approved discharge volume, and physically limited due to the line length and resultant backpressure.

While the membrane systems were the primary focus for investigating alternatives for additional capacity, once additional capacity was available from the membrane trains, the design had to consider the impacts to support systems. To that end, performance operating data for the remainder of the systems was collected and evaluated as to the ability of the existing equipment to support any increase in production capacity.

- Was there sufficient reliable supply from the wellfield?
- Was the withdrawal capacity permitted?
- Were the cartridge filters and pretreatment chemical systems sufficiently sized for the additional flow?
- Did the membrane feed pumps have sufficient capacity for the added flow?
- Was the downstream permeate degas system of sufficient capacity?
- Was the clearwell pumping capacity going to have to be increased?
- Would changes be required to the high-service distribution pumps?
- What would be the impact of added concentrate disposal?

Key Options Developed for Additional Capacity

A total of seven specific alternatives for creating additional capacity were selected for a more detailed review to investigate estimated additional production, impacts to supplementary systems, costs to implement, disruptions to existing service, concentrate disposal impacts, and finished-water quality impacts.

<u>Plant 1 Options</u>

1. Conversion of the existing three-stage array to a two-stage array was considered. Projections for the alternate array of 14-7 did not improve recovery ratio and Beta ratio was a limiting factor. With extensive

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Table 1
Water Quality

Name	Current Water Quality	Projected Water Quality - 2010
Calcium	72.0 mg/L	77.2 mg/L
Magnesium	97.0 mg/L	104.2 mg/L
Sodium	440.0 mg/L	522.0 mg/L
Potassium	18.7 mg/L	18.7 mg/L
Ammonia	0.4 mg/L	0.4 mg/L
Barium	30.0 mg/L	30.0 mg/L
Strontium	33.0 mg/L	33.0 mg/L
Carbonate	0.8 mg/L	0.8 mg/L
Bicarbonate	220.0 mg/L	226.0 mg/L
Sulfate	220.0 mg/L	220.0 mg/L
Chloride	836.8 mg/L	990.0 mg/L
Fluoride	2.7 mg/L	2.7 mg/L
Nitrate	0.0 mg/L	0.0 mg/L
Silicon Oxide	14 mg/L	14 mg/L
Water Temperature	28.0 degrees C	28.0 degrees C
Hydrogen Sulfide	3.0 mg/L	3.0 mg/L
Total Dissolved Solids (TDS)	1955 mg/L	2209 mg/L
pH	7.6	7.6
Total Hardness	580 mg/L as $CaCO_3$	620 mg/L as $CaCO_3$

Figure 4 – Plant One Membrane Train Configuration

Plant 1 Configuration

Circa 1976	
Number of units	10 Trains
Vessel Array	10-7-4 (3 stage)
Elements	Four per vessel - 8 inch X 40 inch
Mfgr	Hydranautics (7 trains) Trisep (3 trains)
Design Recovery	75 %
Average Design Flux	16.3 GFD
Train Flows	
Feed	464 GPM
Permeate	348 GPM
Concentrate	116 GPM
Pretreatment	
Acid	130 ppm to 5.9 pH
Anti-scalant	3 ppm AWC A-111 UL

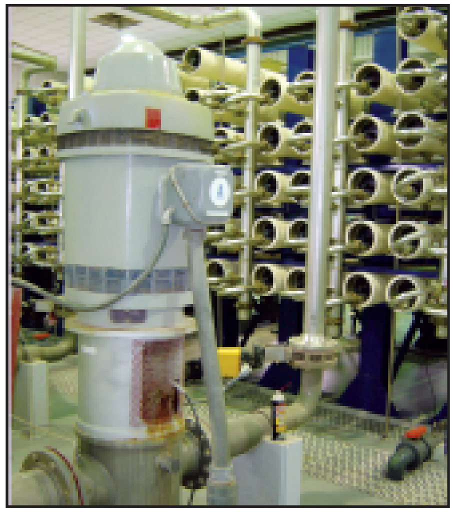
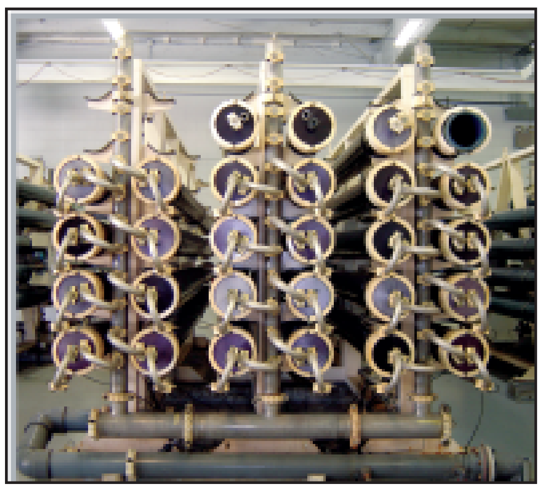


Figure 5 – Plant Two Membrane Train Configuration

Plant 2 Configuration

Circa 1985	
Number of units	8 Trains
Vessel Array	16-8 (2 stage)
Elements	Seven per vessel - 8.5 inch X 40 inch
Mfgr	Koch (5 trains) Trisep (3 trains)
Design Recovery	85 %
Average Design Flux	13.7 GFD
Train Flows	
Feed	800 GPM
Permeate	680 GPM
Concentrate	120 GPM
Pretreatment	
Acid	130 ppm to 5.9 pH
Anti-scalant	3 ppm AWC A-111 UL



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re-piping required to implement this option, it was deemed to be of no value to pursue further.

2. Projections were run for optimizing the current Plant 1 array. The recovery ratio could be increased from 75 percent to 80 percent with an increase in anti-scalant.
3. The existing vessels were configured for eight-inch membranes, but they had sufficient vessel size to replace the eight-inch with 8.5-inch membranes. While a viable option, this required a sizable investment with limited flow increase.

Plant 2 Options

1. The existing Plant 2 membrane rack had been constructed for 24-12 vessel array, yet only equipped to a 16-8 array. We considered two approaches:
   a. Full structure build-out of a 24-12 array would require additional equipment changes to support the added flow capacity, but a 30-percent increase in capacity might warrant the additional costs.
   b. A less aggressive approach might limit the additional impacts to support equipment, so we also considered a rack modification to an 18-9 array.

Additional Options

1. One of the easiest ways to increase finished-water flow at most RO plants is to increase the blend ratio, assuming the plant is equipped with piping to allow a blend of the raw water stream into the permeate flow.

Implementation Strategy

With the options defined, each alternative was evaluated further and the impacts were quantified. As a result, each of the options added incremental additional production capacity; they were then prioritized based upon cost impact for that additional capacity created.

- *Convert Plant 1 from Three-Stage to Two-Stage*—This was eliminated from further consideration based upon the prohibitive cost of re-piping and insignificant additional flow to be acquired.
- *Blend Flow Increase*—Usually, this blend ratio is set on the chloride level, required to be below 500 milligrams per liter (mg/L) in the finished water; however, in our case, there had been a regulatory restriction for finished-water alkalinity to be maintained from 30-60 mg/L. Since the added blend flow would further mitigate corrosion potential, the state confirmed that the restriction to 60 mg/L was not necessary. This allowed an additional 2-percent increase in blend flow ratio (16 to 18 percent) or an added 0.5 MGD.
- *Increase Plant 1 Recovery Ratio*—The chemical supplier was consulted to evaluate the required additional anti-scalant dose required to prevent concentrate scaling. The approach was validated with the membrane suppliers for Plant One in order to maintain warranty conditions.
- *Increase Plant 2 to an 18-9 Array*—Adding three more vessels to each of the current rack configurations, would increase production by approximately 1.1 MGD. Several items had to be considered as well. If the Plant 1 Recovery Ratio was increased to 80 percent, the shared concentrate line backpressure increased only a nominal 4 PSI over the normal operating pressure of 63 PSI. With field testing, the membrane feed pump capacity was confirmed to be able to deliver the flow and pressure required for the new array. Actually, the field test proved the existing pump and motor combination had sufficient capacity beyond the required flows for the 18-9 array, so this option was slightly modified to a 20-10 array (providing 2.3 MGD extra). As a sub-set of this option, consideration was given to manufacturing one new skid and redistributing the vessels from one of the existing skids as a means to minimize operation interruption.
- *Re-membrane Plant 1*—Replacement of 840 existing elements at 365 sf to 400 sf elements was viable but costly, since all supply equipment would need to be replaced for a 10-percent flow increase from Plant 1 (0.5 MGD). The added production (above the previous option), without adjusting recovery ratio, increased concentrate discharge backpressure. Combining the increased recovery ratio and the increased capacity, the concentrate line backpressure was essentially unchanged.
- *Increase Plant 2 to a 24-12 array*—Full build-out of the racks to the 24-12 array would increase production by a further 2.3 MGD. Under this scenario, the investment for the added capacity would encompass all new feed pumps and electrical equipment, replacement clearwell pumps, and the replacement or expansion of concentrate disposal facilities. This option also meant an increase in the permitted concentrate

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Expansion Option	Production Capacity with bypass, (MGD)	Components Requiring Replacement
No Action	14.7	
Existing Arrays and 16% to 18% increase blend ratio	15.2	Requires FDEP Approval of Alkalinity minimum
Plant One Recovery Rate increase to 80%	15.6	Anti-Scalant Increase
Plant Two with 18/9 Array (85% recovery)	16.7	None. Pipework to connect vessels and 150 new elements required as per test train.
Plant Two with 20/10 Array (85% recovery) and Train A skid replacement	17.9	Feed pump modifications, section of feed header replacement, re-piping of cartridge filters, new skid for Train A
Plant One Membrane Replacement (365ft^2 with 400ft^2)	18.4	Replace all 840 membrane elements in Plant 1
Plant Two with 20/10 array & 2MGD skid replacement or 24-12 array for all trains	19.8	New 2 MGD train would require a complete rehab: new RO feed pump, motors, VFDs, Piping & Valves, permeate header replacement, and concentrate disposal pipeline

Figure 6 – Creating Additional Capacity

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disposal capacity; something which was recognized as being quite difficult to obtain.

This evaluation resulted in the following roadmap for implementing the required additional capacity, Figure 6.

Progressive Implementation

To release short-term production gains with little investment, the existing Plants 2 and 2 have both been run with higher recovery ratios. The state has adjusted the finished-water alkalinity standard, which allows the increase in blend. These first two options for expansion (Figure 6) have provided Cape Coral with up to 0.9 MGD additional capacity with essentially no capital investment.

Recognizing that the added capacity from operational adjustments would not satisfy the demands required until the new North RO WTP is constructed, the city authorized contracts to make the following modifications, which are currently in progress and represent the work necessary to ultimately modify Plant 2 to a 20-10 array, available in 2007. Currently the work is nearing completion, and an additional 3 MGD production capacity will be available with a short implementation period. The importance of these short-term improvements has further been emphasized by some minor delays in the implementation of the new North Cape RO WTP, which is currently planned to be operational in 2009.

- The Water Use Permit has been modified.
- Eight new Lower Hawthorne wells have been completed and brought online (Figure 7).
- Additional bends have been acquired to outfit the spare vessels in the existing racks.
- Additional bends and vessels have been acquired to outfit the additional spaces in the existing racks.
- Membrane element replacement is ongoing for Plant 2.
- Each of the Plant 2 membrane feed pumps (eight total) are being reconditioned and new impellers with greater capacity have been added (Figure 8).
- The existing clearwells are being structurally improved and new clearwell pumps installed, with additional capacity.
- The existing degas facility is being replaced, with an extended discharge stack.

Acknowledgments

This project could not have been accomplished without the historic and consistent drive toward excellence by the city of Cape Coral staff, including George Reilly, Shawn Kopko and Andy Fenske. Those left out are certainly not any less significant in their efforts, and have demonstrated a considerable commitment to both their utility and this industry.

Figure 7 – New Southwest Supply Well

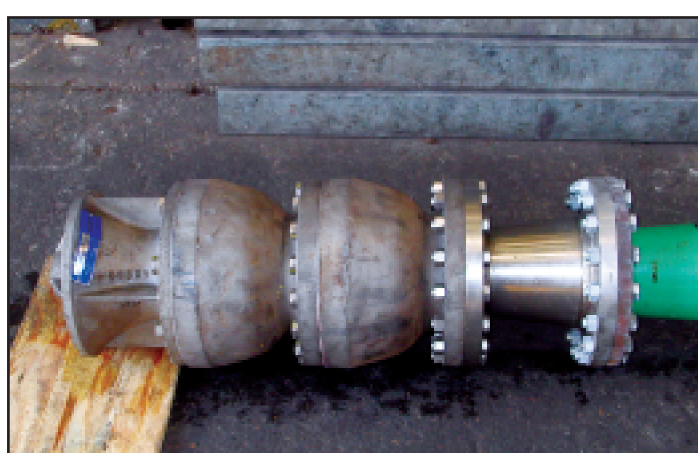

Figure 8 – Reconditioned Membrane Feed Pump