Innovative Potable Water Saving Techniques at Cape Coral

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The demand for fresh water began to increase dramatically in Florida in association with significant increases in population after World War II. The state's population had grown to 2.8 million by 1950 and it ranked 20th among the lower 48 states in total population. By 1970, the state had increased to more than 6.7 million people, making it the ninth most populous state. Rapid growth continued, and today Florida ranks third in the nation with nearly 20 million people (Figure 1).

As population totals continued to increase, many cities across the state began to experience problems associated with potable water supply. Obviously, this large and expanding population places an ever-increasing demand on basic services that include water supply and waste disposal. For these and other reasons, water resource management is extremely important, even in a water-rich state like Florida.

The large demand for potable water supplies prompted the South Florida Water Management District (SFWMD) to encourage local utilities and municipalities to explore alternative water sources for future needs, and options included desalination, reverse osmosis (RO), and recycled water. One of the most widely used technologies has been RO, which forces brackish water through a network of membrane cells to remove the salt. Several cities in south Florida, including Cape Coral, currently use RO as a way to meet the growing demand to potable supplies.

Cape Coral is a newly emerging pre-platted community that was established during the 1950s by the Gulf Guaranty Land and Title Company. It began on a large parcel of land across the Caloosahatchee River from Fort Myers, the county seat of Lee County. The city is located on a large peninsula that is virtually surrounded by water (Figure 2); the Gulf of Mexico is to the west and south, the Caloosahatchee River is to the east, and the city has over 300 mi of internal freshwater canals (Figure 3).

Despite the abundance of nearby and adjacent bodies of water, the city has a limited supply of water that is suitable for human consumption. In addition, rapid population growth has created an enormous demand for potable supplies.

Prior to development, the peninsula that is now the location of Cape Coral was covered by interior forests that were vital to groundwater recharge. Pine forests and palmettos grew on higher elevations, while extensive mangrove swamps and tidal marshes were found near the shoreline. These ecologically fragile and valuable environments stored and purified large volumes of water that drained into them from higher elevations. The peninsula was also the location of wildlife habitat and vital fish nurseries (Allan et al., 1977). Unfortunately, the development of Cape Coral resulted in extensive environmental degradation.

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Cape Coral became one of the largest pre-platted communities (subdivisions), not only in Florida, but in the entire United States. It extends across more than 65,000 acres and has been subdivided into over 138,000 lots. Unfortunately, many of the ill-conceived land development practices proved to be detrimental to both surface and groundwater resources (Allan et al., 1977). Developers installed a gridiron pattern of roads and canals by dredging and filling, particularly in the southern and eastern sections of the subdivision. These extensive drainage-and-fill techniques, de-

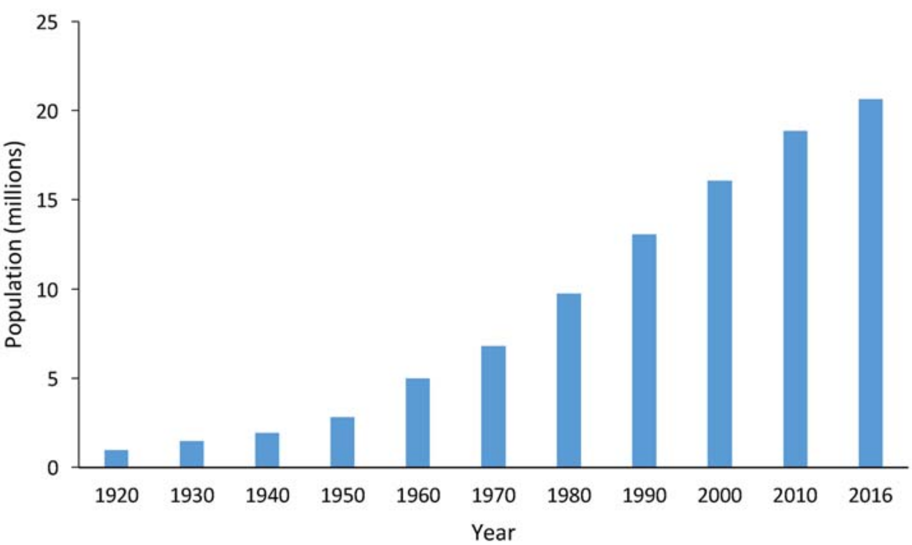

Figure 1. Population growth by decade for the state of Florida. *(source: U.S. Census Bureau)*

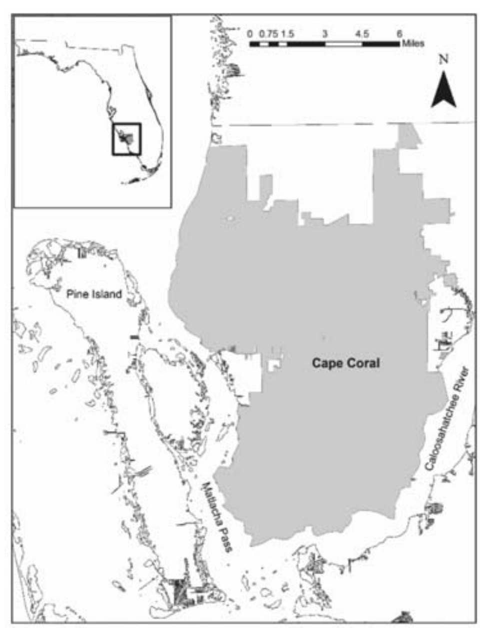

Figure 2. Map indicating location of Cape Coral in relation to nearby bodies of water. ***(source: Geographic information system data layers obtained from City of Cape Coral and the Florida Geographic Data Library)***

Figure 3. Ground view of internal fresh-water canal.
(photo: Hubert Stroud)

Figure 4. Ground view of reverse osmosis plant at Cape Coral.
(photo: Hubert Stroud)

signed to create an elaborate system of coastal and upland canals, caused many problems, including significant damage to the uppermost freshwater aquifer (Stroud, 1995, p. 105).

Phased development was not used, and less than 1 percent of the total land area was provided for open space and parks. Other problems included soil erosion, urban runoff, sewage from septic tanks, and stagnating and weed-choked canals. While some of these problems have been corrected, they remain as potential problems for groundwater and surrounding water bodies, including the Caloosahatchee River and the Matlacha Pass. Water pollution was intensified by an absence of retention basins for stormwater, an absence of buffer zones along streams and canals, an absence of vegetation within and adjacent to disturbed land, and an absence of seawalls to stop erosion along canal banks. The developers also removed 90 percent of the tree canopy and damaged fish nurseries and wildlife habitat (Stroud, 1991).

Water Supply

For many years, water use at Cape Coral was minimal and the need for a sophisticated water supply system was nonexistent. Individual lot owners simply dug wells, most of which were relatively shallow, into the water table (surficial) aquifer and the Mid-Hawthorn Formation to obtain an adequate water supply. The wells were few in number and did not overtax potable water supplies. As water use began to increase, the most readily available and feasible aquifer was the Mid-Hawthorn, a water-bearing layer found in a series of rocks ranging in depth from less than 100 ft to as much as 150 ft.

The trouble-free situation with water supply began to change rapidly during the 1970s, coinciding with a dramatic increase in water use across southwest Florida. As Cape Coral grew in population, some lot owners continued to dig wells, while others were connected to the city's relatively small central water system. The first treatment facility, a lime softening treatment plant, had a supply capacity of 2 mil gal per day (mgd). Both individual wells and city-controlled central systems were tapping the same relatively shallow Mid-Hawthorn aquifer. This aquifer, with a moderate to slow recharge rate, also served as a source of supply for commercial and industrial uses at Cape Coral and as a major source of water for the city of Fort Myers (Stroud, 1991). The aquifer soon became overtaxed and the water level began to decline rapidly (more than 50 ft in some locations). This precipitous decline prompted Cape Coral officials to look for an alternative source of supply.

Water Supply Problems

Due to the increased demand for a reliable water supply, Cape Coral decided to explore alternative water sources. Although the region has a relatively large potential water supply from both surface and subsurface sources, the problem lies in providing potable supplies at a reasonable cost to customers. The city chose to dig deeper wells that would tap into the Lower Hawthorn, an aquifer with a relatively large volume of water and fewer competing interests. Unfortunately, the water from this source has a relatively high mineral content, rendering it unpotable. The Lower Hawthorn aquifer is within the Floridan aquifer system, which typically has chlorides of approximately 1,000 mg/L (Rectenwald et al, 2008). To account for this, the city invested in an RO water treatment plant to remove some, if not most, of the undesirable minerals (Figure 4). This first RO plant was built in 1977, to supplement the supply provided by the lime softening plant.

In 1980, the RO facility was expanded, enabling it to treat up to 5 mgd. Shortly thereafter, it was observed that the wells supplying water to the lime softening plant were deteriorating from salt water intrusion, while the demand for a potable supply was escalating rapidly. Consequently, the city abandoned the lime softening plant in favor of a further expansion of the RO treatment plant. This decision meant that Cape Coral became the first major city in the U.S. to rely solely on RO treatment as its source of potable water (City of Cape Coral, 2014).

Surprisingly, the RO facility proved to be very efficient and the cost of water was less than the supply that was provided by the "old" lime softening plant. Expansion continued, and by 1985 the city had the largest low-pressure RO plant in the world, with a capacity to produce 15 mgd. This facility, named the Southwest Reverse Osmosis Plant, is supplied by 33 wells ranging in depth from 700 to 800 ft, which are located in the southwestern part of the city. Although the RO plant is the oldest of its kind, technological upgrades have made the plant a state-of-the-art facility that produces high-quality water at a reasonable cost (City of Cape Coral, 2014). These upgrades and retrofits include more-efficient low-pressure membranes, variable frequency drives, and computer automation of treatment processes (Figure 5).

In response to the ever-increasing demand for water associated with a rapidly increasing population and the utility's expansion plan, the city chose to increase the capacity of the existing RO plant from 15 to 18 mgd and to build an additional RO plant in the northern part of the city. The new north RO plant was completed in March of 2010 and has a production capacity of 12 mgd. This facility is supplied by 23 wells on property located near the new facility.

Dual Water Systems

As the city continued its phenomenal population growth, the demand for potable water

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had once again outstripped production capacities in Cape Coral. In view of the ever-increasing demand for water and limited options for finding additional sources of supply, the city decided to implement a dual water system that would eliminate the need to use potable supplies for lawn irrigation. The idea of a dual system was supported by the United Nations Economic and Social Council as early as 1958 when it promulgated the following principle: "No higher-quality water, unless there is a surplus of it, should be used for a purpose that can tolerate a lower grade." This means that high-quality water resources should not be used to flush toilets or irrigate lawns when reclaimed wastewater can be made readily available for those purposes (Okun, 2002).

Historically, dual water systems of one kind or another have been used for a long period of time. One of the earliest examples is the ancient Romans to supply water for fountains. More recent examples include the use of dual systems to supply cooling water for steel mills in Baltimore, for toilet flushing in Hong Kong during the 1950s, and many other examples, such as industry and power plant cooling applications (Grigg, Rogers, and Edmiston, 2013).

Dual Water

The plan to implement a dual water system at Cape Coral (Figure 6) was very controversial and triggered considerable public debate over the cost and the type of dual system that should be installed. Eventually, the city decided to use a gravity system rather than a less-expensive above ground method. The utilities expansion program that was implemented divided the city into segments or phases that, when completed, would eventually provide a dual water supply for the entire community.

The first Cape Coral home was connected to the new irrigation system in March 1992. Having the new system in place prompted the utility director at the time to declare that this marked the beginning of the end of water shortages at Cape Coral, and the city's mayor stated that it was a model community and would be nationally recognized. Cape Coral is the only Florida city that has a detailed utility master plan that includes a citywide nonpotable irrigation system. Currently, approximately 50 percent of the city is connected to the dual system (Godman and Kuyk, 1997).

Water Reuse

The dual water system is important because it allows the city to use reclaimed water as its source of supply for the nonpotable water line. Access to this nonpotable supply is extremely important in Cape Coral as it is recognized as having one of the largest municipal residential irrigation demands in the country, with a daily average use of 26.54 mil gal (City of Cape Coral Water Reclamation Division, 2017). The major components of the reclamation system include two wastewater facilities (the 13.4-mgd Everest Water Reclamation Facility and the 15.1-mgd Southwest Water Reclamation Facility), 277 wastewater pump lift stations, and five freshwater canal pump stations that are used to sustain the irrigation system.

Wastewater at Cape Coral is collected through more than 500 mi of sewer lines, transported through several lift stations, and treated at the Everest Parkway and Southwest water reclamation facilities. The Everest plant uses a five-stage Bardenpho process and has recently been expanded to 13.4 mgd. Expansion has also occurred at the southwest plant where 15 mgd are treated using the three-stage Bardenpho process. Reclaimed water from these plants is distributed to more than 40,000 homes, 17 parks and playgrounds, 11 schools, several commercial buildings, and a limited number of fire hydrants (Long, 2016).

As the city grew in population, demand for residential water rose from approximately 4.8 mgd in 1980 to more than 13 mgd by 1990. In that year, for example, 351 gal of potable water were used per connection per day, often for activities such as lawn irrigation, which did not require potable water. This amount began to decline significantly as an increasing number of customers were connected to the new dual system. By 2015, the single connection use per day had dropped to 171 gal of potable water. This represents a potable water use savings of at least 16 bil gal between 1993 and 2015. Potable water use per person has also decreased from a peak in 1990 of 161 gal per day (gpd) prior to the implementation of the dual system to only 78 gpd in 2015 (Fenske, 2016).

Furthermore, in recent years, no surface water discharges into the Caloosahatchee River have been made. Implementation of the dual water system, water reclamation, and expansion of the system's storage capacity has enabled the utility to avoid discharges into the river, since all of the reclaimed water is being used to sustain the dual system. Because of Florida's stringent discharge regulations, avoiding surface water discharge allows the utility to save on treatment costs. Currently, the average daily use of reclaimed water is 21 mgd, most of which is used for lawn irrigation.

Water use is controlled through city-imposed restrictions on lawn irrigation and an increasing block rate structure for potable water

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Figure 5. View of membranes in use at the reverse osmosis plant in Cape Coral. *(photo: Hubert Stroud)*

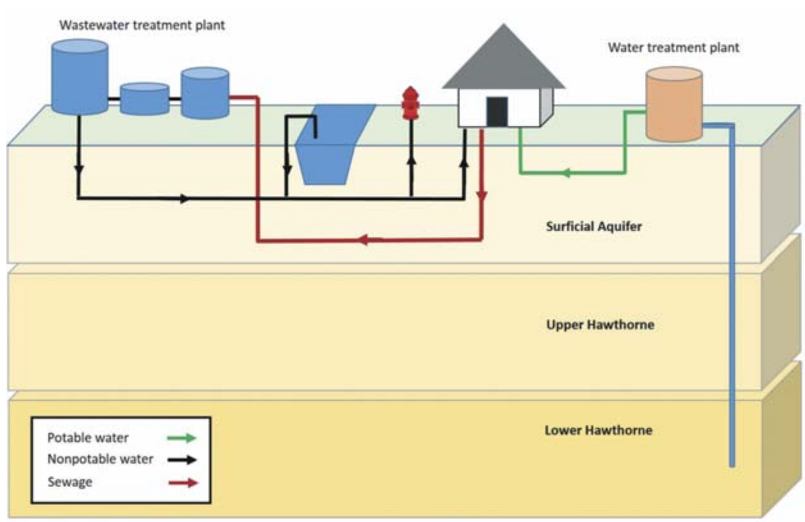

Figure 6. Illustration of the dual water system used in Cape Coral. *(source: modified from Godman and Kuyk, 1997)*

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consumption. Reclaimed water is not metered; instead, residential customers are charged a fixed rate of $9.50 per month and $0.50 per 1000 gal for commercial use. In terms of water conservation, it is unfortunate that residential use of reclaimed water is not metered (Long, 2016). It is also unfortunate that the city's utility department does not have sufficient personnel to enforce citywide watering restrictions. While it is illegal to water on restricted days and times, the city does not have the additional staff that would be needed to monitor and to write citations for water use violations (Fenske, 2016).

Reclaimed water is playing an important role in Florida as an increasing number of cities are implementing water reuse as part of their water resource management strategy. According to the water reuse workgroup that was established as part of a water conservation initiative in 2003, Florida is a national leader in water reuse (Water Reuse Workgroup, 2003). The state has been remarkably successful in moving toward water reuse, and it has become an integral part of wastewater management, water resource management, and ecosystem management. In the 16-county area of SFWMD, for example, more than 110 wastewater facilities are reusing 278 mgd, and the remainder of the wastewater (590 mgd) is being sent to the ocean or injected 3000 ft underground (SFWMD, 2017).

Incentives for water reuse include the ever-increasing demand for water, particularly within urban areas and the increasingly stringent wastewater discharge regulations. Disadvantages or hindrances associated with water reuse are the capital investment that is required to build a wastewater treatment plant and the ongoing operation and maintenance costs. Other concerns include the availability of grants, perceived risks and social attitudes, and regulatory difficulties (Grigg, Rogers, and Edmistor, 2013).

Summary and Conclusion

Cape Coral is a good example of a Florida city that took the lead and has implemented a dual water delivery system that uses reclaimed water as its source of supply for the nonpotable water line. The effectiveness of this system illustrates the importance of implementing innovative approaches to water resource management. The dual water system and wastewater reclamation have extended the life of potable supplies and provide an example of what can be done to preserve vital and very limited water resources. It's interesting that a city built in a very inefficient manner (in regards to water resources) is now serving as a model city in terms of water resource management.

Cape Coral has made significant progress in expanding its water supply capacity and in incorporating reclaimed water into its water delivery system. Now that the north RO plant has been completed, Cape Coral is well on its way to providing an adequate supply of potable water for its build-out population of more than 350,000 people (Stroud and Graff, *Florida Water Resources Journal*, 2009).

Sustaining future fresh water supplies may require even more innovation and conservation techniques. The success of these practices will in part depend on climate change and the extent to which precipitation patterns vary in the future. Extended periods of drought, for example, will exacerbate the current need to increase water supplies. Water management strategies will more than likely need to include both supply-side and demand-side changes. Adaption options that would expand the water supply include greater extraction capabilities, increases in storage capacity by building reservoirs and dams, expansion of rainwater storage, and the transport of water to areas of greatest need.

One of the most important areas of improvement is associated with water demand and conservation. Much more is needed to improve water efficiency, and areas of emphasis should include recycling and irrigation practices. While the city has made substantial progress in water reuse, it could and should be expanded. A particularly important area of concern is the amount of recycled water that is used for irrigation; far too much water is used for watering grass. Reduction options include changes to lawn grasses that require less water and changes in the timing and the amounts of water used for lawns. The city should also restructure the rates charged for water use to encourage water conservation and tax those that "waste" large volumes of water on nonessential uses.

While the increasing population and the predicted stresses of climate change will likely continue to challenge water resources globally, Cape Coral has shown itself to be a leader in the adoption of water conservation and management strategies. The implementation of a dual water system, using reclaimed water for nonpotable uses, and the subsequent reduction in demand for potable water indicates the potential for dual water systems to be effective in other cities, both in Florida and beyond.

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