The Environmental and Economic Benefits of Blending Nanofiltration Concentrate Water With Reclaimed Water as a Method of Disposal

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Seacoast Utility Authority (Authority) is a utility providing potable water, wastewater, and reclaimed water services to the City of Palm Beach Gardens, the Village of North Palm Beach, the south portion of the Town of Juno Beach, the Town of Lake Park, and areas of unincorporated Palm Beach County in south Florida. The Authority was formed in August 1988 to acquire the assets of Seacoast Utilities, a privately-owned water and sewer company. It has a governing board made up of one member from each of the five entities to which it provides services.

The Authority does not have the ability to levy any taxes, but instead receives funding from the rates and fees that it charges its customers. These rates and fees must be approved by the governing board. It also has the ability to secure additional funds through the issuance of government bonds, which must also be approved by the board. In this way, the Authority functions in a very similar fashion as utilities within cities where they are designated as enterprise funds. However, because the Authority was once a part of the private MacArthur Foundation (and later became publicly owned) there are some legacy agreements from that process (including some for reclaimed water allocations) that will not be considered in this article. All return on investment (ROI) and feasibility calculations will be performed as if these agreements were not in place, as they are truly unique to the Authority and not at all applicable in a general sense for other utilities considering this option for the disposal or reuse of their nanofiltration (NF) concentrate.

The Authority is in the process of replacing its two lime softening water treatment plants (WTPs) with a combined rated capacity of 30.5 mil gal per day (mgd) with a single NF and reverse osmosis (RO) water treatment plant rated at 30.5 mgd. While the disposal method for the RO concentrate will be deep well injection, the primary method for disposal of the NF concentrate will be through the existing reclaimed water system by being

Table 1. Existing Authory Customers

User	Maximum Allocation (gpd)	Time (Hours)
Customers with Storage		
Mirasol	1,750,000	24
Encon (Abacoa / Bear's Club)	1,500,000	24
Old Palm	1,600,000	24
Frenchman's Reserve	800,000	24
BallenIsles East	750,000	24
BallenIsles West	750,000	24
Regional Center	700,000	24
Frenchman's Creek	500,000	24
Eastpointe Country Club	300,000	24
Eastpointe Racquet Club	300,000	24
Paloma	300,000	24
Village of North Palm Beach	300,000	24
Sub-Total	**8,920,000**	**24**
Customers without Storage		
The Isles	300,000	10
Old Port Cove	200,000	10
Eastpointe HOA	100,000	10
Mirasol Walk	55,000	10
PGA Blvd. Streetscape	40,000	10
Oak Harbor	80,000	10
Governor's Pointe	50,000	10
Mariner's Cove	100,000	10
FPL - Juno	55,000	10
Waterway Terrace	31,000	10
FPL Monet Substation	4,000	10
Royale Harbor	40,000	10
Seamark	20,000	10
Season's 52	55,000	10
Gemini Condo	34,000	10
Southampton	39,000	10
Central Park	20,000	10
Hood Road WTP	38,880	10
Sub-Total	**1,853,000**	**10**
TOTALS	**10,773,000**	**N/A**

Table 2. Supplemental Wells

Well Name	Daily Capacity (gpd)
Frenchman's Well	250,000
MacArthur Well	250,000
The Isles Well	250,000
Totals	**750,000**

blended with the treated effluent from the PGA Wastewater Treatment Plant (WWTP) in Palm Beach Gardens (in the western portion of the Authority's service area) already being distributed via the reclaimed water system.

As a permit requirement, there must be a secondary disposal method for the NF concentrate for periods where the WTP deep well is out of service. The secondary disposal method will be via the same deep well that is utilized for the RO concentrate disposal. There is no requirement for an alternative means of disposal for the RO concentrate, as the RO is a supplemental process at the WTP and can be curtailed or even shut down until the primary disposal method (deep well injection) is brought back on line. The environmental and economic benefits of disposing of the NF concentrate through the reclaimed water system, in lieu of more traditional methods of disposal such as multiple deep injection wells, is presented here.

Existing Reclaimed Water System

The Authority currently delivers reclaimed water to 30 large-usage customers throughout its distribution system from the PGA WWTP. There are two distinct types of customers in the reclaimed water system: customers that receive the water continuously each day over a 24-hour period in large storage lakes, and customers that do not have reclaimed water storage facilities and must receive the water only during the period when they irrigate. The latter customers typically receive and distribute the reclaimed water during a 10-hour period overnight. Table 1 lists each customer, the agreed-upon daily maximum allocation the customer can receive, and the time when the reclaimed water is typically delivered. Figures 1, 1A, and 1B depict the existing reclaimed water system, with end-user locations shown.

Based on the reclaimed water agreements, the total demand of the customers with storage is 8.92 mgd and the total demand of customers without storage is 1.853 mgd, giving a total daily demand of 10.773 mil gal (MG). The average annual wastewater effluent generated from the PGA WWTP produced approximately 8.2 mgd of reclaimed water, less than the total reclaimed water agreement allocation. In order to supplement the reclaimed water that is available to its customers each day, the Authority has installed three supplemental surficial aquifer wells that are available to augment the reclaimed water system at 0.25 mgd each, for a total supplemental well contribution of 0.75 mgd. In addition, the Authority utilizes a surface water supplemental system that withdraws up to 1.5 mgd of water from the C-17 Canal and pumps it via the wastewater collection system to the PGA WWTP when it is necessary to increase effluent available for the production of reclaimed water. Withdrawals from the supplemental wells and surface water pump are permitted by the South Florida Water Management District (SFWMD) as consumptive use.

The three supplemental wells are capable of pumping directly into the reclaimed water distribution system at the capacities included in Table 2. As a result, the three wells can provide up 0.75 mgd of additional reclaimed water to Authorty customers. Monthly or annual limitations established by the SFWMD may restrict the duration of the withdrawals indicated; however, for the purposes of this evaluation, the flow rates depicted in Table 2 from each well are assumed to be constant.

Therefore, the approximate average daily effluent flow from the PGA WWTP, plus the water from the C-17 Canal and supplemental wells, equates to approximately 10.45 mgd of available reclaimed water, which is less than the reclaimed water demand of 10.773 mgd. However, the existing reclaimed water agreements state that the Authority does not have to pro-

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vide the agreement amounts if the reclaimed water is not available. The users that do not have storage ponds may not receive the agreed-upon amount of reclaimed water during irrigation hours, as the water is not available.

Existing Revenue Stream

Currently, the Authority charges reclaimed water users at a rate of $0.28 per 1,000 gal of reclaimed water utilized. The revenue generated if the Authority meets all customer reclaimed water demands, or 10.773 mgd, is approximately $1.1 million per year, not considering the unique legacy agreements associated with the MacArthur Foundation.

Quality and Quantity of Concentrate Water

In order to decrease the reliance on supplemental wells, and to provide additional reclaimed water to existing customers or to new customers, the Authority will supplement its reclaimed water supply with NF reject water or "concentrate" from its Hood Road WTP. Based on a maximum NF permeate capacity of 26.0 mgd and a membrane recovery rate of 80 percent, the maximum expected reject or concentrate flow rate will be 6.5 mgd. The minimum concentrate flow rate will be based on the minimum capacity of the NF membranes operated, which is expected to be at a rate of approximately 14 mgd of permeate. Assuming an 80 percent recovery rate, the concentrate generated from 14 mgd of permeate production will be approximately 3.5 mgd. If the recovery rate is 85 percent, then the concentrate generated from 14 mgd of permeate production will be 2.47 mgd. Therefore, the NF concentrate will potentially range in flow from 2.47 to 6.5 mgd. The expected water quality of the NF concentrate is shown in Table 3.

The NF concentrate will be conveyed to the PGA WWTP through a 16-in. pipeline from the Hood Road WTP, which is approximately four miles west of the PGA WWTP. During the preliminary stages of design, an evaluation was performed to determine the most cost-effective method of constructing the NF concentrate main. During this evaluation, it was decided that the main would be installed via open-cut methods where possible, even through a private golf course. Through close coordination with the owners of the course, the construction was phased in so that the main was installed across the golf course while it was closed during a two-month period for maintenance.

A portion of the open-cut section of the NF concentrate main would utilize high-density polyethylene (HDPE) welded pipe to allow the main to be installed directly adjacent to an existing raw water main, where the required separation would not be possible through bell and spigot pipe. With one exception (Central Boulevard), the major roads were crossed via horizontal directional drilling (HDD) of HDPE pipe in order to minimize restoration efforts and construction costs. The HDD was the only feasible and allowable means of installation for the crossings of I-95 and the Florida Turnpike; open cutting these major highways was not an option, for obvious reasons.

Both Palm Beach County and the Florida Department of Transportation allowed the HDPE pipe to be installed without a casing; however, the Florida Turnpike Authority required that a 30-in. HDPE casing be utilized. At Central Boulevard, an abandoned section of 24-in. ductile iron pipe was used for a casing and the NF concentrate main was installed within the 24-in. ductile iron casing. Figure 2 shows the major road crossings and the pipe installation method utilized throughout the pipe route.

The concentrate main was ready for use in mid-2013. Based on the NF water quality, it was determined that the concentrate main would be constructed of polyvinyl chloride (PVC) pipe, ceramic epoxy-coated ductile iron fittings, and rubber-lined butterfly valves in order to minimize required maintenance and to extend the expected lifetime of the main. The rubber-lined butterfly valves were selected because only the rubber would come into contact with the NF concentrate, prolonging the expected life of the valve. Originally, the main was designed with high-performance, wafer-style stainless steel butterfly valves with restrained-flanged coupling adapters; however, upon inspection, when the valves were delivered, the Authority and its consulting engineer were not comfortable with the possible maintenance issues associated with the design and construction of the actuator for buried service of the wafer-style butterfly valve. Because of this, the original valves were returned and a rubber-lined, mechanical-joint butterfly valve was used in lieu of the stainless steel wafer-style butterfly valves.

The NF concentrate will be pumped through the new pipeline into a lined storage pond at the PGA WWTP, where it will be stored prior to blending. A new variable speed pump station at the PGA WWTP will convey concentrate from the lined pond to the chlorine contact basin, where it will be blended with reclaimed water and pumped to the reclaimed water distribution system. By sending the NF concentrate to the chlorine contact basin, the Authory is eliminating the expense and lost capacity of putting the concentrate through the treatment system at the PGA WWTP. An additional benefit of blending with the effluent of the plant is that the monitoring equipment used to determine if the reclaimed water meets treatment standards is located immediately after the blending point. Should the cause for the non-compliance-requiring diversion be the concentrate itself, there is no appreciable amount of concentrate still moving through the treatment system. If the concentrate were introduced to the front of the treatment process, there would be the potential of several MG of effluent that would need to be diverted until the concentrate has passed through the treatment process.

The lined concentrate storage pond will also allow the NF concentrate to be conveyed from the Hood Road WTP to the PGA WWTP at the rate it is produced, regardless of the effluent flow rate at the PGA WWTP. During wet weather periods, when reclaimed water demand is low, the NF concentrate can be disposed of at the WTP through an existing deep well utilized for the reverse osmosis portion of the new WTP.

Based on previous experience, it is expected that as the NF membranes age, the quality of the NF concentrate will "improve." As the

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Table 3. Nanofiltration Concentrate Quantity and Quality

Parameter	Units	Value at 80 Percent Recovery	Value at 85 Percent Recovery
Flow (MDF)	Mgd	6.5	4.59
Chlorine	mg/L	320	417
Total Dissolved Solids	mg/L	2,983	3,927
Calcium	mg/L	608	803
Magnesium	mg/L	29	38
Sodium	mg/L	166	215
Barium	mg/L	0.1	0.13
Nitrate	mg/L	0.04	0.05
Fluoride	mg/L	2.8	3.6
Sulfate	mg/L	527	699
pH	Standard Units	7.2	7.3

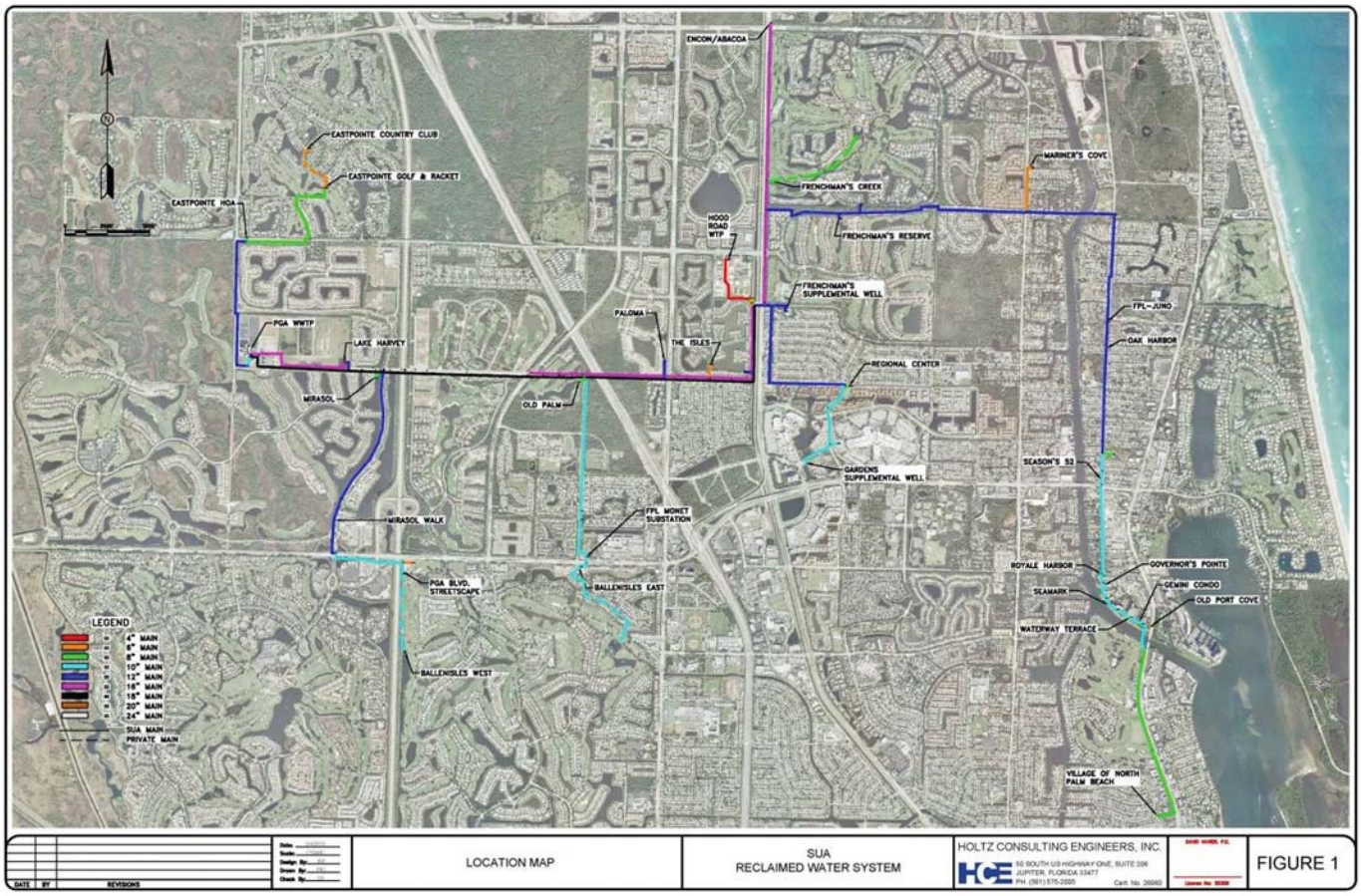

Figure 1. Existing Authority Reclaimed Water System

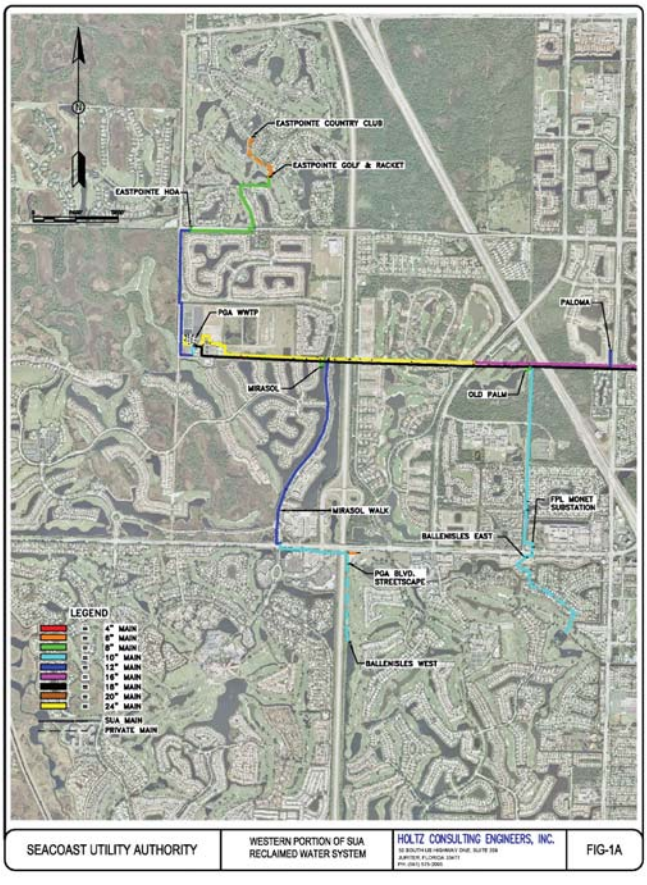

Figure 1A. Authority Reclaimed Water System: Western Portion

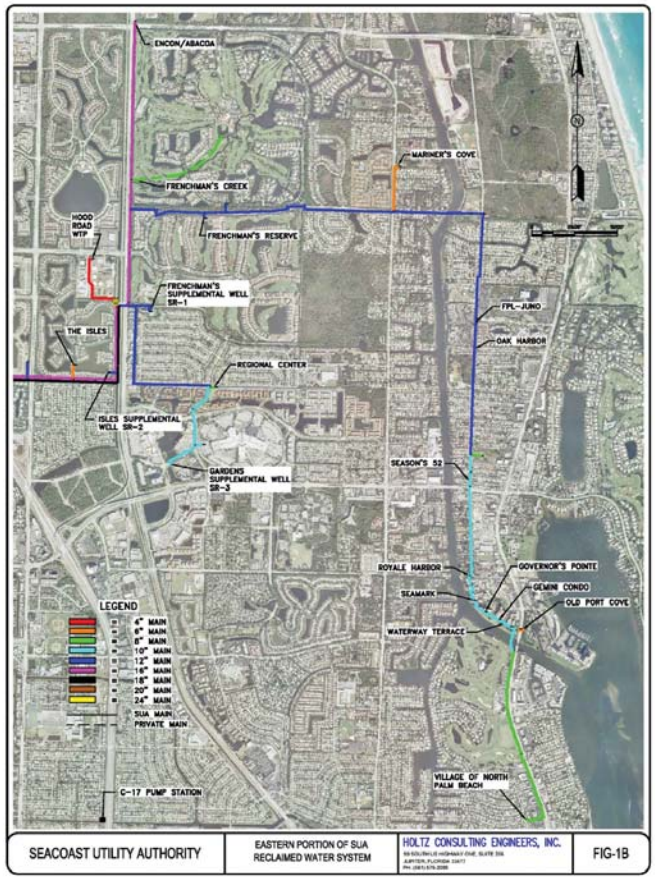

Figure 1B. Authority Reclaimed Water System: Eastern Portion

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membranes at the WTP age, the concentrate will contain less and less total dissolved solids (TDS); in other words, the concentrate becomes less concentrated. This will happen because the membrane will start fouling up, allowing less permeate to pass through the membrane. When this occurs, the expected water quality of the NF concentrate will improve because the volume of NF concentrate water will increase as the volume of permeate decreases. The increased volume of NF concentrate water will allow for an increased blending ratio with reclaimed water, based on the TDS.

While this is great on the reclaimed end of the operation, it is less so at the production end. As the reject rate goes up, so does the cost of producing water from those membranes. There is a significant cost associated with the replacement of membranes, which must be considered when looking at the increased cost of water production. At a certain point, the cost of producing water with aged membranes becomes more expensive, and the membranes will be replaced. When this happens, the NF concentrate water quality will return to the original quantities, listed in Table 3.

Permitting and Blending Obstacles Encountered

The concentrate will be discharged into a recently constructed lined storage pond at the PGA WWTP. A proposed concentrate pump station there will pump the concentrate from the storage pond to the chlorine contact basin, where the concentrate will be blended with the reclaimed water at a ratio of 1 part of concentrate to 3.5 parts of reclaimed water. It is expected that this ratio may be modified in the future to allow for a higher blending ratio, based on blended TDS once the actual water quality of the NF concentrate is known, but that modification is a) possibly not needed as the new plant is not actually producing concentrate at this point and the quality could be more or less concentrated than estimated, and b) not guaranteed as it needs regulatory approval.

As the water quality of the NF concentrate changes because of the fouling of the membranes, it is expected that the higher blending ratio mentioned will be utilized. This blending ratio will be determined by the TDS concentration. As part of the NF concentrate blending pump station project, a sample pump and conductivity analyzer is being installed that will continuously monitor the conductivity. After a baseline ratio of conductivity-to-TDS concentration is determined, the ratio of NF concentrate to reclaimed water can be modified so that a constant TDS level is maintained in the effluent. For this reason, the blending pump station is equipped with variable frequency drives, allowing the pump speed to increase or decrease in order to maintain a constant TDS level by continuous monitoring of the conductivity of the blended effluent.

There were several permitting obstacles that needed to be overcome, not the least of which was the requirement from the regulatory agency that there be a physical separation between the piping and appurtenances of the WTP and treatment systems at the WWTP. Effectively, this meant a complete separation of concentrate storage pond and any process streams at the WWTP. This also meant that additional design was required to repipe and isolate the existing lift station that was previously installed to drain the effluent reject storage pond, and which would now become the concentrate storage pond.

The lift station is now dedicated solely to the north storage pond, which remains as an effluent reject storage pond and allows it to be drained through the lift station and pumped directly to the anoxic zone for retreatment. The liner will be peeled back over the path of the new piping to be installed, and hard pipe will be installed to connect the north pond with the existing lift station. This approach will provide two complete barriers between the reject storage and the concentrate storage: piping and liner. Either separation method would likely have satisfied the regulatory concerns, but by providing both, it removes any lingering concerns of cross contamination in the event of a failure of one of them. Additional piping changes needed to be made to sever existing cross connections to other storage ponds so that all possible sources of cross contamination were removed. The "duckbill" check valves installed in the chlorine contact chamber satisfied the required check valve and air gap separation requirements of the regulatory agencies.

The design for the blending station was incorporated into the five-year permit renewal for the WWTP, which saved the Authority the cost of performing a permit modification in addition to the cost of renewing the permit. By taking that path, however, the Authority was unable to renew the permit until it was able to satisfy all concerns. Alternatively, had any of the outstanding issues with the changes to the permit as submitted not been resolved, the Authority could have withdrawn the sections pertaining to the blending system and later submitted them as a substantial modification to the new permit. In the end, the Authority was able to accommodate all the requests by the regulating agencies and retain them as part of the permit renewal.

Figure 2. Concentrate Main Route

In addition to the permitting obstacles discussed, the Authority was also in the process of renewing its water use permit (WUP) from the SFWMD. One concern that the SFWMD had as part of the WUP renewal was the supposed effect that the Hood Road Wellfield had on several wetlands within the Mirasol development. Mirasol is a golf-course community located west of Florida's Turnpike that surrounds the PGA WWTP and is an existing reclaimed water customer that receives 1.75 mgd of reclaimed water through a single metered location. Ac-

cording to SFWMD, during drought conditions, the water level within the existing wetlands was decreasing faster than normally observed, and this drawdown was caused by the adjacent wellfield owned and operated by the Authority. In order to alleviate this possible issue, it was determined that during drought conditions, an additional 2.1 mgd of reclaimed water would be delivered to the Mirasol lake system to minimize the drawdown of the wetlands, should certain threshold conditions occur. Without the supplemental NF concentrate water, the Authority would need to decrease the volume of reclaimed water delivered to existing customers during drought conditions, when the reclaimed water is needed the most. However, with 3.5 to 6.5 mgd of NF concentrate available, existing customers will still receive the agreed-upon volume, even during drought conditions.

New Reclaimed Water Volume and Revenue Available

The quantity of new reclaimed water available from NF concentrate will vary slightly day-to-day, depending on finished water production, but is estimated to be approximately 3.5 mgd. This additional volume of reclaimed water will generate $357,700 of revenue per year, based on the current billing rate of $0.28 per 1,000 gal received.

The cost of construction of the 16-in. NF concentrate main is $2.5 million and the cost of constructing the NF concentrate blending pump station is $1 million. The Authority will also receive $500,000 in grant funding from the SFWMD to help fund this project. The funding from SFWMD is due to the benefit this reclaimed water will have in regards to minimizing the drawdown on the wetlands within the Mirasol development. Therefore, the total cost for the additional reclaimed water paid by Authority rate payers is $3 million.

Based on an additional revenue stream of $357,700, the ROI for this project is 8.4 years, which is significantly less than the expected life span of either the pipeline or the pump station. In this evaluation, it is assumed that the additional reclaimed water will be conveyed to existing customers, or that new customers will pay for the capital improvements needed to receive reclaimed water. There are several existing customers with small daily allocations who have approached the Authority in the past about increasing their daily allocation, but they have been denied because of the lack of available reclaimed water. In addition, there are several potential large-development customers who have approached the Authority about obtaining reclaimed water for irrigation of their landscaping and golf courses. With the additional reclaimed water available, the Authory will be able to expand its reclaimed water customer base and better serve existing customers.

Conclusion

The use of NF concentrate main as reclaimed water will allow for the required elimination of withdrawal of supplemental surficial water should a severe drought occur that results in the curtailment of water use permits, decrease the quantity of concentrate being sent to the deep injection well, allow for additional customers to be provided with reclaimed water, and provide additional reclaimed water to existing customers. Utilizing NF concentrate will also allow the Authority's reclaimed water to be "drought proof" in that reclaimed water from surficial water sources will no longer be required to meet current obligations. This will, at the same time, return additional flows back to the surficial aquifer through irrigation that would otherwise have been permanently lost through disposal via deep well injection.