

Doing More with Less: Improving Effluent Quality, Reducing Energy Costs, and Managing Water Resources

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Recent societal pressures to reduce the costs associated with energy consumption and the related greenhouse gas emissions have created a driver that is inconsistent with traditional goals of water quality and environmental protection. This conflict is particularly compelling for wastewater treatment facilities, as more stringent effluent requirements are being promulgated. The result is that the actual concentrations of the permitted constituents are well below the permitted limits, at the expense of wasted energy.

City of North Port Capital Improvement Program

The City of North Port is a small community that is approximately 129 km (80 mi) south of Tampa. It was incorporated in 1958 and started as a planned unit development. The City's wastewater service area consists of nearly 275 km² (106 mi²) of area. More interestingly, it consists of nearly 87,000 platted lots and currently has less than 15 percent build-

out. The City's wastewater service area and customers are illustrated in Figure 1.

Due to the randomness of the development throughout the service area with septic tanks, the City's wastewater system had experienced negligible growth, averaging less than 1 percent annually. In the early 2000s, the City began to experience more development, and the wastewater system experienced annual growth rates greater than 6 percent. As the City matured and its infrastructure aged, it was quickly understood that its facilities needed to be upgraded and expanded to keep up with the growth.

In 2005, the City's utilities department had to decide how to expand its wastewater facilities to meet the growing demands of the region. It completed a much needed Utility System Master Plan that recommended two additional wastewater treatment facilities. The City's existing facility was permitted to treat 11,735 m³/day (3.1 mgd), with flows expected to reach slightly over 30,283 m³/day (8 mgd) by 2015 (Black & Veatch, 2005). Since the com-

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pletion of the master plan, the economic downturn caused development to slow, resulting in a decrease in the growth rates projected. This resulted in one change to the master plan, which was to expand the existing facility while deferring the capital necessary for the construction of the two proposed treatment facilities until a later date.

Although the development schedule has been pushed back, the City and developers will continue to establish the infrastructure that will be necessary to serve the area in the future.

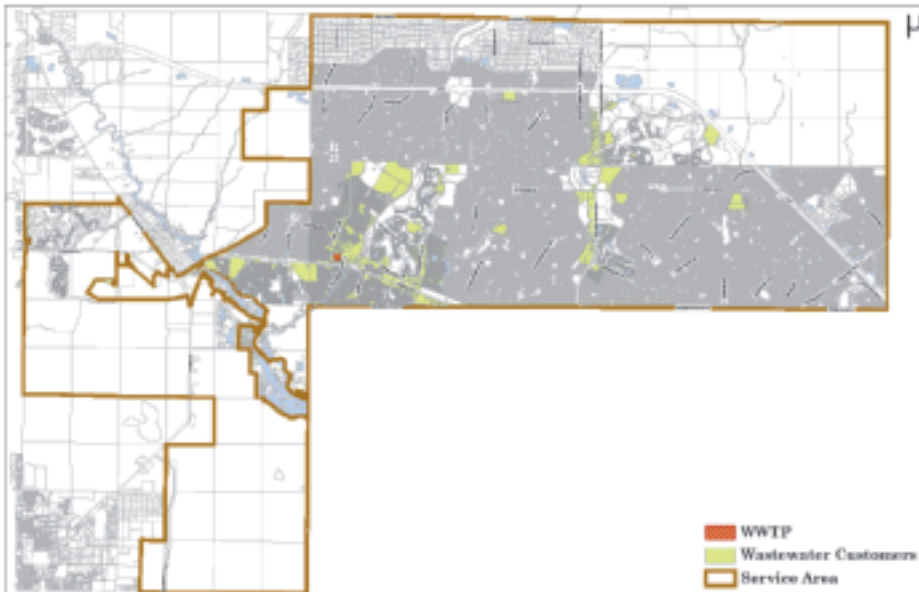


Figure 1. City of North Port Wastewater Service Map

Existing Treatment Facility

The City's treatment facility is a conventional activated sludge facility that was last expanded in 2002. Six force mains enter the facility site and combine into a single 406 mm (16 in) diameter force main that discharges raw wastewater at the pretreatment structure. Pretreatment consists of two mechanically cleaned bar screens with clear openings of 6 mm (0.25 in) and a single mechanically induced vortex grit unit.

Pretreated wastewater enters a distribution box that diverts the flow to one of five aeration basins. Air is supplied via a coarse bubble air diffuser system and five multi-stage centrifugal blowers: three 150 High Pressure (HP) and two 250 HP. Dissolved oxygen (DO) measurements taken every eight hours are used to control the aeration during the process. The mixed liquor suspended solids

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(MLSS) discharge to a common channel that flow to a splitter box, diverting the flow to three secondary clarifiers.

The effluent from the secondary clarifiers flows by gravity to a flow splitter structure that diverts a portion of the flow to the deep injection well (DIW) pump station and to two disk filters, each with a capacity of 3,785 m³/day (1.0 mgd). The effluent that does not undergo filtration is pumped to the DIW for ultimate disposal. Filtered effluent flows by gravity to the chlorine contact basin for disinfection, using liquid sodium hypochlorite. Effluent that meets high level disinfection (HLD) requirements is pumped to the reclaimed water storage tank for distribution to the reclaimed water system. Effluent that does not meet the HLD requirements is diverted to the deep injection well pump station for disposal.

A Road Map to Success

The City's utilities staff recognized that there was room for improvement at the treatment facility. They tasked the project team with these goals:

- ◆ Improve the effluent quality to minimize the nitrogen in the effluent.
- ◆ Reduce the energy required to treat the wastewater.
- ◆ Maximize reuse and minimize the effluent that discharged to the DIW.

The City's consultants and operations staff conducted a number of workshops to develop alternatives to meet the City's goals. To meet the anticipated requirements, a number of treatment options were evaluated, which included:

- ◆ Option 1: 5-stage Bardenpho™ and chemical addition for polishing phosphorus removal.
- ◆ Option 2: 4-stage Bardenpho™ and chemical addition for phosphorus removal.

◆ Option 3: Step-feed activated sludge process with denitrification filtration and chemical addition for phosphorus removal.

◆ Option 4: Modified Ludzack-Ettinger (MLE), with denitrification filters and chemical addition for phosphorus removal.

Due to site configuration and existing tankage limitations, only Options 3 and 4 were determined to be practical treatment alternatives. An operational and economic analysis for both options processes was performed. Based on the additional piping and tankage required to configure these processes, Option 4 was chosen as the desired treatment alternative for the project.

To size the biological process, the proposed improvements were modeled using the EnviroSim BioWin™ process model. Using wastewater samples collected from a special sampling effort, the BioWin™ model was calibrated to accurately predict the treatment facility performance under varying conditions. The facility was modeled for various flows and loading conditions to produce an annual average effluent total nitrogen (TN) of less than 10 mg/L. Illustrated in Figure 2 is the BioWin™ screenshot of the process configuration of the MLE process for the City's proposed upgrades.

Improvements at the City's treatment facility included a complete overhaul of the treatment process from pretreatment through the reclaimed water pumping facilities. The influent force main entering the facility was enlarged from a 406 mm (16 in) to a 914 mm (36 in) diameter force main to improve system hydraulics. The headworks structure was expanded to include two new mechanically cleaned bar screens with 6 mm (0.25 in) clear openings, and the two existing screens and dewatering screw press were refurbished. The open channels were covered, the screening and grit collection area was enclosed, and a biofil-

ter was added for odor control.

The biological treatment process was converted from a conventional activated sludge facility to a MLE process. Two anoxic basins and a sixth aeration basin were added, and the coarse bubble aeration system was replaced with a tapered fine bubble system (45 percent/32 percent/23 percent). Three 150 HP multi-stage blowers were replaced with two 125 HP dual vane single-stage centrifugal blowers, and the existing two 250 HP multistage blowers remained as backup units. An internal mixed liquor (IMLR) system to recycle the nitrified MLSS to the anoxic basins and DO analyzers to control the blowers supplying air for the biological process were included as part of the project. The flow-through anoxic basins were designed to operate in parallel, discharging to a common channel designed to divert the flow to the aeration basins. The flow scheme was reversed through the initial three aeration basins operating in parallel and then through the remaining three basins. The flow from the MLE process discharges to the splitter box was designed to divert the flow to the one new, and three existing, secondary clarifiers.

Due to the operational problems and hydraulic limitations with the existing disk filters, it was decided to replace the filtration system with a deep bed filtration system. The design of the new filters incorporated provisions to add a carbon source feed to reduce the effluent nitrogen further should the City be required to meet the promulgated limits that are outlined in the numeric nutrient criteria from the U.S. Environmental Protection Agency (USEPA).

The filtered effluent discharges and flows by gravity to both an existing and new chlorine contact basin that operate in parallel and consist of two distinct internal chamber basins that will permit one side of each basin to be taken out of service without impacting plant flow. The filtered effluent is continuously

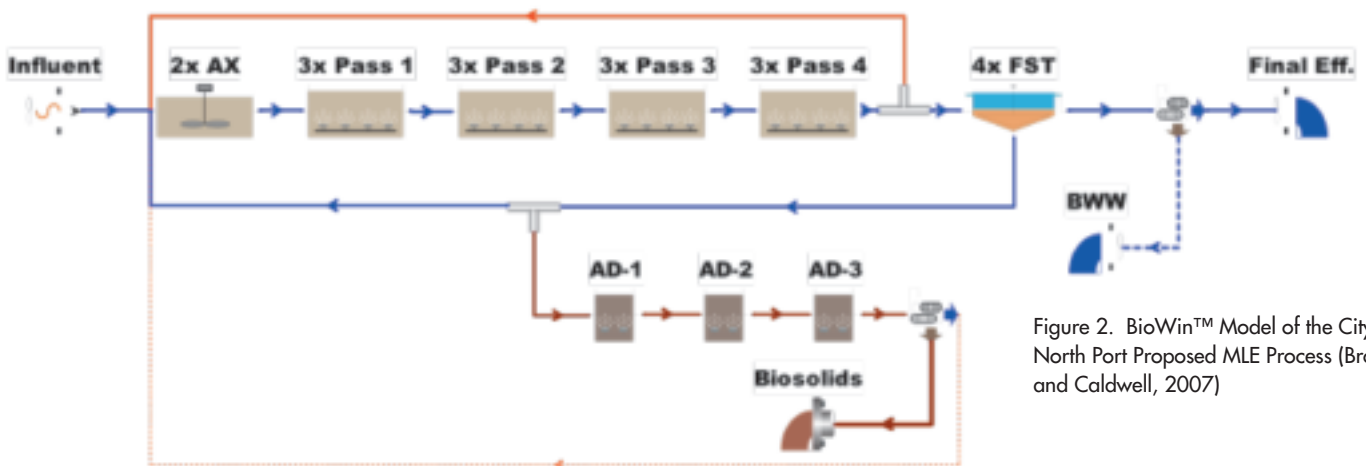


Figure 2. BioWin™ Model of the City of North Port Proposed MLE Process (Brown and Caldwell, 2007)

monitored for turbidity levels, prior to the addition of the liquid chlorine. The effluent from the chlorine contact basins is continually monitored for chlorine residual and discharges into a common effluent transfer pump station that pumps the effluent to onsite ground storage tanks, or to the DIW pump station should a HLD deviation occur.

Illustrated in Figure 3 is the City's upgraded treatment facility.

Successful Outcome

A project can be defined as successful by many means, such as being completed on time and under budget, producing a better effluent, and lowering operating costs, as well as many others. In fact, most utilities would consider that meeting just one of these descriptions would define their project as a success.

Delivery of the Project

The project was constructed using a conventional design-bid-build approach. A budget of nearly \$27.5 million was set aside for the project, and the bid of \$21.52 million from the Encore Construction Company was accepted. The City prepurchased major pieces of equipment, and throughout the construction, the facility was continually being value-engineered to further reduce the cost of the project. Construction began in April 2009 and was certified complete on June 30, 2010—five months ahead of schedule and nearly \$764,000 under budget.

Better Effluent

The City's treatment facility is obliged to meet the requirements summarized in Table 1.

The BioWin™ process simulation model was used to establish the treatment capacity and identify improvements necessary to provide for an HLD effluent that met the following criteria:

- ◆ Carbonaceous biochemical oxygen demand (CBOD)₅ < 5 mg/L
- ◆ Total suspended solids (TSS) < 5 mg/L
- ◆ TN < 10 mg/L

Illustrated in Figure 4 are the predicted results from the model for effluent CBOD5 and TSS, and in Figures 5 and 6 are the predicted model results for TN, and NH₃-N (Ammonia-Nitrogen), NO₃-N (Nitrate-Nitrogen), and total kjeldahl nitrogen (TKN), respectively.

The BioWin™ process model predicted that the TN from the upgraded treatment facility would result in an annual average effluent TN concentration of approximately 8.5 mg/L. Annual average concentrations for NH₃-N, TKN, and NH₃-N in the effluent were determined from modeling 0.3 mg/L, 1.2 mg/L, and 7.0 mg/L, respectively on an annual average basis.

Since January 2007, and prior to starting



Figure 3. Upgraded Wastewater Treatment Facility (Florida Aerial Services Inc., January 2010)

Table 1. Effluent Permit Limits

| Parameter | Annual Average | Monthly Average | Weekly Average | Single Sample |
|---|----------------|-----------------|----------------|---------------|
| CBOD ₅ , mg/L | 20 | 30 | 45 | 60 |
| TSS, mg/L | - | - | - | 5.0 |
| pH, SU | - | - | - | 6.0 to 8.5 |
| Fecal coliforms ¹ , #/100 mL | - | - | - | 25 |
| Total chlorine residual, mg/L | - | - | - | 1.0 |
| Turbidity, NTU | - | - | - | 3.5 |
| Giardia ² , Cysts/100L | - | - | - | - |
| Cryptosporidium ² , Oocysts/ 100 L | - | - | - | - |

1. In addition to the single day limit, 75 percent of the samples taken must be reported as nondetectable to be in compliance.
2. No standard for Giardia or Cryptosporidium; report only and sampled once every two years.

up the MLE process, the effluent TN, NH₃-N, TKN, and NO₃-N averaged 20.88 mg/L, 0.32 mg/L, 1.43 mg/L, and 19.38 mg/L, respectively. After the MLE process was successfully started and acclimated (July 2009), the effluent TN, NH₃-N, TKN, and NO₃-N averaged 7.70 mg/L, 0.14 mg/L, 1.00 mg/L, and 6.55 mg/L, respectively. Illustrated in Figure 7 are the actual effluent data from the City's treatment facility beginning in January 2007 and ending in December 2011.

Other parameters (e.g., BOD₅, TSS, fecal coliforms, turbidity, etc.) have been monitored

in accordance with the City's Florida Department of Environmental Protection (FDEP) Operations Permit, and since putting the new facilities online there have been no permit excursions. In fact, the turbidity levels have consistently been less than 1.0 Nephelometric Turbidity Units (NTU) since the filters were put into service in September 2009.

An Emphasis on Reclaimed Water

The City is located in an area of the state that has been identified as a Water Use Caution Area. *Continued on page 18*

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tion Area (WUCA), which is defined as an area that requires a regional action to address cumulative water withdrawal concerns that are causing, or may cause, adverse impacts to the water and related land resources or the public interest (Chapter 40D-2.801, FAC). While the Southwest Florida Water Management District (SWFWMD) implements many strategies to protect the water resources in its region, it has determined that reclaimed water is an impor-

tant resource that can help meet future demands in all use sectors. The District's goals are to utilize 75 percent of all reuse flows and to achieve a 75 percent offset of potable sources (SWFWMD, 2010). In addition to the water conservation initiatives from the District, the FDEP in 2001 embarked on the *Water Conservation Initiative* (FDEP, 2002), which is a program designed to promote water conservation in an effort to ensure water availability for the future.

As noted earlier, one of the primary goals of the City is to maximize the use of the reclaimed water produced at its facility, and minimize the quantity of this resource pumped down the DIW. Prior to this expansion, the City's reclaimed water facilities were plagued with many problems, all of which were addressed with this upgrades program.

The first, and probably the major problem, was the disk filters that never operated efficiently. These filters were limited in treatment capacity, which was 7,117 m³/day (1.88 mgd), and experienced many operational problems, namely consistently meeting the turbidity requirements (3.5 NTU) for HLD. This resulted in numerous excursions and a lost resource that had to be diverted to the DIW for disposal. This problem was resolved with the addition of the deep bed filters that were installed as part of the upgrades program.

Another problem was the on-site and off-site storage facilities, and the controls in place to deliver this resource. The City found that managing and allocating reclaimed water supplies was significantly different from the operation of its potable water system. For example, the City withdrew only the volume of raw water necessary to meet its potable water demand; in the case of its reuse system, however, reclaimed water was continuously being generated, and what could be used immediately was either stored or disposed down the DIW.

The on-site storage is limited to 1,514 m³ (400,000 gallons) and the off-site storage is limited to 68,516 m³ (18.1 MG). As a result, if none of the reclaimed water customers were not requiring reclaimed water, then all reclaimed water produced over 1,514 m³ (400,000 gallons) was sent to the DIW. As part of this, 9,464 m³ (2,500,000 gallons) of additional on-site storage was added, which increased the on-site storage to 10,978 m³ (2,900,000 gallons).

Coupled with the inadequate on-site reclaimed water storage facilities was the fact that there were no off-site controls that would permit the City to remotely pump the reclaimed water to the two largest off-site storage facilities. Prior to these upgrades, all of the transfer of the reclaimed water from the City's treatment facility to its off-site storage facilities was manual. Automatic controls were installed at the off-site storage sites, which enabled the City to remotely fill these sites and maximize the delivery of the water resource.

Reclaimed water usage data was evaluated from the period when the disk filters were put into service to December 2011. Illustrated in Figure 8 is the percentage of reuse water delivered to reclaimed water customers since May 2002.

Prior to the date that the new effluent fil-

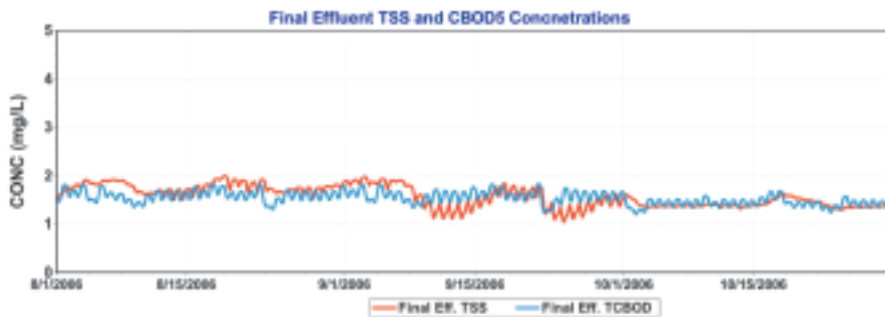


Figure 4. Predicted Effluent CBOD₅ and TSS (Brown and Caldwell, 2007)

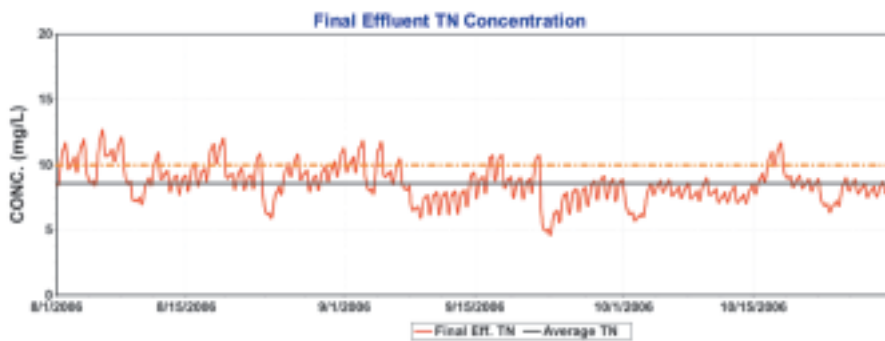


Figure 5. Predicted Effluent TN (Brown and Caldwell, 2007)



Figure 6. Predicted Effluent NH₃-N, TKN, and NO₃-N (Brown and Caldwell, 2007)

ters were put online in September 2009, the City's water reclamation facility (WRF) was plagued with permit excursions, primarily attributed to the effluent filtration system. These permit excursions resulted in the City diverting effluent to its Class I deep injection well. Since December 2009, the facility has had "zero" permit excursions, and the effluent TSS has averaged less than 1mg/L. In addition to the problems associated with the permit excursions, the City has nearly doubled the volume of reclaimed water to its customers. Prior to the new reclaimed water facilities being placed into service, the City reused 34.9 percent of the wastewater treated. After the new filters were installed, the City increased to 74.2 percent the volume of wastewater treated. This has resulted in the City selling slightly over \$82,600 of additional reclaimed water.

Operational Optimization

By and large, it can be said that the greater the required level of treatment, the greater the energy demand. In most cases, many facilities over-aerate, with no regard to how much air is required for the process in order to obtain an adequate margin of safety against permit excursions. The result is that the actual effluent concentrations of these constituents in the reclaimed water are well below the permitted

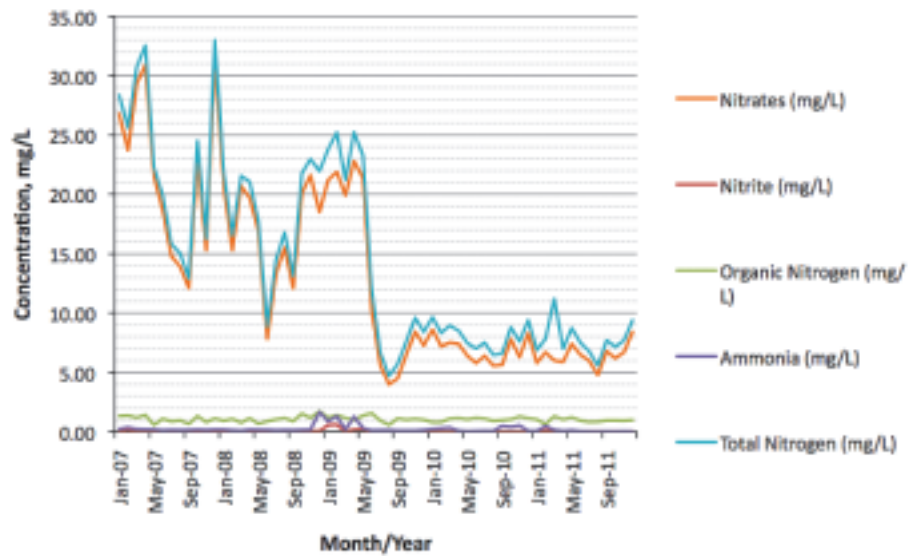


Figure 7. City of North Port Effluent Nitrogen Species (January 2007 – December 2011)

discharge concentration, while a significant amount of energy is wasted.

It is a known fact that aeration alone can account for between 50 and 70 percent of a treatment facility's overall power consumption. The City's conventional activated sludge system incorporated multi-stage centrifugal

blowers to provide air to the coarse bubble diffusers. Control of the air to the biological process was controlled manually using DO grab samples during each shift, which was very inefficient. The new system that was installed consisted of fine bubble diffusers and dual-

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vane single stage centrifugal blowers with DO analyzers to control the blowers supplying air to the biological process.

Once the fine bubble diffusers were installed, the City immediately experienced a savings in energy costs. In December 2008, flow was diverted to three aeration basins that

were now equipped with fine bubble aeration, and acclimated in January 2009. The overall new aeration system, exclusive of the controls, was brought online in April 2009 and the MLE process was brought online in July 2009. By September 2009, the MLE process and DO controls were put into service and became operational. Illustrated in Figure 9 are the

monthly kilowatt requirements for the City's treatment facility beginning in January 2007 and ending in December 2011.

As noted in Figure 9, from September 2009 to December 2011, the City has experienced an energy savings of nearly 44 percent, which has represented an annual savings of \$161,000 in each of the past two years. These savings were realized even though additional energy (e.g., filters, IMLR pumping, return activated sludge/waste activated sludge (RAS/WAS) pumping, etc.) was required for the process and the flow and loads to the facility were approximately 10 percent greater. Overall incorporation of these improvements will result in a simple payback for the improved aeration system of 6.1 years.

What Does the Future Hold?

The City, having met the goals (improved effluent water quality, better management of their water resources, and lower operation costs) set in 2006 for its treatment facility upgrades, is looking to the future. In regard to its wastewater and reclaimed water facilities, the City is considering a number of improvements to further reduce carbon and water resources management footprints, which include:

- Increasing reclaimed water production by incorporating reject from a future reverse osmosis water treatment plant (WTP), which could potentially provide an additional 1,893 m³ (500,000 gpd) of reclaimed water.
- Expanding its reclaimed water system. The City has grant funding applications for this work under the SWFWMD Alternative Water Supply Funding Program.
- Reducing sludge management costs by dewatering the sludge in-house, rather than outsourcing this work. Hauling and ultimate disposal of biosolids will continue to be outsourced.

References

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- Brown and Caldwell (2007), City of North Port Preliminary Engineering Report – Existing Wastewater Treatment Facility Upgrades. Brown and Caldwell, Maitland, Florida.
- FDEP (2002), Florida Water Conservation Initiative. Florida Department of Environmental Protection, Tallahassee, Florida.
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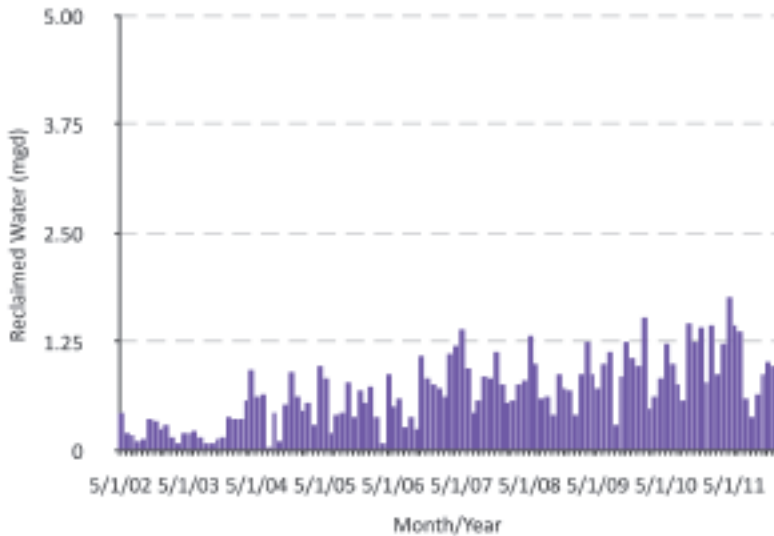


Figure 8. City of North Port Reclaimed Water Delivered to City Customers (January 2007 – December 2011)

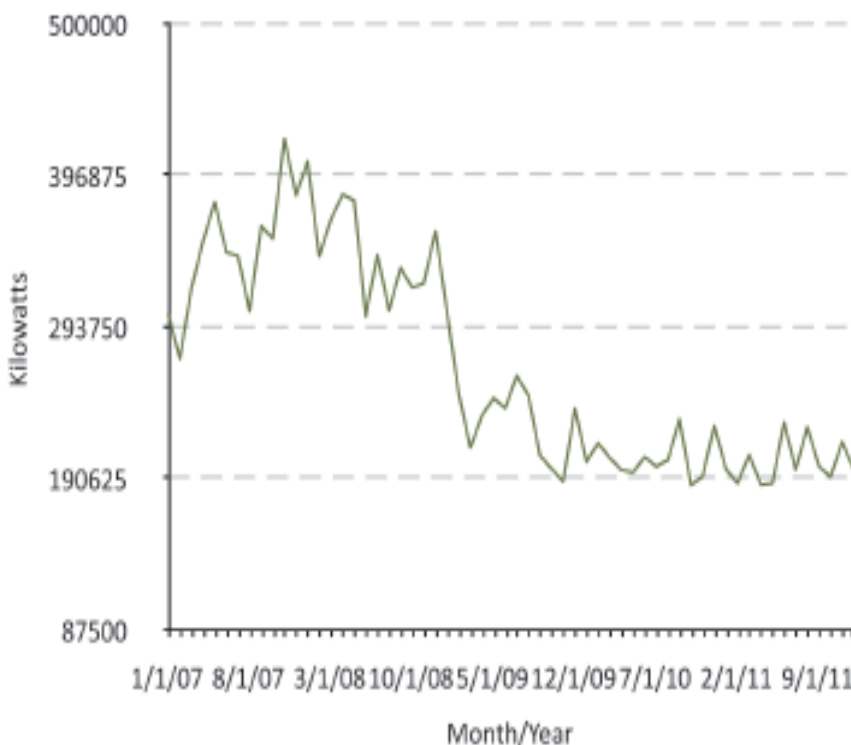


Figure 9. Monthly Kilowatt Requirements (January 2007 – December 2011)