Meeting New Total Maximum Daily Load Limits: Decommission, Reuse, or Upgrade?

A Royal Lakes Wastewater Treatment Facility Case Study

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The Royal Lakes Wastewater Treatment Facility in Jacksonville is a 3.25-million-gallon-per-day (MGD) package treatment plant that was built in the 1980s. It was recently acquired by the Jacksonville Electric Authority (JEA), the largest community-owned electric utility in Florida. JEA also owns and operates six regional wastewater reclamation facilities.

Existing treatment at the Royal Lakes Facility consists of screening, biological treatment, secondary clarification, ultraviolet disinfection, a sludge holding tank and thickener. The plant effluent is discharged into the St. Johns River, a surface water categorized as impaired by the Florida Department of Environmental Protection (FDEP).

Total Maximum Daily Loads (TMDLs) have been proposed for the St. Johns River; however, the existing plant can not meet the proposed TMDLs without supplemental treatment for nutrient removal.

The purpose of this project was to evaluate options for managing the wastewater treated at the plant. Three alternatives were evaluated: 1) decommissioning the facility, 2) upgrading the facility to produce reclaimed water for public access reuse applications, and 3) upgrading the facility to meet water quality requirements and TMDL levels established for the St. Johns River.

Conceptual designs were developed for each alternative, and the University of South Florida team developed a recommendation based on the following criteria:

- Environmental Impact
- Engineering and economic feasibility
- Operation and Maintenance
- Ability to test and implement
- Likelihood of success
- Public Perception

Process	No.	Size	Remarks
Influent Tank	1	2 feet wide	Mechanically cleaned influent bar.
Aeration Tanks	2	Plant #1: 0.743 MGD Plant #2: 0.628 MGD	
Centrifugal Blowers	3	#1: 7000 cfm & 275 hp #2: 7000 cfm & 275 hp #3: 3000 cfm & 125 hp	
Clarifiers	2	Plant #1: 0.254 MGD Plant #2: 0.254 MGD	
Chlorine Contactor	1	Total volume: 0.049 MG	To be used for emergency situations only.
UV Disinfection Contact Basin	1	8 modules with 40 low pressure lamps, each designed to treat a flow of 1 MGD.	Installed in old chlorine contactor # 1
Digester	3	#1: 0.067 MGD #2: 0.124 MGD #3: 0.062 MGD	
Thickener Tank	1	0.088 MGD	
Digested Sludge Tank	1	0.33 MG	Located in Plant #1 and not used.
Effluent Pumps	2	Each with capacity = 2500 gpm, 25 hp, TDH of 25 ft.	Effluent mostly runs to St. Johns River by gravity. Pumps run for less than 4 hrs. per day.
Old Chlorine Contactor	1	N/A	Abandoned.
Sand Filter	1	N/A	Abandoned.
Vortex Grit Remover	1	N/A	Abandoned.
Booster Pumps	2	N/A	For washdown.
Waste Pumps	2	N/A	
Sludge Pump	1	N/A	
Emergency Generator	2	N/A	

Table 1: Royal Lakes Unit Processes

The authors are members of the University of South Florida's team that won the FWEA Student Design Competition with their presentation of this study in April 2005, then won the national Student Design Competition during WEFTEC in October.

Existing Conditions & Design Criteria

The Royal Lakes Facility was issued a permit through the FDEP under the provisions of Chapter 403, Florida Statues, and the Florida Administrative Code on April 5, 2000. The permit was due to expire on April 4, 2005. The Royal Lakes Facility was operating at 2 MGD at the time of the study. Details of the unit processes are shown in Table 1.

The following supplemental design criteria were provided by JEA (Memorandum dated November 15, 2004).

- The maximum design velocity for the force main is 5 ft/sec at peak flow.
- The existing flow rate in the Southbrook force main is 130 gpm at 30 psi.
- Existing force mains and pump stations have sufficient capacity to handle the additional flow.
- The Bradley Road lift station is sufficiently sized to handle the additional flow from Royal Lakes.
- The Arlington Wastewater Treatment Plant has adequate capacity to handle additional flow from Royal Lakes.
- Flow from Royal Lakes is negligible with respect to the existing flow into Arlington.
- Flow from Royal Lakes will have a negligible impact on the O&M expenses associated with treatment at Arlington.

Members of the design team visited the Royal Lakes Facility and met with JEA personnel on March 4, 2005. Observations made by the field team were incorporated into each alternative, specifically the need for rehabilitating and upgrading existing equipment at Royal Lakes.

Decommissioning

To decommission the facility, the existing flow must be re-pumped to another waste-

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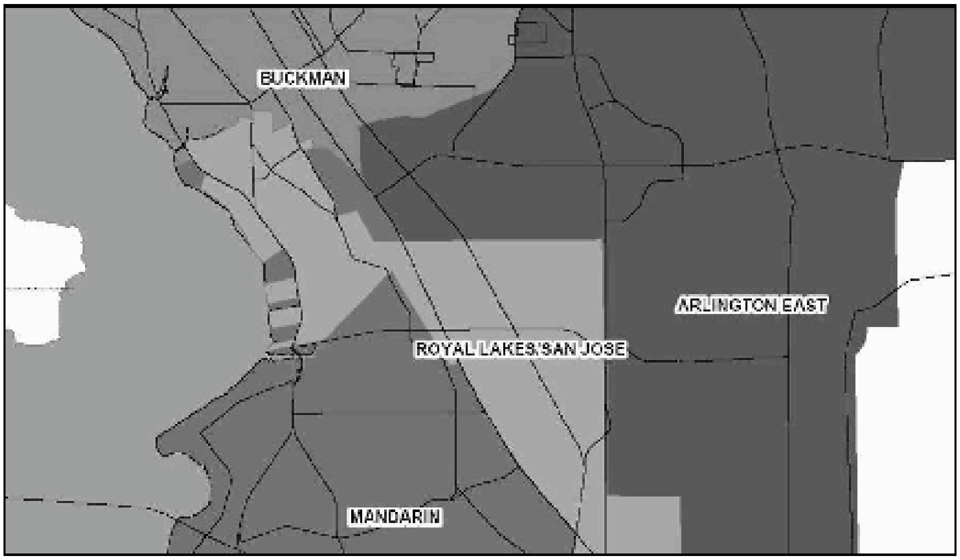

Figure 1: Portion of JEA Collection Area Map

Continued from page 17

water facility capable of receiving the flow within the JEA system. The service areas adjacent to Royal Lakes are shown in Figure 1.

Listed in Table 2 are the facilities that the University of South Florida team identified as candidates for receiving the flow from the Royal Lakes service area, showing the current average flow and permitted capacity for each candidate treatment facility. Each of the candidate facilities has adequate capacity to handle the 3.25 MGD flow from the Royal Lakes service area.

The Arlington Wastewater Treatment Plant was chosen by the team because its collection system borders that of Royal Lakes.

There are two ways the flow can be diverted from the Royal Lakes service area:

- Constructing a master pump station to re-pump the flow.
- Redirecting the flow through existing and new mains without re-pumping.

Redirecting the flow involves laying some new force mains and tying into the collection system at a few key points that would allow the flow to be pumped via existing lift stations to Arlington's collection system. Because of scope restrictions and unknowns about the system, the option of redirecting the flow without re-pumping is not presented in this article.

<u>Master Pump Station and Proposed Routes</u>

This alternative consists of designing a pump station at the Royal Lakes Facility and a pipe route to transmit the wastewater to the Arlington Plant. The pump station design includes pumps as well as electrical, mechanical, structural, HVAC, and ancillary facilities. Two alternative pipe routes were investigated.

The peak hourly flow used for design is 5.1 MGD as determined from data received from JEA. The necessary pumping capacity can be provided by two 90-horsepower pumps, with a 20-horsepower jockey pump for low flows. The pump station is designed to have sufficient space for an additional 90-horsepower pump if future flows reach higher levels than anticipated from currently available data.

The pipe route proposed by JEA winds through a residential area before tying into an existing main. An alternative route that avoids the residential area is proposed for JEA's consideration and runs from the Royal Lakes Facility, located on Western Way, east to Southside Boulevard and then north to J. Turner Boulevard, where it would tie into a 24-inch force main.

The existing right of way should allow for easy construction and minimal impact on residents in the area during construction; however, utility locates are needed before the feasibility of this pipe route can be fully assessed. If there are numerous utility lines (gas, electric, water, etc.), this alternative route could become more costly.

To fully understand the financial implications of the decommissioning alternative, an economic analysis was performed. The construction of the master pump station and the laying of the new pipe constitute a significant cost; however, the cost of construction will be offset by the operation and maintenance (O&M) savings realized by taking the Royal Lakes Facility off line. The construction and O&M present worth costs are shown for a 20-year planning horizon in Table 3.

Some of the cost assumptions include: no land acquisition costs, dewatering of the entire route, and a 17-foot deep submersible pump station; the discount rate of 5 percent was used.

Converting Royal Lakes to a Reclaimed Water Facility

JEA has a goal of providing 10 MGD of reclaimed water to customers by 2007. Using the Royal Lakes Facility to provide reclaimed water can help JEA meet that goal. This alternative includes upgrading the facility to meet Chapter 62-610 and Class I reliability requirements and constructing a reclaimed water transmission main to a point of connection in JEA's existing reclaimed water system.

Necessary upgrades to the plant include installing a bar screen to reduce floatable solids, adding a sand filter for total suspended solids (TSS) removal, refurbishing all tanks, retrofitting Wastewater Treatment Plant No. 1 from a sludge holding tank to add aeration capacity, refurbishing grit removal, installing an additional blower for increased aeration capacity, installing an additional sludge pump for truck pickup, and replacing diffusers in Wastewater Treatment Plant No. 1.

To upgrade the Royal Lakes Facility and sustain flow, the sludge digester will be converted temporarily to a treatment plant and additional sludge transport will be required. The existing ultraviolet disinfection, coupled with the new filtration unit, should be adequate to meet 62-610 fecal coliform requirements.

The reclaimed water transmission main is proposed to be a 20-inch main, approximately 3.8 miles long, to a point of connection at the intersection of Baymeadows Road and Pointe Meadows Drive.

Continued on page 20

Facility	Average Flow	Permitted Capacity[1]
Buckman	28 MGD	52.5 MGD
Arlington	13.84 MGD	20 MGD
District II	3.6 MGD	10 MGD

Table 2: Candidate JEA WWTP Average and Permitted Flows

Facility	Average Flow	Permitted Capacity[1]
Buckman	28 MGD	52.5 MGD
Arlington	13.84 MGD	20 MGD
District II	3.6 MGD	10 MGD

Table 3: Present Worth Opinion of Probable Cost

Alternative	Construction Cost (2005 $)	20-Yr O&M PW Cost (2005 $)	Total Present Worth Cost (2005 $)
Reclaim	$6,146,000	$1,996,000	$8,142,000

Table 4: Summary of Costs

Continued from page 18

Alternative Discharge Sites

Alternative discharge sites may be needed to accommodate reject flows and potential lower demands for reclaimed water. Assumptions provided by JEA to the team stated that all reclaimed water from the Royal Lakes Facility can be accepted by the system; however, the University of South Florida team considered other alternative discharge options which could be considered at a future date.

To discharge into the St. Johns River, nitrogen loading requirements need to be met. This option is considered as a separate alternative (Alternative 3). The use of Pottsburg Creek Swamp as an alternative site would eliminate flow to the St. Johns River and augment the wetlands habitat; however, this alternative is not feasible because of high costs and an increased risk for operational problems due to chemical addition for required phosphorous removal. These two discharge options are not included in the construction cost estimate.

A reject storage tank will be needed to store flow in the event of a plant upset. Regulatory requirements dictate that it be sized sufficiently to handle one day's worth of permitted flow, or 3.25 million gallons.

Construction and O&M Costs

Table 4 is a summary of the construction and O&M costs related to converting the plant to a reclaim facility.

This cost estimate includes upgrading and rehabilitating existing facilities, the addition of filtration and a reject storage tank, and all of the appurtenances and staffing necessary to meet regulatory requirements.

Upgrading Royal Lakes to Meet TMDL Standards for the St. Johns River

The feasibility of upgrading the Royal Lakes Facility to comply with TMDLs for the St. Johns River was investigated. Based on the information provided (St. Johns River Water Management District study), discharge to the St. Johns River will require effluent total nitrogen levels to be reduced to 5.9 mg/l. Three treatment technologies to meet the criteria were investigated for economic feasibility and constructability.

The biological removal of nitrogen from wastewater is achieved by nitrification-denitrification. Untreated wastewater contains organic nitrogen and ammonia (NH_3) and nitrogen. Some organic nitrogen is in particulate form and can be removed by physical treatment processes.

Ammonia is soluble and is oxidized to nitrite and nitrate. It can also be removed by air stripping. In nitrification, ammonia is oxidized by aerobic bacteria forming nitrite (NO_2) and then nitrate (NO_3).

The aeration tanks which provide dissolved oxygen perform the nitrification function in a wastewater treatment plant. A minimum dissolved oxygen (DO) level of 2.0 mg/l is recommended for proper nitrification.

Nitrate and nitrite can be converted to N_2 gas through an anoxic (low DO) process called denitrification. The heterotrophic bacteria require a carbon to accomplish denitrification. The carbon source can be provided by the wastewater or added in the form of a readily degradable substrate such as methanol (CH_3OH).

Preliminary screening of candidate treatment approaches was conducted to identify technologies that meet several criteria: optimization of existing on-site infrastructure, meeting nitrogen effluent limits, and compatibility with existing site constraints. To help control the costs of upgrading the facility, efforts were made to identify technologies that could be retrofitted into existing tankage.

Three alternatives for nitrogen removal were selected by the University of South Florida team for detailed analysis: denitrification filters, integrated fixed film with denitrification, and membrane bioreactors. Each of the three alternatives will fit within the existing site boundaries, each is capable of meeting the treatment goals, and each can be implemented using the existing plant flow process.

A comprehensive analysis of the current treatment facilities is recommended to determine if they require upgrading or replacing, in addition to implementing a new treatment technology. The condition and performance of the existing equipment affects the likelihood of success for any plant enhancements. It will also insure a uniform life expectancy in all steps of the process.

During the field review, existing equipment was identified as being in poor condition or offline completely. Modifications to replace or repair some of the identified equipment are necessary and are included in the cost estimates.

Successful implementation relies upon the ability to maintain flow while plant upgrades are being constructed. A smooth transition from old technology to new will insure that minimal burden is placed upon existing facility. Implementation plans vary based on the selected treatment alternative and will determine the method of flow main-

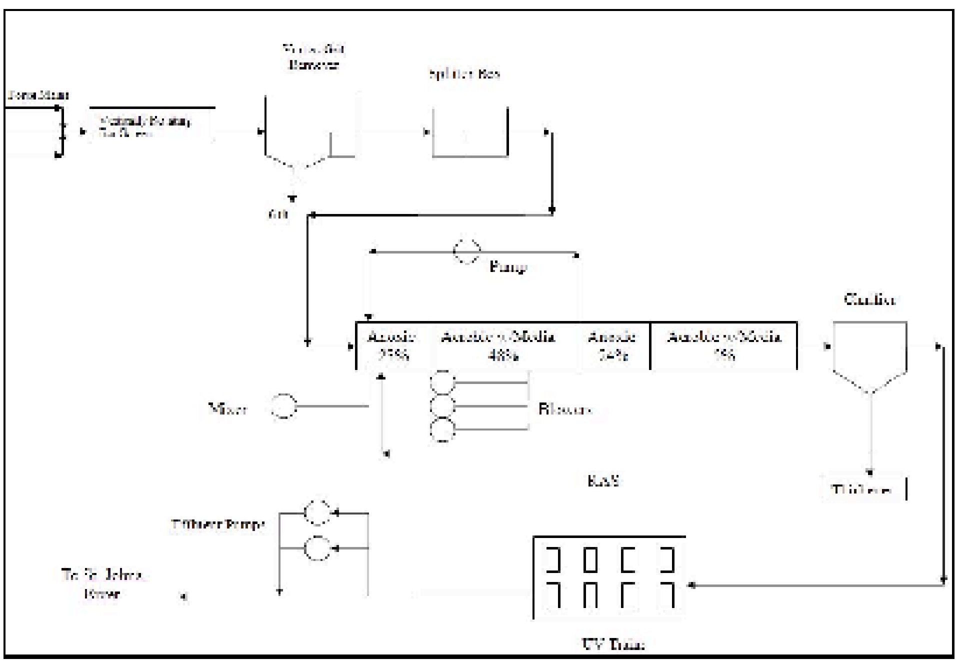

Figure 2: IFAS Flow Diagram

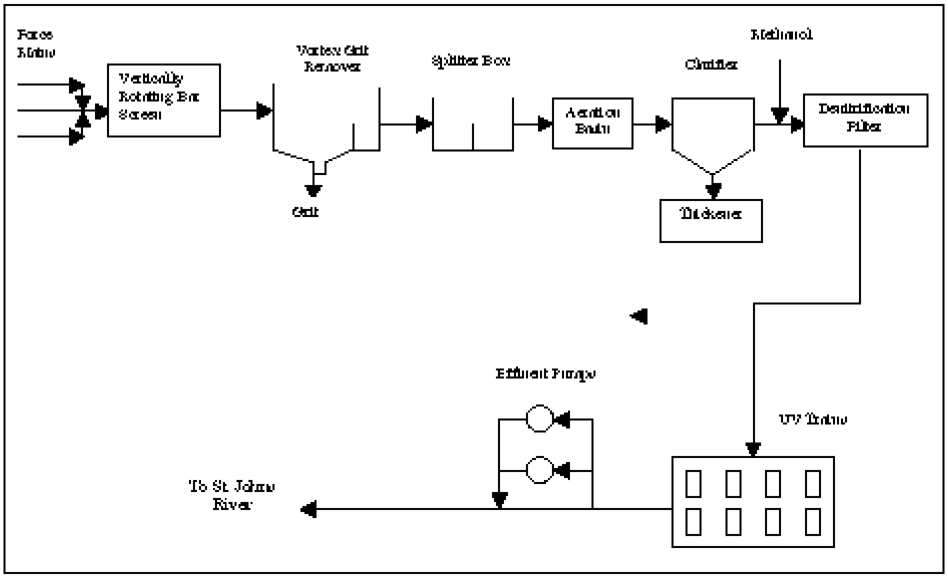

Figure 3: Denitrification Filter Flow Diagram

tenance. The availability of land was also considered for the potential success or failure of a given treatment option.

Each of the three technologies was analyzed based on ease of operation, potential environmental impact, public perception, and costs. The three upgrade alternatives were compared to develop a recommendation for the Royal Lakes Facility.

Integrated Fixed Film Activated Sludge Process (IFAS)

The IFAS system is a two-part biological treatment process which combines attached-growth and suspended-growth treatment. The increased attached-growth surface area, along with the suspended growth, results in a high biomass concentration. The concentration of biomass provides an increased capacity enabling the package plants to incorporate an effective four-stage Bardenpho denitrification process without the need for any additional structures. A process flow diagram is provided in Figure 2.

Some rehabilitation of the existing facility would be required and would include rehabilitating the vortex grit remover and cleaning and patching the existing package plants. The implementation of this facility upgrade utilizes the existing package plants. Modifications to these package plants would include the introduction of fixed film media into the aeration segments for the attached growth process. Screens to retain the media within the aeration basins would be constructed. Partitions for the four-stage Bardenpho process would also be needed.

Implementing this alternative will require a phased maintenance of flow with several steps during construction. Construction would need to be scheduled during the low-flow season (approximately 1.5-1.7 MGD). The steps would involve the alternation of work and treatment flow between separated sections of the existing package plants. A flow of 2.0 MGD would be available for treatment while the remaining 0.5 MGD can be worked on. The costs associated with this alternative are $8.6 million.

Denitrification Filters

Denitrification filters utilize an attached-growth method of denitrification. In the absence of oxygen, heterotrophic microorganisms grow on the filter media and convert NO_3-N to N_2 gas. Denitrification filters would require the reuse of processes currently in place at Royal Lakes in addition to the filters. Sufficient conversion of ammonia to nitrates (NO_3) and nitrites (NO_2) occurs in the aerobic digesters currently in use.

Denitrification occurs at a higher rate when a supplementary carbon source is added. Methanol (CH_3OH) addition would achieve this. Optimum methanol is 3 mg/l per mg/l of NO_3-N. A process flow diagram is provided in Figure 3.

Costs associated with installation include piping, power runs, and site preparation. Operation and maintenance costs include chemical addition (methanol) and, if necessary, automatic analyzers. Excess methanol could interfere with UV transmittance.

Operation of denitrification filters requires a nitrogen gas release cycle, or bump, in addition to normal backwashing. The filter is backwashed once every one to two days. It is bumped once every two to four hours.

Hydraulic loading rates for average and peak flow are 2.5 gpm/sf and 5.0 gpm/sf respectively. At 75 percent of peak flow, 5.0 gpm/sf can not be exceeded. The footprint of the filter would be approximately 1,200 sf plus 20 ft on each side additional space allowed for face piping, blowers, and pumps. This option requires the least manipulation of the current facilities. Most construction could take place while the current package plants are under normal operation.

Membrane Bioreactor (MBR)

MBR technology is based on the combination of an activated sludge process and membrane filtration. The separation of the activated sludge from the effluent is achieved using membranes. A flow diagram for this process is shown in Figure 4.

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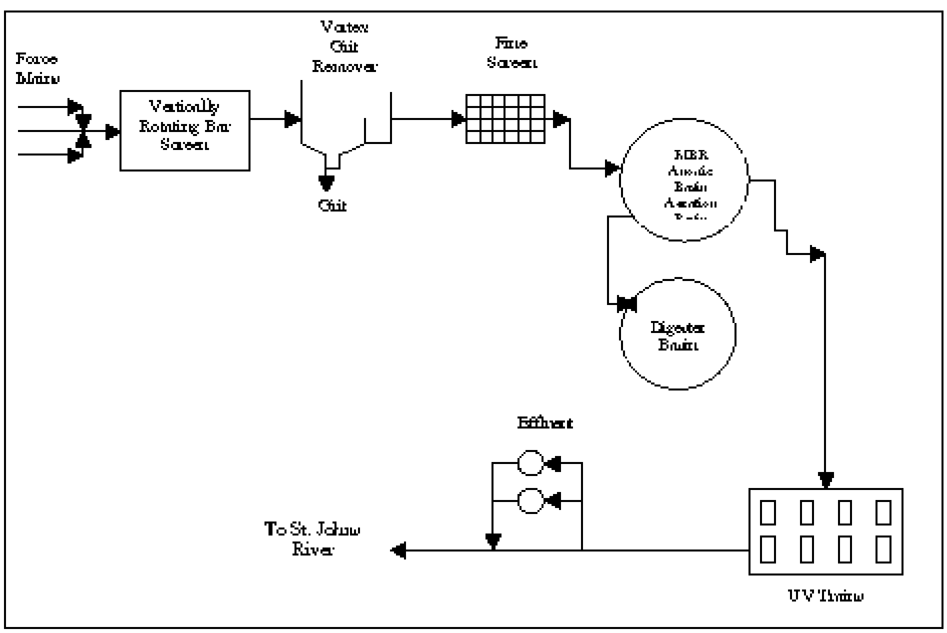

Figure 4: MBR Flow Diagram

Alternative	Construction Cost (2005 $)	20-Yr O&M PW Cost (2005 $)	Total Present Worth Cost (2005 $)
IFAS	$2,771,000	$5,882,000	$8,653,000
Denitrification Filters	$2,012,000	$6,686,000	$8,698,000
MBR	$13,771,000	$9,331,000	$23,103,000

Table 5: Summary of Costs for Upgrade Alternatives

Continued from page 21

One advantage of MBRs is that they operate at a higher mixed-liquor suspended solids (MLSS) concentration, allowing the footprint of a conventional plant to be significantly reduced (about 50 percent or more). A higher MLSS concentration also allows for a more efficient biological process that increases solid retention time, reduces sludge yield, and improves reactor efficiency for nitrification and denitrification.

Most MBR plants operate at a sludge age in excess of 40 days. Long sludge ages can decrease plant sludge production by 40 percent, significantly reducing solids handling capital and operating costs.

MBR also can provide full biological nutrient removal if an anoxic zone and a nitrified MLSS recycle line is present. To remove phosphorous, the MBR system traditionally uses chemical addition, which achieves low effluent phosphorus levels.

Generally surface cleaning of membranes is required only twice a year, but daily cleaning is necessary. Daily cleaning can be achieved using membrane back pulse, which consists of reversing the flow for about one hour using permeate or chlorinated permeated at a designated interval. Cleaning also may be achieved using membrane relax, which consists of taking the membranes out of service for one to two minutes at 10-to-12-minute intervals.

Construction and O&M Costs

Table 5 shows a summary of the construction and O&M costs for the IFAS, denitrification filters, and MBR alternatives:

All treatment alternatives were evaluated using a net present value of 20 years. The cost comparison includes equipment, installation, operation, and maintenance. An issue related to economic feasibility is the ability to reuse the existing equipment.

Based on several factors, including overall water quality, cost, and ease of operation, the best upgrade treatment option is IFAS. The cost of this technology is comparable to denitrification filters, but IFAS has greater ease of operation and requires less additional land space. Membrane technology has good overall water treatment capabilities, but is much more costly than the other alternatives.

Public perception of all upgrade options is the same because the new treatment will not intrude on the public beyond what is currently in place.

Comparison of Alternatives

Each alternative for the Royal Lakes Wastewater Treatment Facility was evaluated based on its environmental impact, engineering and economic feasibility, operation and maintenance, ability to test and implement, likelihood of success, and public perception. The ability to test and implement and the likelihood of success were considered equivalent for all three alternatives; therefore, these criteria are not considered in the final comparison. All the criteria were given equal weight in the evaluation and were scored over a range of 1 to 5 (1 = lowest, 5 = highest).

<u>Alternative 1 – Decommissioning the Facility</u>

- *Environmental Impact* — Decommissioning the Royal Lakes Facility would have a positive environmental impact because it would reduce the amount of discharge currently going into the St. Johns River. It also could have the benefit of reducing the amount of water being pulled from wells for irrigation or other uses because the flow would be directed to a reuse facility.
- *Ease of Operation and Maintenance* — The equipment associated with this option would include about three miles of transmission mains, a pump station with three pumps installed, an odor control system and a backup generator. This equipment requires very little maintenance and can be fully automated, making this option relatively simple to operate, and with the proper SCADA system it can be monitored and controlled from an off-site monitoring location.
- *Cost* — This option has the lowest capital cost of the alternatives, along with the lowest O&M cost.
- *Public Perception* — This option should have a positive impact on public perception. As stated, it eliminates discharge into the river and will have substantially less noise and odor associated with it than any treatment plant.

<u>Alternative 2 – Converting to a Reclaim Water Facility</u>

- *Environmental Impact* — Upgrading to a reuse facility would be beneficial to the environment because it would eliminate discharge to the river and reduce the nitrogen loading to the watershed. It would also provide an alternate source of irrigation and other nonpotable water uses to offset potable water use.
- *Ease of Operation and Maintenance* — Routine operation of a reuse facility involves two basic operational elements: monitoring and control. Monitoring refers to tracking influent and effluent characteristics and process parameters specifically for process control. Based on influent characteristics and effluent water quality requirements, monitoring the following parameters is recommended at the indicated frequencies:
  - Influent and effluent flows: Continuous
  - pH, Chlorine residual, Turbidity: Continuous
  - Effluent TSS, Fecal Coliform: Daily
  - Aeration MLSS, Return MLSS, Settlability: Daily
  - Influent and effluent BOD: Weekly
- *Cost* — The capital cost for this option is slightly higher than the decommissioning option, but similar to the upgrade option. This option will require additional staffing to operate the plant, so the O&M costs are significantly higher than the decommissioning option and are approximately the same as the upgrade option. This option will also allow the JEA to realize additional revenues for providing the reclaimed water services.
- *Public Perception* — This option should also have a positive impact on public perception. The use of reclaimed water is widely viewed in a positive light. The use of reclaimed water for irrigation is less costly than the use of potable water, and residents should appreciate the cost savings.

<u>Alternative 3 – Upgrading the Facility to Meet TMDL Standards</u>

- *Environmental Impact* — This option does not eliminate the discharge to the river. It treats the water to meet the new TMDL requirements and also provides sustained flows in the river to provide and protect aquatic habitat.
- *Ease of Operation and Maintenance* — Routine operation of an IFAS facility involves the same two operational elements involved in the operation of a reuse facility: monitoring and control. Monitoring the same parameters is recommended but should also include the following:
  - Influent and effluent TKN, ammonia-N, nitrate-N, nitrate-N, and alkalinity

Alternative	Construction Cost (2005 $)	20-Year O&M PW Costs (2005 $)	Total Present Worth Cost (2005 $)
Decommissioning the Plant	$3,443,000	$593,000	$4,036,000
Converting to a Reclaim Facility	$6,146,000	$1,996,000	$8,142,000
Upgrading the Plant to meet TMDL Standards (IFAS Option)	$2,771,000	$5,882,000	$8,653,000

Table 6: Construction and O&M Cost Summary for all Alternatives

- Nitrified recycle nitrite and nitrate
- Aeration basin ammonia, nitrate and nitrate

The O&M requirements of an IFAS system are substantially similar to those of a reuse facility. O&M tasks related to the clarifiers are eliminated, but are replaced by tasks related to the maintenance of the membrane modules.

- *Cost* — The 20-year present worth for this option is the highest of all the alternatives.
- *Public Perception* — This should have a positive impact on public perception. It will help improve the quality of water in the St. Johns River; therefore, this alternative receives the highest score for this criterion.

Construction and O&M Cost Summary for all Alternatives

Based on the design information and the sizing of the components, construction costs and O&M costs with a 20-year horizon were estimated for each alternative. These estimates are summarized in Table 6.

Summary of Evaluation Results

Table 7 summarizes the results of the evaluation process.

Recommendation

Based on the analysis, the University of South Florida team recommended *Decommissioning the Royal Lakes Wastewater Treatment Facility* and re-pumping the flow using a master lift station at the existing plant. The lift station is designed so that it can be bypassed and taken offline if major repairs are ever needed in the wet-well.

This alternative requires the least expensive O&M costs and, in addition to the benefits described, also helps JEA centralize its facilities, which should provide for easier operations at those larger facilities. In addition, the water diverted from the Royal Lakes Facility will be treated to meet reclaimed water standards at the Arlington Plant, thus helping provide JEA with an additional source of reclaimed water. Furthermore, elimination of the discharge into the St. Johns River will help reduce the nitrogen loading to the river.

EPILOGUE

JEA reviewed the proposed design recommendations from each team participating in the FWEA Student Design Competition and decided to phase out the Royal Lakes Wastewater Treatment Facility in 2007-2008, pending TMDL final limit determination for the Lower St. Johns River. The existing operating permit was renewed, based on the commitment to phase out the facility in the near future.

JEA officials were very pleased with the work conducted by the different teams. The design reports written by each team were not only a good learning tool for the students but also proved valuable to JEA officials as they developed their final decision on the Royal Lakes Facility.

Acknowledgements

The members of the University of South Florida Student Design Team wish to thank the following people for their valuable contributions to the team's project: Dr. Audrey Levine, P.E., DEE, the FWEA Student Chapter advisor at the University of South Florida; Chris Howard, Prentiss Garraway, and other staff members at the Royal Lakes Wastewater Treatment Facility; Scott Kelly, Brad Russell, Charles Steves, Daran Hollifield, Alan Flood, and Colin Groff from JEA; and engineers from CDM's Tampa and Jacksonville offices.

Alternative	Construction Cost (2005 $)	20-Year O&M PW Costs (2005 $)	Total Present Worth Cost (2005 $)
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Table 7: Summary of Evaluation Scores