

Phased Control Allows Lake Wales to Achieve Outstanding Effluent Quality and Nitrate Removal from an Existing Oxidation Ditch Basin

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The City of Lake Wales is situated in the headwaters of the Everglades. Near the geographic center of the Florida peninsula along Highway 27, the Lake Wales community is located on what is known as the Lake Wales Ridge, a sandy upland area running roughly parallel to both coasts in the center of the Florida peninsula. All waters channel through this deposit in a southerly direction toward the Everglades National Park.

The Everglades is an extremely delicate ecosystem that is susceptible to eutrophication caused by excessive nutrient discharges. Excessive nutrients in surface waters can lead to a large amount of algal growth, so discharges into these types of ecosystems must be of exceptional quality.

The City discharges its treated effluent to groundwater through two different types of outfalls: R-001, which is a rapid rate land application system consisting of a seven-cell rapid infiltration basin system (RIB); and R-002, designated as a slow-rate public access reuse system consisting of designated irrigation uses listed within the City's permit. Treated effluent travels through the soil media of these outfalls and enters the groundwater flowing toward the Everglades.

Major compounds that contribute to a wastewater's readily available nutrient quantity are nitrate-nitrogen and phosphorus. The City's current discharge permit limits nitrate-nitrogen (NO₃) discharges to 12 mg/L and requires a quantitative study of its phosphorus discharges. This is consistent with known groundwater discharge guidelines based on the capability of the soil to remove phosphorus by absorption via its Cation Exchange Capacity (CEC), leaving nitrate-nitrogen as the major pollutant of concern for these systems.

The focus of the retrofit for the existing wastewater treatment system by Lakeside Equipment Corp. (Lakeside) was to implement a design that would remove nitrate-nitrogen now and be easily upgraded in the future for biological phosphorus removal should the City's discharge permit require phosphorus discharge control.

Existing System

In 2010, the existing treatment plant was 25 years old. The plant was in need of repairs and updating due to deferred maintenance that was not performed. This issue was identified by the City's newly elected commissioners, who realized that work needed to be done to bring the treatment facility back to standard condition. The commission quickly approved the expenditures needed to accomplish a plant upgrade.

Kimley-Horn and Associates Inc. was contracted to perform the design and make recommendations for rehabilitation and process improvements. The design approach was to listen to plant operators to fully understand the issues and include their recommendations in the process design and equipment selection. This ability to see the issues from the operator's point of view provided an insight that is often overlooked in the wastewater treatment engineering field.

Prior to project implementation, the existing treatment system consisted of headworks with mechanical screening and grit removal systems. Secondary treatment was provided by a 1.83-mil-gal (MG) oxidation ditch with rotary brush aerators, which was followed by two 65-ft diameter clarifiers. The return activated sludge (RAS) was returned from the clarifiers to the aeration basin. Tertiary filtration was provided by an automatic traveling bridge sand filtration system; the effluent was then chlorinated for disinfection prior to discharge. Waste sludge was digested in one aerobic digester with a capacity of 176,300 gal before being dewatered in a rotary drum thickener and screw press.

The plant was manually operated and did not include an automated control system. The aerators were operated solely to maintain aerobic conditions, with limited focus on maintaining proper anoxic conditions for denitrification. Prior to the plant modification, nitrate levels in the effluent as high as 20 mg/L were common. A plant redesign would be required to meet the new total nitrogen discharge requirements issued in the 2012 permit.

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Process Design Considerations

The engineering team carefully considered the technical aspects of the project and interviewed several manufacturers. Lakeside had extensive experience in designing phase-controlled reactors for nutrient removal in many applications. In this specific application, the basin could be redesigned with an organic load of up to 20 lb/1000 gal to provide the additional capacity required to meet a 2.19-mil-gal-per-day (mgd) design flow. This higher loading would also promote the driving force required for a well operating nutrient removal system.

One of the challenges that had to be met on this project was that the state of Florida required this single-basin oxidation ditch to remain in service treating wastewater throughout the construction phase; the existing limits would still be enforced throughout this time period. Because the mixed liquor suspended solids (MLSS) are mixed by the rotors as they add oxygen, the basin's MLSS level could not even be lowered. To accomplish this tricky startup, Kimley-Horn and Lakeside's engineering department collaborated to create a precise rotor aerator design.

The aerator's framework would have to be manufactured to exactly match the existing concrete structure. This required coordination of field measurements taken by the engineering team with Lakeside's manufacturing team. The teamwork was successful and allowed the installation of the rotor aerators to be accomplished one at a time while the tank was in full service actively treating wastewater.

New Treatment System Redesign

One of the goals of the new treatment plant redesign was to increase the design flow rate while incorporating a new Sharp™ biological control system that could meet the new permit requirement of 12 mg/L NO₃-N in a cost-effective manner.

The redesign started with a new fine screen to replace the existing mechanical bar screen. The fine screen was then followed by the existing grit chamber and grit removal equipment. Wastewater flow is then directed to the existing 1.83-MG oxidation ditch. The existing oxidation ditch was redesigned to include high-performance Magna-Rotor aerators to handle the increased load. Additionally, the existing rotors were retrofitted with variable frequency drives (VFDs) to allow for more precise oxygenation rates and conservation of energy use. Therefore, the ditch now has five efficiently operating Magna-Rotors, all operating on VFDs. The new biological nutrient reduction (BNR) control system was designed to monitor the basin's oxidation reduction potential (ORP) and dissolved oxygen (DO) conditions.

Flow from the ditch then travels to the two clarifiers. These were retrofitted with new sludge collection systems for optimum solids removal efficiencies. New telescoping valves were also provided to improve RAS return and waste activated sludge (WAS) control. Because of space limitations, the existing traveling bridge sand filters were retrofitted with disc filters. This resulted in increased filtration capacity within the same footprint as the existing filtration system. Also, a new 176,300-gal digester was added to the system to double the plant's sludge stabilization process capacity. The WAS portion of the flow now initially goes to the primary digester where treatment and thickening occurs. The sludge is then transferred on to the secondary digester for further stabilization.

Both of the digesters have now been upgraded to include new blowers, mixers, and controllers to allow for precise treatment of residual solids. Waste solids are processed by the aerobic digestion process, dewatered by a screw press, and loaded onto trailers for transfer for final disposal by land application. The effluent from the clarifiers is directed to two disc filters for final filtration, chlorinated for disinfection, and then discharged to either the RIBs or the public access reuse system for final disposal.

The operational concept of the BNR system was to continuously monitor DO levels and adjust the rotor speed to maintain a preset DO concentration. This concept included flex-



Lakeside's rotor as seen from the bridge of an operating rotor upstream in the channel.

Date	Flow (mgd)	influent		BOD			TSS		
		BOD (mg/L)	TSS (mg/L)	Permitted	Measured	% removal	Permitted	Measured	% Removal
July 2013	0.99	265	325	30	1.64	99.38	30	1.61	99.50
Aug 2013	0.99	323	243	30	1.00	99.69	30	1.97	99.19
Sept 2013	1.03	345	227	30	4.25	98.77	30	2.45	98.92
Oct 2013	0.98	285	206	30	1.00	99.65	30	1.16	99.44
Nov 2013	1.00	278	345	30	1.00	99.64	30	2.12	99.39
Dec 2013	1.01	210	152	30	1.00	99.52	30	1.24	99.18
Jan 2014	1.01	311	258	30	1.00	99.68	30	2.19	99.15
Feb 2014	1.05	364	158	30	1.00	99.73	30	1.75	98.89
Mar 2014	1.06	392	649	30	1.00	99.74	30	1.61	99.75
Average	1.01	308.11	284.78		1.43	99.54		1.79	99.37
Maximum	1.06	392.00	649.00		4.25	98.92		2.45	99.62

Figure 1. Operational Data After Project Execution

ibility by providing a choice of two methods of operation for plant personnel: cyclic aerobic/anoxic operation and simultaneous aerobic/anoxic operation. Cyclic aerobic/anoxic operation occurs when aerobic conditions are maintained throughout the entire ditch, and biochemical oxygen demand (BOD) oxidation and nitrification occur throughout this time period. This is then followed by a period of time where anoxic conditions are maintained, allowing denitrification to occur.

Simultaneous aerobic/anoxic operation occurs when both aerobic and anoxic conditions are maintained at the same time in different zones of the ditch. The location and extent of the aerobic and anoxic zones are controlled by varying the speed and duration of rotor operation, which is known as phased isolation measurement and control. The placement of the probes measuring DO and ORP is critical in allowing the programmable control system to reliably operate in this mode, allow-

ing suitable aerobic and anoxic conditions to occur within the appropriate zones of the ditch to produce maximum nitrogen removal.

The BNR system configuration incorporates two DO probes and one ORP probe. The DO probe located nearest to the discharge of the oxidation ditch is the primary controller for aerobic settings. The current set point for this aerobic zone is 1.5 mg/L of DO. The ORP is measured for informational purposes, but the anoxic zone is controlled by time sequencing of the rotor and mixer operation. At the present influent flow rates (approximately 50 percent of rated capacity), the rotors are operated to maintain the 1.5-mg/L DO for approximately 60 minutes for the nitrification phase. Mixers are used during the denitrification phase to maintain proper ditch mixing velocities during this low-flow and loading condition.

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Results

The BNR control system has proven to be very beneficial for controlling the nitrification-denitrification processes within the single basin. Figure 1 is a tabular excerpt of data showing the plant's BOD and total suspended solids (TSS) data since the plant retrofit was completed. The

results indicate that a very stable operation has been achieved. The discharge to the tertiary filter is consistent and stable, containing low levels of solids. Since startup, BOD and TSS removal efficiencies have averaged greater than 99.54 and 99.37 percent, respectively.

Figure 2 is a graph of effluent nitrate-nitrogen results that have been measured since the plant was modified. The average discharge of NO₃-N has been 1.99 mg/L,

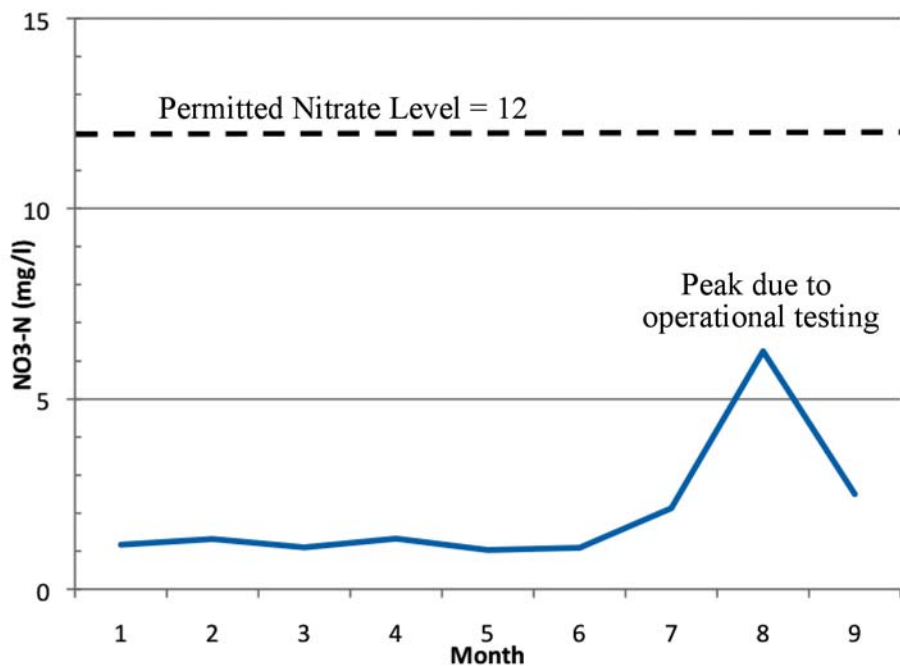


Figure 2. Monthly Effluent Nitrate-Nitrogen Since Startup



Lakeside's biological nutrient reduction control system utilizes dissolved oxygen and oxidation reduction potential measurements to operate the aerators as needed to meet the incoming oxygen demand.

with a maximum of 6.26 mg/L occurring in February 2014. The nitrate-nitrogen effluent limit of 12 mg/L has not been approached. Reduction of nitrate is possible because of the higher organic loading allowed to flow into the basin. When BOD is present but free oxygen isn't, the microbes utilize combined oxygen, such as that found in nitrate to metabolize the food; the microbes utilize the oxygen and discharge nitrogen gas when in this condition. By manipulating the control system to maximize nitrification of ammonia in the aerobic phase of the cycle, followed by an anoxic denitrification phase, the nitrates formed can be quickly denitrified and removed from the system and a very low level of effluent NO₃ can be achieved. This is a notable accomplishment for phased control in a treatment system consisting of a single aeration basin when zone separation is not physically possible.

The plant's staff has experimented with different time settings to control the amount of aerobic/anoxic staging in the ditch. The current seasonal flows have been studied and it was found that the maximum removal rate of nitrate-nitrogen was achieved when the timer was set to produce 110 minutes of aerobic treatment, followed by 60 minutes of anoxic denitrification time. This has resulted in an excellent reduction of nitrogen levels.

In one of the operator's experiments, manipulation of the cycle times also resulted in a reduction of the effluent phosphorus levels by 80 percent in April and May of 2013. However, long-term operation in this mode was not possible because of decreased effluent quality and increased nitrate levels. Since the focus of this redesign has been on nitrate reduction, the phosphorus removal mode of operation was quickly abandoned.

Conclusion

The redesign of the Lake Wales wastewater treatment system has been a great success, with sorely needed maintenance and equipment replacement achieved. New equipment has been installed allowing the expected life of the treatment system to be expanded to 2030 and beyond. The design flow of the activated sludge system was successfully increased to 2.19 mgd. The flexible aeration control system has allowed the operators to discover the most effective phase control set points, allowing the system to produce an effluent that consistently meets the new discharge permit requirements, with room to spare. Most importantly, nitrate discharge levels to the environment from the City of Lake Wales are no longer a concern. ◊