Boonville, Missouri

MO 0040738
MoDNR Municipal Wastewater Nutrient Optimization Pilot Project
August 2025

Boonville Wastewater Treatment Plant (WWTP)

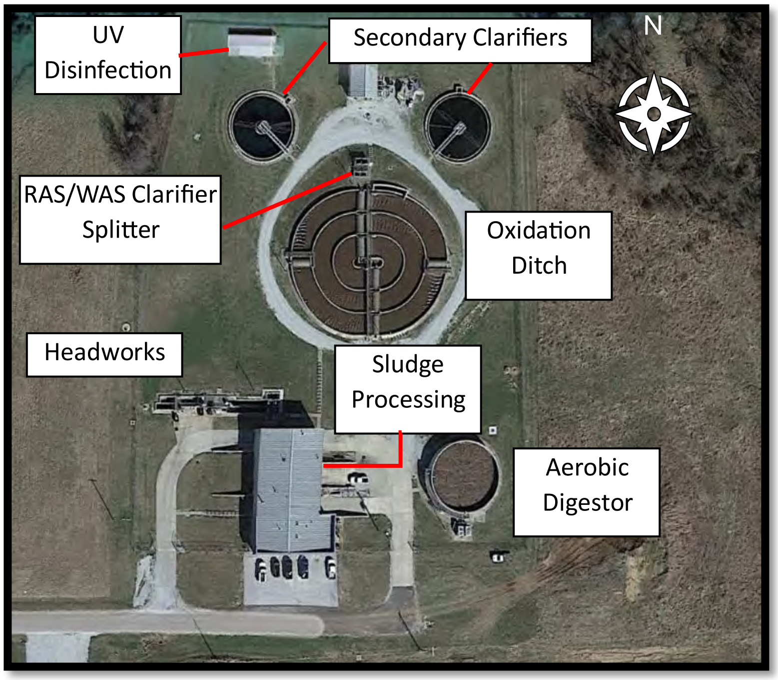
Orbal™ Oxidation Ditch

Design Flow: 2.0 MGD
Actual Flow: 0.954 MGD

1545 Cauthon Drive
Boonville, MO 65233
Latitude 38.975
Longitude -92.722778

City
Jeff Ditto, Director of Public Works

Alliance Water
Kevin McKee, Local Manager
Jake Doran, Division Manager



Summary of Optimization Efforts:

The Boonville WWTP historically discharged total nitrogen (TN) and total phosphorus (TP) at levels significantly above the Missouri Department of Natural Resource (MoDNR) target values. Initial efforts focused on inline TN reduction followed by TP reduction. Boonville started optimization later than the other facilities due to the loss of the plant manager at the beginning of the project. However, thanks to teamwork between the City and their contract operator (Alliance Water), the Boonville WWTP effort quickly caught up and demonstrated the ability to meet both the MoDNR TN and TP goals. In doing so, the City saved around 30% on the WWTP energy costs.

Nitrogen Removal

The biological treatment at the Boonville WWTP is a typical "bullseye" oxidation ditch process. The WWTP has one ditch that is configured with 8 rotor-type aerators that are used for both aeration and mixing – Figure 1. Rotors 1 – 4 in the outer ring of the ditch are each independently controlled.

The rotors for the middle and inner two rings are coupled - one motor drives the set of middle ring and inner ring rotors. Therefore, the middle and inner rotors must run at the same time or be shut off at the same time; they cannot be operated independently. The coupled rotors are referred to as rotors #5 and #6 since they must be operated together. Optimization focused on operating the various outer ring rotors in an air-ON and air OFF manner. After optimization, the Booneville WWTP staff consistently reduced TN to below the MoDNR goal.

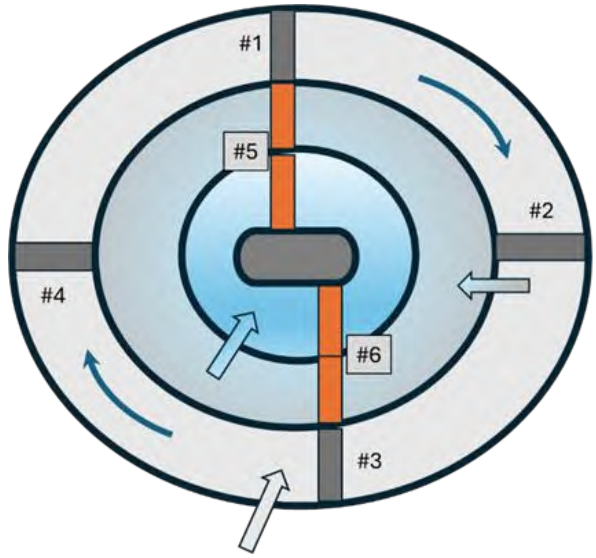


Figure 1 - Boonville Oxidation Ditch

Phosphorus Removal

Phosphorus reduction initially occurred with the inline treatment scheme for nitrogen – operating in an air-ON and air-OFF manner. Inline treatment attempts utilizing various combinations of rotors were operated in air-ON and air-OFF mode to establish septic or anaerobic zones. Once rotor control was added to the plant system control and data acquisition (SCADA) system, rotor on/off times were fine tuned to optimize both TN and TP reduction while maintaining compliance with the NPDES-permitted ammonia limits. The Boonville WWTP staff routinely met the 1.0 mg/L TP goal.

Nutrient and Energy Reductions

The amounts of TN and TP reduced post-optimization was significantly more than reduced pre-optimization as shown in Table 1. In addition, energy use and cost were reduced and resulted in large cost savings.

The Boonville WWTP reduced the concentration of TN and TP in their discharge by 67% and 61%, respectively during the project. The TN of 7.8 mg/L is well below the MoDNR target. The post-optimization TP concentration is 1.7 mg/L. While this is above the 1.0 mg/L target, it is believed the 1.0 mg/L target can be met based on five months at or below the target, with one outlier month in February 2025.

The facility removed 55% more TN mass in terms of pounds per day (lb/day). Optimization reduced the amount of TN by 65 lb/day (184-119 lb/day) which equals 11.8 tons per year. More impressively the staff at the WWTF reduced an additional 100% of TP – 14 lb/day (2.6 tons per year). By reducing the number of operating rotors to achieve both the MoDNR TN and TP targets, the Boonville staff managed to reduce the amount of energy used per MG by one-third. The savings allowed Boonville to pay for an upgrade to the WWTP SCADA system.

Table 1 – Nutrient and Energy Reductions

	Pre-Optimization	Post-Optimization	% Improvement
TN – mg/L	23.6	7.8	67
TP – mg/L	4.3	1.7	61
TN – lb/day Reduced	119	184	55
TP – lb/day Reduced	14	28	100
Energy Cost – kWh/MG	4,050	2,705	33
Energy Cost - $/MG	314	224	29

Costs and Return on Investment

Three factors contribute to the cost of optimization: (a) MoDNR's investment in consulting support, (b) Boonville's investment in equipment and instrumentation, and (c) ongoing operational expenses relating to energy (i.e., electricity), chemicals, lab supplies and personnel.

The Boonville WWTP had significant energy savings in cost and kWh, 29% and 33%, respectively. The efficiency of energy use improved by an incredible 56%. This means that for every kWh used in treatment, much more pollutant is now being removed.

MoDNR's cost for optimizing the Boonville plant was $30,596, one-eighth of the $244,765 pilot project contract fee awarded to Grant Tech, Inc. and T8 Environmental LLC. One-eighth because there were eight municipal wastewater treatment plants in the pilot study. Boonville's costs (as estimated by facility staff) total $12,782 but are offset by $24,845 in energy savings as shown in Table 2.

Table 2 – Facility Reported Costs

Item	(Cost) / Savings
Instrumentation	($3,484)
Lab Supplies	($3096)
Added Personnel Time	0
Other	($5,492)
Energy Savings	$24,845
Total	$12,782

The total cost of optimization therefore was $17,814 ($30,596 - $12,782), less than $9,000 per MGD of treatment capacity. Conventional facility upgrades for nutrient removal typically cost hundreds of thousands, if not millions, of dollars per MGD of plant capacity.

As shown in Table 1, the year-long optimization effort resulted in an increased TN removal of 65 lbs/day (23,725 pounds per year) and an increased TP removal of 14 lb/day (5,110 pounds per year). Dividing the cost of the project by the sum of the additional annual mass of TN and TP removed results in pilot project cost of $0.62 (62 cents) per pound per year ($17,814 ÷ (23,725 lb/yr + 5,110 lb/yr)).

Initial Optimization Strategy:

The initial Optimization Strategy focused on inline TN reduction. The contractors' experience with oxidation ditch treatment technology showed that significant TN reduction can generally take place in an oxidation ditch. Turning off select rotors can create an anoxic zone for nitrate reduction. Sometimes, solids settling in the bottom of a ditch can also create a septic/anaerobic zone for generating volatile fatty acids (VFA) and phosphorous accumulating organisms (PAOs) that can simultaneously reduce phosphorus once returned to aeration. After TN reduction was achieved, the focus would shift to phosphorus reduction.

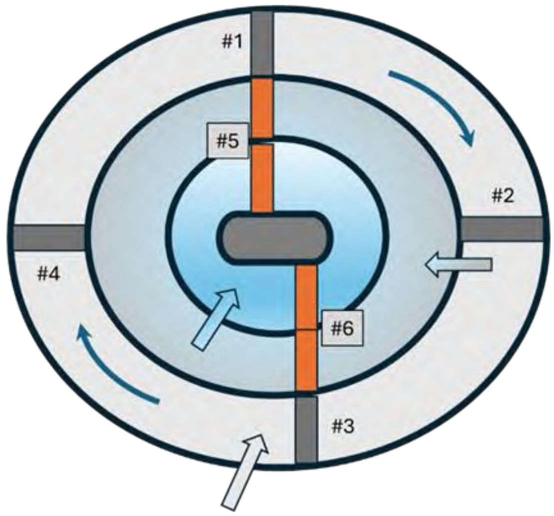


Figure 2 - Boonville Oxidation Ditch

Boonville staff began by turning off one of the outer ring rotors and observing the effect on the ammonia and nitrate levels in the effluent for two weeks. Since the rotors had to be turned on and off manually, the rotors were only turned off on weekdays while the plant was manned. The plant still achieved ammonia limits and dropped nitrate from 20 mg/L to 6 mg/L. Next, two rotors were shut off for two weeks. The Boonville staff decided to "bunny hop" which two rotors were off – turning off two adjacent rotors each day, then the next two adjacent rotors the next while cycling through all of the rotors. For example, on day one rotors #3 and #4 were turned off; day two rotors #4 and #1 were turned off; day three rotors #1 and #2 were turned off; day four rotors #2 and #3 were turned off. The result was improved nitrogen and phosphorus removal.

After two weeks with two rotors off, staff moved to 3 rotors off per day. Both TN and TP were reduced even more and the ORP readings in the ditch showed an excellent gradient for achieving TP and TN reduction while not compromising ammonia removal.

Location	ORP (mV)	Result
Outer Ring	-195	Anaerobic/septic region creating VFAs and phosphorus release by PAOs
Middle Ring	+90	Anoxic region causing microorganisms to utilize oxygen from nitrate (denitrification)
Inner Ring	+150	Aerobic/oxic region where BOD uptake, ammonia conversion to nitrate (nitrification), and phosphorus uptake by PAOs takes place.

Staff experimented with all four outer ring rotors off while only running one rotor an hour per day for mixing, however the middle and inner rings could not produce enough dissolved oxygen (DO) to fully nitrify and the sludge in the outer ring became too septic. Boonville staff reverted to always running one outer ring rotor with the other three rotors turned off. They cycled which rotor was on daily to ensure solids moved around the ditch.

Modifications to Initial Strategy:

The main modification to the initial plan came after the City updated the plant SCADA system. The upgrade occurred halfway through the project and allowed the operators to automate the air-ON and air-OFF cycling by setting timers to turn different rotors on and off. This allowed the operators to continue air-ON and air-OFF cycles during times when the plant was unmanned – nights and weekends. For most facilities, consistent operation around the clock generally results improved operation.

Ongoing Optimization Strategies for Boonville:

- Continue to fine tune warm and cold weather operating schemes by altering the run times of specific aerators.
- Consider monitoring phosphorus leaving the oxidation ditch and compare to the plant effluent to ensure there is no re-release of phosphorus from the clarifiers. If the effluent phosphorus is higher than that leaving the ditch, adjust sludge blanket depths in the final clarifiers to minimize re-release of phosphorus from the solids.
- Consider adding variable frequency drives (VFDs) to the aeration system. VFDs allow the speed of the aerators to be controlled which can allow better aeration and mixing control while saving additional energy.
- Consider adding SCADA-connected DO probes to the outer and inner rings in the ditch to better control treatment. DO control can fine tune nutrient reduction by helping to better establish anaerobic, anoxic and oxic zones in the ditch, particularly if it is coupled with VFDs on the aerators. This can also save energy.
- Consider installing additional in-line instrumentation such as ammonia, nitrate, and orthophosphate analyzers. These would allow operators to more quickly respond to changes in treatment efficiency.

Additional Plant Information:

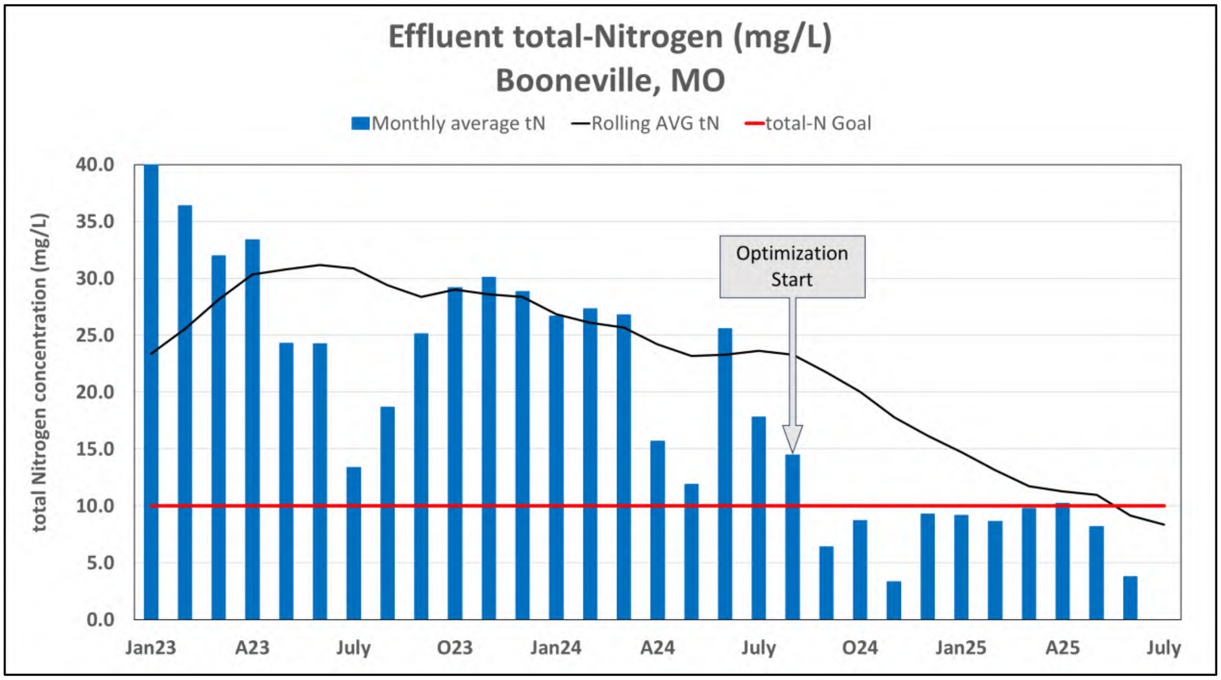
The Boonville WWTP operates with a daily average flow of around 1.0 million gallons per day (MGD) versus a design flow of 2.0 MGD. The treatment facility includes a mechanical bar screen and grit removal followed by a single Orbal™ oxidation ditch and two secondary clarifiers. Disinfection is provided by ultraviolet (UV) lamps. The plant has one aerobic digester, and a belt filter press. Biosolids are landfilled.

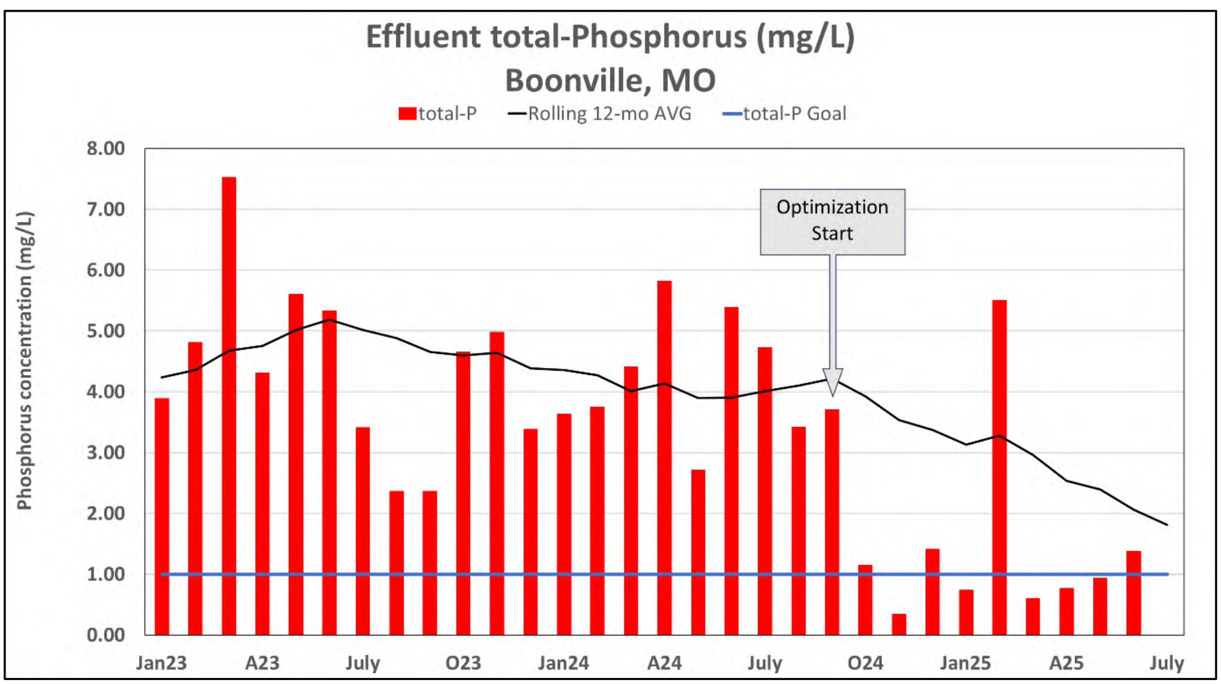
Contractor Information:

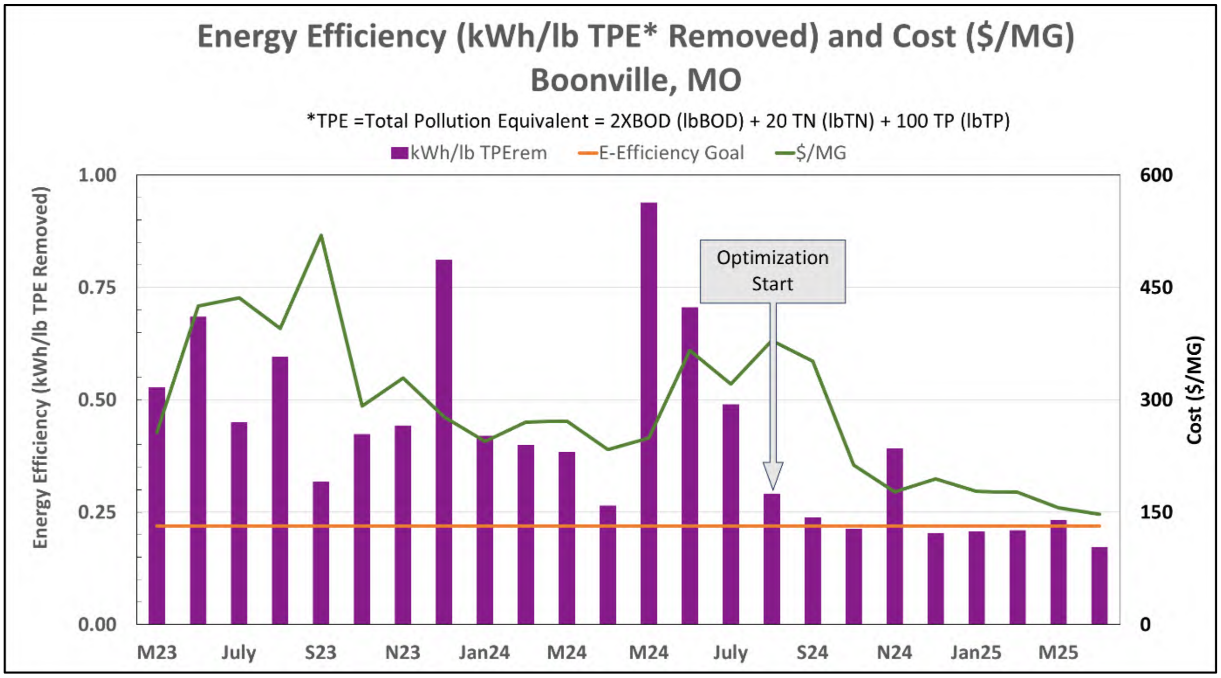
The year-long MoDNR funded nutrient optimization study was initiated in May 2024 by Grant Weaver of Grant Tech, Inc. and Mike Tate of T8 Environmental LLC and completed July 2025.

The contractors made four site visits and held 23 video call meetings with Booneville plant staff.

Nutrient Removal & Energy Efficiency Graphs







Lessons Learned / Guidance for Others Considering Optimization:

Facilities not designed for nutrient removal must be operated differently than those designed to achieve nutrient removal. Data beyond that required to meet permit conditions need to be collected and compared against targets. This is also true for most facilities designed for nutrient removal as well.

The air-ON, air-OFF cycles in the oxidation ditch can and should be adjusted to optimize nitrate removal by creating anoxic conditions while maintaining effective ammonia removal for TN removal. Frequent testing and periodic adjustments are advised.

Boonville also found that which rotors were turned on and off in the outer ring played a role in nutrient reduction performance. As seen in Figure 2, wastewater from the outer ring moves to the middle ring just downstream of rotor #2. Solids seemed to excessively move to the middle ring when rotor #2 was turned on. If solids had settled out near rotor #2 and become septic, they appeared to move in excess to the middle ring when rotor #2 was turned on and negatively affected the amount of DO in both the middle and inner rings. Keeping solids mixed upstream of #2 became a priority.

For phosphorus removal, the air-OFF cycles can often be extended to provide sufficiently septic conditions for inline VFA formation and phosphorus release by PAOs. When the PAOs are delivered to the aerated zone, they propagate and remove phosphorus.

In the case of Boonville, turning air on and off in only the outer ring of the oxidation ditch was sufficient to create both an anoxic zone and septic/anaerobic zone. Booneville was able to better control the way the aeration was cycled on and off by upgrading their system control and data acquisition (SCADA) system. The upgrade allowed staff to automate air-ON and air-OFF cycles rather than having to manually turn aerators on and off. Automation also allowed weekend and overnight application of the air-ON and air-OFF cycles to further enhance nutrient reduction. Energy savings from reducing aeration paid for the SCADA upgrade and any additional costs associated with project.

An empirical approach to optimization is greatly enhanced with regulatory encouragement and support as was the case with this project. Offers of enforcement discretion are a strong motivator for highly regulated and therefore risk-adverse municipalities to seek optimization opportunities.

Given that Nitrogen and Phosphorus are chronic pollutants, permitting discharges as rolling average mass loadings accommodates day-to-day and month-to-month variability with minimal environmental consequence while accommodating the impacts of infiltration and inflow (I/I), seasonality, and day of week variability in flows and loadings.