

Herculaneum, MO

MO0027111

MoDNR Municipal Wastewater Nutrient Optimization Pilot Project

August 2025



Herculaneum Wastewater Treatment Plant (WWTP)



Oxidation Ditch

Design Flow: 1.05 MGD

Actual Flow: 0.88 MGD

Location:

200 School Road

Herculaneum, MO 63048

Latitude 38.255278/Longitude -90.3775

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Summary of Optimization Efforts:

The Herculaneum WWTP historically discharged total nitrogen (TN) and total phosphorus (TP) at levels significantly higher than the Missouri Department of Natural Resources (MoDNR) target values. Initial efforts focused on getting the plant to run consistently and to reduce nitrogen. The optimization effort was hindered by a variety of issues including a high initial mixed liquor suspended solids (MLSS) concentration, equipment breakdowns, the possibly undersized belt press, and infiltration and inflow (I/I). Some headway was made with TN and TP between setbacks; however, both remained above the MoDNR targets.

Nitrogen Removal

The biological treatment at the Herculaneum WWTP consisted of two traditional racetrack oxidation ditches with a single vertical shaft aerator in each ditch – Figure 1. The aerators are controlled by variable frequency (VFD) drives that were tied into a single dissolved oxygen (DO) probe in the westerly most area of the ditches. By slowly reducing the DO setpoint, the aerators would run at lower speeds and create anoxic zones in the ditches which would reduce nitrate and total nitrogen. Unfortunately, the VFDs were not always operable. At those times, the rotors were turned on and off to create anoxic conditions for nitrate reduction which results in total nitrogen (TN) reduction.

Phosphorus Removal

The plant never reduced TN sufficiently to focus on TP. However, based on some reduction of TP in the effluent, it does appear that the operational changes for TN control created some septic conditions that promoted TP reduction.

Another option that was under consideration at Herculaneum was to utilize one of the aerobic digesters as a sidestream fermenter. However, with the numbers of issues at the WWTP, there was insufficient time to explore fermentation.

Nutrient Reductions

As indicated in Table 1, the Herculaneum WWTP reduced the concentration of TN and TP in their discharge by 33% and 14%, respectively during the project. The levels do not approach the MoDNR targets, but as will be discussed later, give some insight into what might be possible if the plant were fully functioning for an extended period.

The percentage removals of over 100% are deceptive. Prior to optimization there was little TN (total Kjeldahl nitrogen plus nitrate and nitrite) mass removed by the facility. Total phosphorus reported at the facility actually showed slightly more TP in the effluent than the influent, thus the “negative removal” pre-optimization. It is possible to discharge more phosphorus in the effluent than comes into the plant depending on the timing of compliance samples. One common reason is if a significant amount of water from solids processing is returned to the head of the plant, the pressate is generally very high in terms of both phosphorus and nitrogen.

The plant removed an additional 37 lb/day (42 – 5 lb/day) equal to 6.8 tons per year. An additional 0.5 lb/day (0.09 tons per year) of TP was reduced. By reducing the operation time of the aerators, the Herculaneum staff managed to reduce the amount of energy used per MG by nearly 28%.

For all mass-based calculations, the results were normalized for flow to fairly compare pre- and post-optimization since flows during the pilot period were 20% higher than previous flows. Without normalizing for flow, discharging the same concentration (mg/L) pre- and post-optimization would yield more mass reduced post-optimization simply because of higher flows. Normalization involved reducing the mass removed by the increase in flow – 20%.

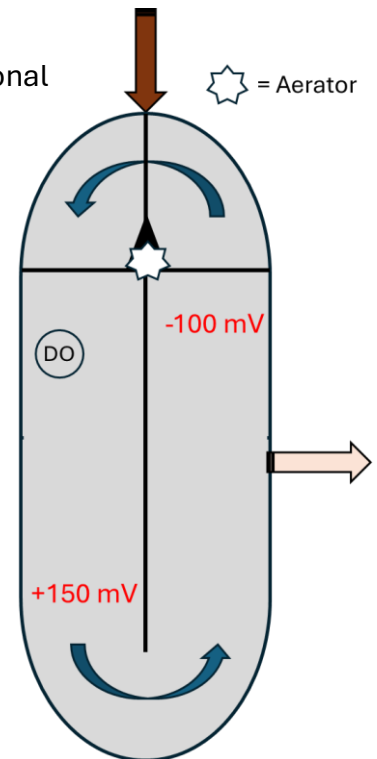


Figure 1 - Herculaneum Oxidation Ditch

Table 1 – Nutrient and Energy Reductions

	Pre-Optimization	Post-Optimization	% Improvement
TN – mg/L	33.5	22.4	33
TP – mg/L	4.0	3.5	14
TN – lb/day Removed	5	42	669
TP – lb/day Removed	-1.6	1.7	207
Energy Use – kWh/MG	3,595	2,601	28
Energy Cost - \$/MG	282	228	19

Costs and Return on Investment

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

Optimization resulted in energy cost savings of 7%, or \$10,960/year. Energy efficiency improved by 56%, meaning that nearly a third more pollutant was removed for each kWh input after optimization.

MoDNR’s cost for optimizing the Herculaneum 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. Herculaneum’s costs (as estimated by facility staff) total \$14,616 as shown in Table 2. Those cost were partially offset by \$10,960 in energy savings.

Table 2 – Facility Reported Costs

Item	(Cost) / Savings
Instrumentation	(11,443)
Lab Supplies	(\$938)
Added Personnel Time	0
Other	(\$2,235)
Energy Savings	\$10,960
Total	(\$3,656)

The total cost of optimization therefore was \$34,251 (\$30,595.62 + \$3,656), less than \$32,650 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 37 lbs/day (13,505 pounds per year) and an increased TP removal of 0.5 lb/day (183 pounds per year). Dividing the cost of the project by the sum of the additional annual mass of TN and TP removed results in a pilot project cost of \$2.50 per pound per year ($\$34,251 \div (13,505 \text{ lb/yr} + 183 \text{ lb/yr})$).

Initial Optimization Strategy:

A key part of the initial optimization strategy called for some physical improvements to the plant:

- Repair the variable frequency drives (VFDs).
- Begin slowly reducing the MLSS concentration down to around 3,500 mg/L. One ditch was running over 5,000 mg/L and the other closer to 4,000 mg/L.
- Remove the gate between the two ditches that was stuck in place. Removing the gate would allow flow between the ditches to equalize and more evenly distribute solids.

After those items were addressed, optimization would consist of dropping the DO setpoint in small, 0.2 mg/L increments if ammonia concentration remained within permit limits. The goal was to achieve an ORP of -100 mV just upstream of the aerator – the point furthest away from aeration – to establish an anoxic zone (Figure 1). Downstream of the aerator, the ORP goal was +150 mV to maintain an oxic zone to remove BOD and support nitrification (ammonia reduction). Staff began reducing the DO setpoint from 3 mg/L (very high). For a variety of reasons, the MLSS remained high in the ditches. The ditches also remained very different in terms of their MLSS concentrations – one around 3,000 mg/L and the other as high as 7,000 mg/L. In December 2025, the operators believed they had discovered a possible reason the ditches were operating at different MLSS concentrations – the effluent weirs in the two ditches were set at different heights. That meant one ditch had more volume than the other. The operators adjusted the weir heights and the solids equalized, but the ditches were still carrying too many solids. The operators processed solids daily and still could not get the MLSS down to the desired 3,500 mg/L. This likely indicates the belt press at Herculaneum is undersized and unable to process enough solids to maintain the desired MLSS level.

During an onsite visit in January 2025, the operators noted that nitrate rose back to very high levels. At the request of the contractor, the operators measured DO at the fixed probe in the ditch - the probe that controls the VFD based on the DO setpoint and used a calibrated portable probe to measure DO at the same location. The portable probe read about four times higher than the fixed probe. This meant the erroneous fixed probe data was causing significantly more oxygen to be added than was needed. That explained why nitrate values had increased – with so much oxygen, an anoxic zone could not be created. This also explains why the ORPs rarely reached a negative value at the point in the ditch furthest from aeration.

After reducing the VFDs as low as possible to minimize aeration, the DO was still high.

Modifications to Initial Strategy:

Because the VFDs could not be turned down any further, the contractor suggested periodically turning the aerators off. The plant system control and data acquisition (SCADA) system allowed the operators to set timers to turn the aerators on and off. The aerators were to be turned off for two hours twice per day. This was working well. Later in January 2025, some issues occurred with setting the timers and the aerators were off for extended periods. The extended aerator shut down caused some ammonia issues. However, prior to that unexpected shut down, the TN had dropped to <15 mg/L. Unfortunately, in February 2025 a SCADA reset cleared the timers and the aerators

were shut down for nearly 12 consecutive hours. This was one of the few times ORP readings were negative. The timer issue was resolved and the plant returned to optimization by late February.

In March 2025, disaster hit the plant. The VFD for one ditch quit working, the SCADA system was not working properly, and one of the secondary clarifiers quit working. A metal skirt mounted to the outer wall of the clarifier had broken loose and jammed the bottom clarifier sweep, causing it to buckle and damage the gear box that drove the sweep. Although the VFD was repaired, the out-of-service clarifier effectively ended the optimization experiment since parts for the clarifier repair were not expected until June 2025.

Ongoing Optimization Strategies for Herculaneum:

- Regardless of whether optimization is pursued, the operators should aim to achieve an MLSS concentration of 3,500 mg/L in the ditches.
- Oxidation ditch treatment can reduce both phosphorus and nitrogen. Herculaneum has demonstrated that to a small degree, and the contractor has worked with numerous other oxidation ditch plants and achieved significant TN and TP reduction – three in the Missouri Optimization Pilot Project. Herculaneum is encouraged to apply the initial optimization plan along with what they have learned regarding optimization to try optimization once all repairs are in place. They should be able to reduce nutrients that are discharged and save money on electricity.
- Consider having an engineer evaluate the belt press to determine if it has the capacity required to allow the operators to properly process and manage solids.

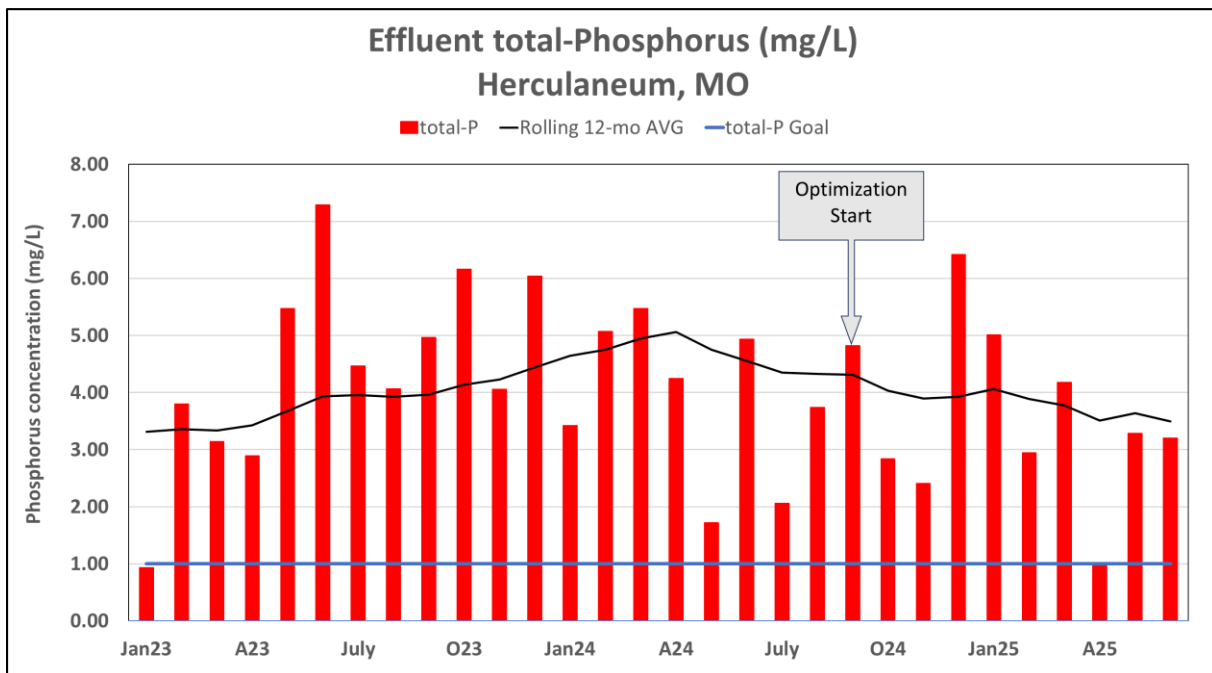
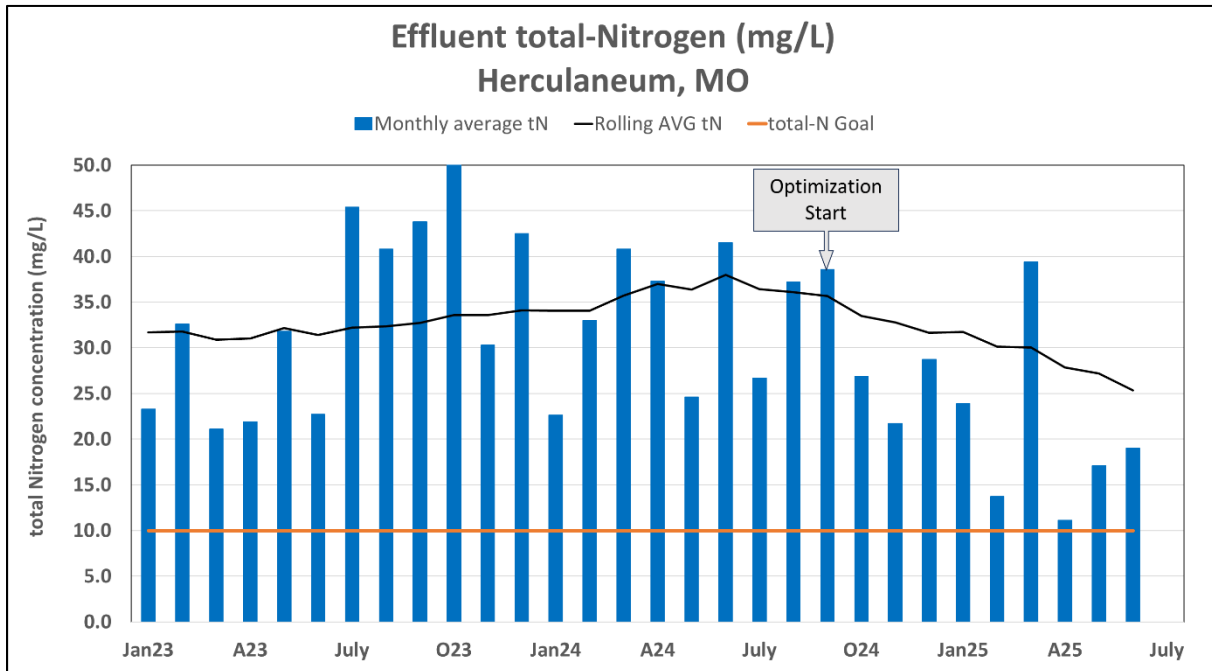
Additional Plant Information:

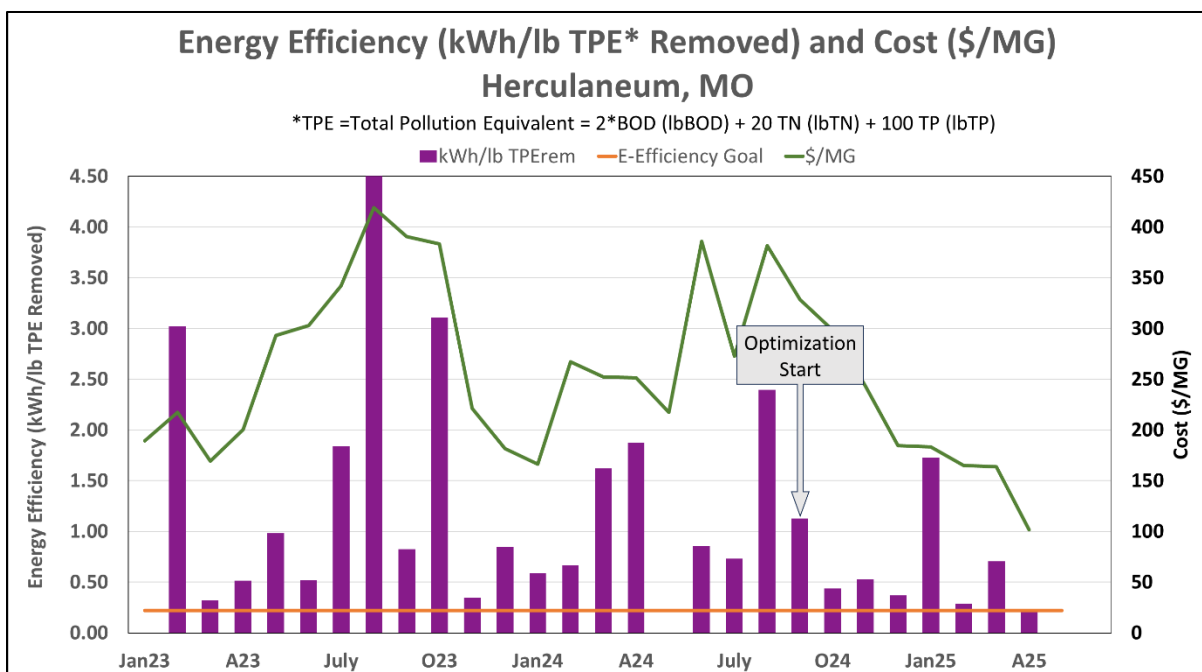
The Herculaneum Wastewater Treatment Plant operates with a daily average flow of 0.88 MGD versus a design flow of 1.05 million gallons per day. The treatment facility includes a bar screen and grit removal followed by two oxidation ditch basins and two secondary clarifiers. Disinfection is provided by ultraviolet (UV) lamps. The plant has two aerobic digesters, and a single 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 18 video call meetings with Herculaneum 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 Herculaneum plant operators were handicapped by what appeared to be cost-savings efforts in the original design. The ditches, clarifiers, and return activated sludge (RAS) pumping were paired and not plumbed to be operated independently – essentially two different treatment plants. In other words, solids from ditch #1 were routed to clarifier #1 and the RAS from clarifier #1 was routed to a wet well and pump paired exclusively with clarifier #1 that could only return sludge to ditch #1. Normally, effluent from clarifiers flows to splitter boxes with moveable gates or valves that would direct solids to either or both RAS wet wells. This became an issue when the aerator in ditch #1 and clarifier #2 went down. The operators had to rig temporary above-ground piping to return sludge from clarifier/RAS wet well #1 to ditch #2 since clarifier #2 was out of service. Any future upgrades should strongly consider building in maximum flexibility for operators to run the plant.

The oxidation ditch process lends itself to optimization for nutrients. The Herculaneum plant began to show optimization could occur, however equipment failure and lack of operational flexibility greatly inhibited optimization during the Pilot Project.

An empirical approach to optimization is greatly enhanced with regulatory encouragement and support as was the case in Missouri. 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.