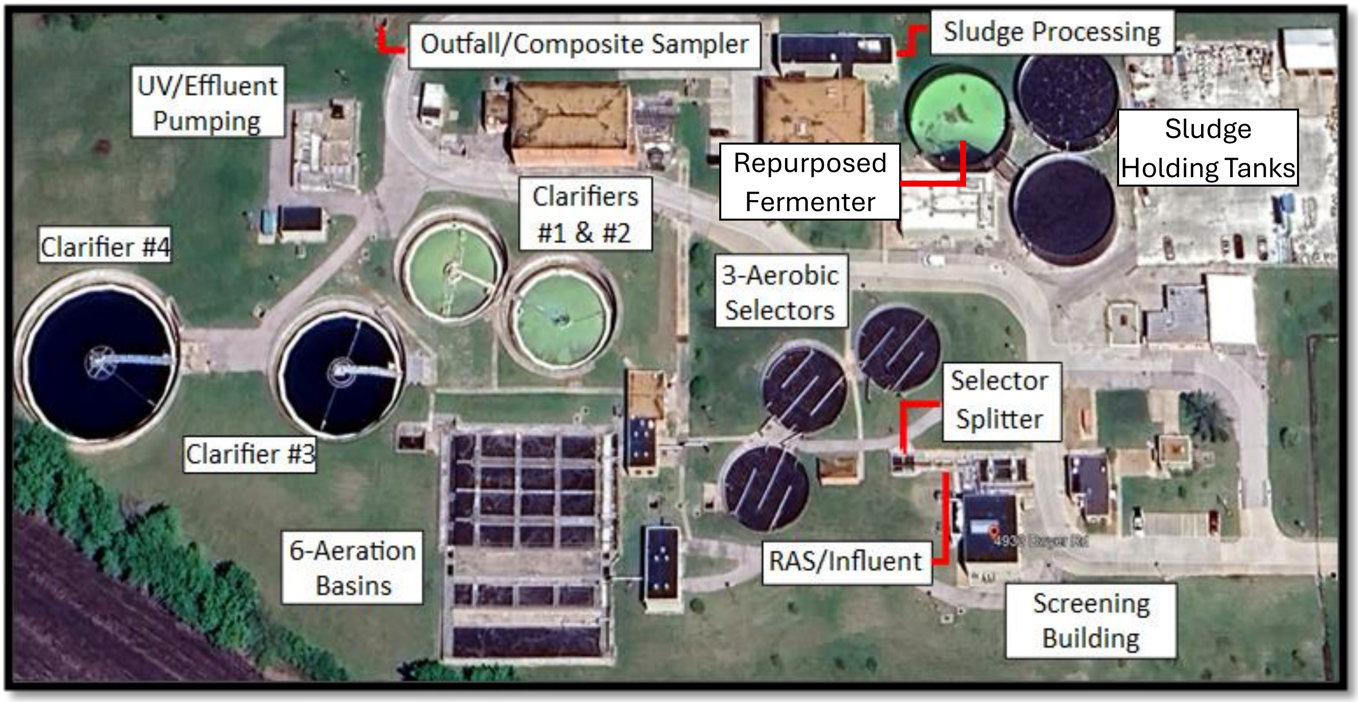
St Charles, Missouri

MO0058343
MoDNR Municipal Wastewater Nutrient Optimization Pilot Project
August 2025

St Charles Mississippi River Wastewater Treatment Facility (WWTF)



Complete Mix Activated Sludge
Design Flow: 9.6 MGD
Actual Flow: 5.1 MGD

4933 Dwyer Road
St Charles, MO 63301
Latitude 38.87556/Longitude -90.514167

City
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Summary of Optimization Efforts:

The St Charles Mississippi River WWTP (St Charles) 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 two different methods to achieve TN reduction but were later abandoned. Later in the project, sidestream phosphorus reduction was tried, and is still being evaluated.

Nitrogen Removal

The biological treatment at the St Charles WWTP is a conventional complete mix activated sludge (CMAS) process with the addition of what are referred to as "selector" basins preceding the CMAS basins. Historically, the operators were not sure why the aerated selector basins were included in the plant design. Selector basins are typically used to establish treatment zones that "select" certain types of organisms. They can be aerobic to help control filaments, anoxic to promote denitrification (nitrate removal), or anaerobic to promote phosphorus accumulating organisms (PAOs). Initially, aeration in the basins was turned on and off to establish anoxic zones. While somewhat successful, solids built up in the basins due to serpentine walls in the basin which did not allow for good mixing. Thus, the idea of anoxic selectors was abandoned.

Next, an attempt was made to create an anoxic zone in the front zone of the CMAS basins. While initially showing some promise, staff stated solids were building up in the basins and the attempt was abandoned.

Phosphorus Removal

If the selector basins worked for TN reduction, one of the basins would have been made more septic in order to promote phosphorus reduction. However, since the selector basin nitrogen reduction effort was abandoned, so was the initial phosphorus reduction effort.

After abandoning the nitrogen reduction effort, a sidestream process for phosphorus was initiated by repurposing an empty aerated sludge holding tank as a sidestream fermenter. Unfortunately, due to exceptionally cold weather, the implementing process was delayed until March 2025. The operators have established a good operating scheme for the fermenter, and have seen moderate success, but are still tweaking the process.

Nutrient Reductions

As shown in Table 1, the St Charles WWTP data are somewhat confounding. TN concentration improved by 14% while the TN mass reduced worsened by 4.6%. Similarly, TP concentration improved by 23% while TP mass worsened by 10%.

Table 1 – Nutrient and Energy Reductions

	Pre-Optimization	Post-Optimization	% Improvement
TN – mg/L Effluent	19.0	16.3	14
TP – mg/L Effluent	3.0	2.3	23
TN – lb/day Reduced	609	581	-4.6
TP – lb/day Reduced	69	62	-10
Energy Use – kWh/MG	2,734	2,564	6
Energy Cost - $/MG	194	193	0.1

The explanation lies in influent concentration reported by St Charles pre- and post-optimization. The influent TN concentration was 10% higher pre-optimization which means there was more TN to remove than post-optimization. This led to slightly more mass removed pre-optimization even though the concentration was reduced. For TP, the pre-optimization influent concentration was 19% higher than post-optimization, also leading to slightly more mass removed pre-optimization even though the concentration was reduced.

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 6% higher than pre-optimization 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 – 6%.

The St Charles WWTP had modest energy savings based on million gallons per day (MGD) treated. In terms of kWh per million gallons treated, a reduction of 6% was observed. The cost savings were 0.1%.

Costs and Return on Investment

Three factors contribute to the cost of optimization: (a) MoDNR's investment in consulting support, (b) St Charles' investment in equipment and instrumentation, and (c) ongoing operational expenses relating to energy (i.e., electricity), chemicals, lab supplies and personnel. The St Charles Mississippi River WWTP had small energy cost savings.

MoDNR's cost for optimizing the St Charles 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. St Charles' costs (as estimated by facility staff) total $27,663 but are partially offset by $17,545 in energy savings as shown in Table 2.

Table 2 – Facility Reported Costs

Item	(Cost) / Savings
Instrumentation	($928)
Lab Supplies	($1030)
Added Personnel Time	($24,938)
Other	($767)
Energy Savings	$17,545
Total	($10,118)

The total cost of optimization therefore was $40,714 ($30,596 + $10,118), less than $4,250 per MGD of treatment capacity. As shown in Table 1, the year-long optimization effort resulted in no reduction in TN or TP mass even though plant performance improved in terms of concentration. Again, this was due to significantly higher TN and TP concentrations in the influent pre-optimization which means there is more mass available to reduce.

Initial Optimization Strategy:

The initial optimization strategy involved the use of the selector basins to create anoxic and anaerobic environments to promote denitrification and phosphorus release. WWTPs designed for biological nutrient reduction (BNR) utilize anoxic selector basins to promote denitrification (nitrate removal) by selecting denitrifying microorganisms. Denitrifying organisms thrive in a low free oxygen environment by utilizing the nitrate (NO_3) oxygen molecules as their oxygen source. Anaerobic selectors promote phosphorus accumulating organisms (PAOs) by generating volatile fatty acids (VFAs) that are consumed by phosphorus accumulating organisms (PAOs) under anaerobic conditions. The PAOs subsequently release phosphorus in the anaerobic selector but take up the released phosphorus as well as influent phosphorus for a net reduction in phosphorus at the WWTP effluent.

Initially, aeration in the selector basins was reduced. The blowers providing air were controlled by variable frequency drives (VFDs) but were oversized to the point where they could not be turned down any further without risking damage to the motors and blowers. Therefore, the air was turned on and off manually at the air drops to establish anoxic zones. While this was somewhat successful, solids built up in the basins due to serpentine walls in the basin not allowing for good mixing – the solids "parked" behind the walls. Thus, the idea of anoxic selectors was abandoned.

In the initial plan, if the selector basins worked for TN reduction, one of the basins would be made more septic to promote phosphorus reduction. However, since the selector basin nitrogen reduction effort was abandoned, so was the initial phosphorus reduction effort.

Modifications to Initial Strategy:

After abandoning the selector basin option, an attempt was made to create an anoxic zone in the front zone of the CMAS basins. Each of the six CMAS basins had three air drops at the beginning, middle, and end of the basins. Each basin had only a single electronic control valve to control aeration, but only manual valves on each air drop. So, an entire basin could only operate with air-ON or air-OFF via the plant system control and data acquisition (SCADA) system. Operators would have to manually shut off the valves at the beginning of the basins to try to create an anoxic zone. While this option also initially showed promise, staff stated solids were building up in the CMAS basins and the attempt was abandoned.

After abandoning the nitrogen reduction effort, a sidestream process for phosphorus was initiated by repurposing an empty aerated sludge holding tank as a sidestream fermenter. The tank had to be cleaned, and the operators set up a system to use an existing pump to pull solids from the bottom of the tank and return them at a higher level to mix the solids.

The idea was to send around 10% of the waste activated sludge (WAS) flow to the fermenter each day, let the solids ferment, then begin returning a volume of fermented solids equal to 10% of the WAS to the head of the plant each day. To assess the proper degree of fermentation, the operators should look for effluent phosphate concentration three times higher than the influent and an ORP reading in the bottom of the unmixed tank of around -200 mV. Unfortunately, due to exceptionally cold weather, that process was delayed until late February 2025.

By late March 2025 the fermenter had reached the desired 3:1(effluent:influent) ratio and solids were returned to the head of the plant. The expectation was that in six weeks' time St Charles might begin to see some TP reduction in the effluent.

In April 2025, the fermenter had reached a 10:1 (effluent:influent) phosphate ratio. The ORP appeared in range, however the plant ORP probe cable was not long enough to reach the bottom of the tank. It was theorized there may be solids settling out in the bottom of the tank and becoming too septic. ORP in the bottom solids would probably be well below -200 mV if they could be measured. It was determined that the solids mixing via the pumping scheme probably did not provide enough mixing, leaving some dead spots in the fermenter that released too much phosphorus. Therefore, the aerators in the tanks would run for 30 minutes per day to better mix solids. This seemed to work and by May 2025, the 3:1 (effluent:influent) phosphate ratio had been re-established. Some phosphorus reduction was taking place, but not enough to reach the MoDNR target of 1 mg/L.

By July 2025 the effluent to influent phosphate ratio in the fermenter was again around 10:1. To bring the ratio down closer to 3:1, the operators planned to reduce the hydraulic retention time in the fermenter by dropping the liquid level and also mix the fermenter twice per day for 30 minutes.

There was an ongoing question as to whether there was enough food (BOD) in the CMAS basins. Based on previous sampling, it was noted the selector basins used up most of the BOD in the influent before the wastewater flowed to the CMAS basins. Only about 10 mg/L of BOD remained in the effluent from the selector basins which might not be enough food for the microorganisms to reduce phosphorus. Therefore, the contractors questioned whether the fermenter solids could bypass the selector basins and go directly to the CMAS basins. The operators believed they could be and briefly experimented with returning solids to the CMAS basins, but uneven distribution of solids caused them to stop.

The contractors suggested measuring BOD coming out of the selector to see how much remains. Results have not been acquired as of late July 2025.

The operators have established a very good operating scheme for the fermenter and have seen moderate success dropping effluent TP by around 25% but are still tweaking the process.

Ongoing Optimization Strategies for St Charles:

- Continue to optimize phosphorus release in the fermenter to consistently produce an effluent phosphate to influent phosphate ratio of 3:1. This can be accomplished by altering the hydraulic retention time (HRT), altering the amount of solids added, or aerating/mixing the solids more often.
- Determine how much treatment is taking place in the selector basins. One set of samples indicated that BOD was reduced to 10 mg/L in the selectors. If that is routinely the case, that may not leave enough food available to drive treatment in the CMAS basins. The contractor has worked with a number of treatment plants that have optimized fermentation but struggled with phosphorus uptake during aeration. Their experience – not reported elsewhere in the literature – is this: underloaded wastewater treatment plants remove so much of the BOD in the pre-

aeration tanks that there is not enough BOD remaining in the wastewater to promote PAO growth during aeration. As a result, the PAOs don't pull as much phosphorus out of solution. This is particularly evident in warm wastewater in southern climates.

- If phosphorus continues to be pursued, automating the process by adding functionality to the plant system control and data acquisition (SCADA) system would facilitate operational control.

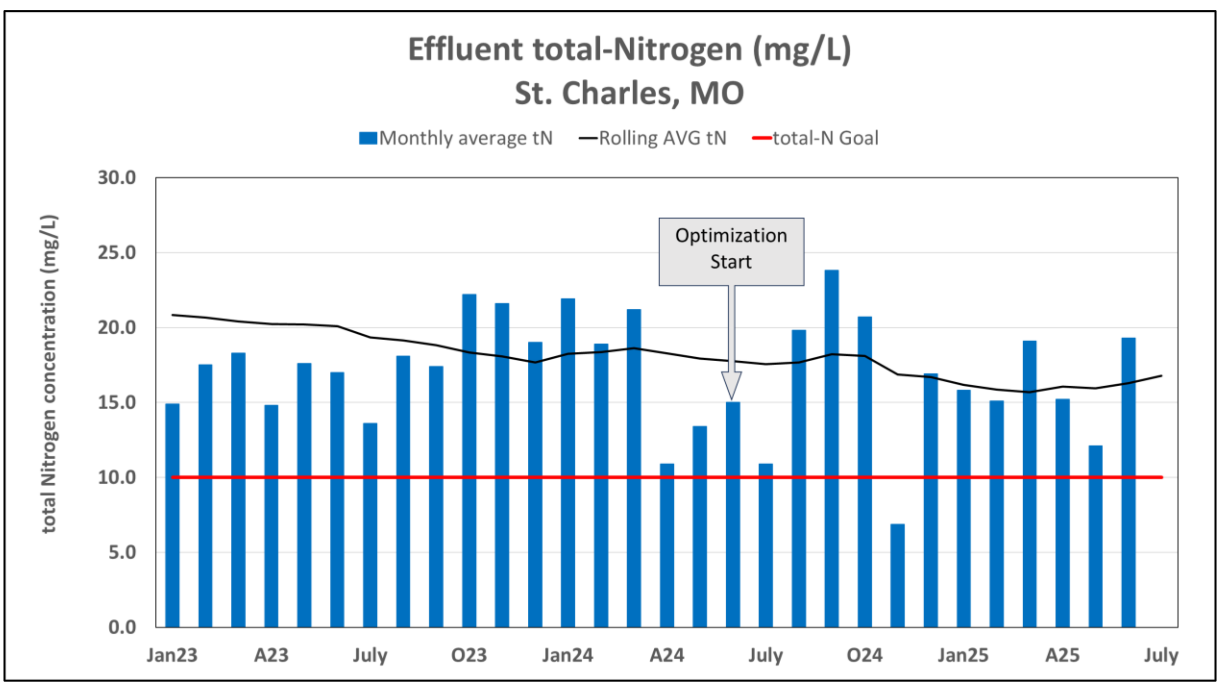
Additional Plant Information:

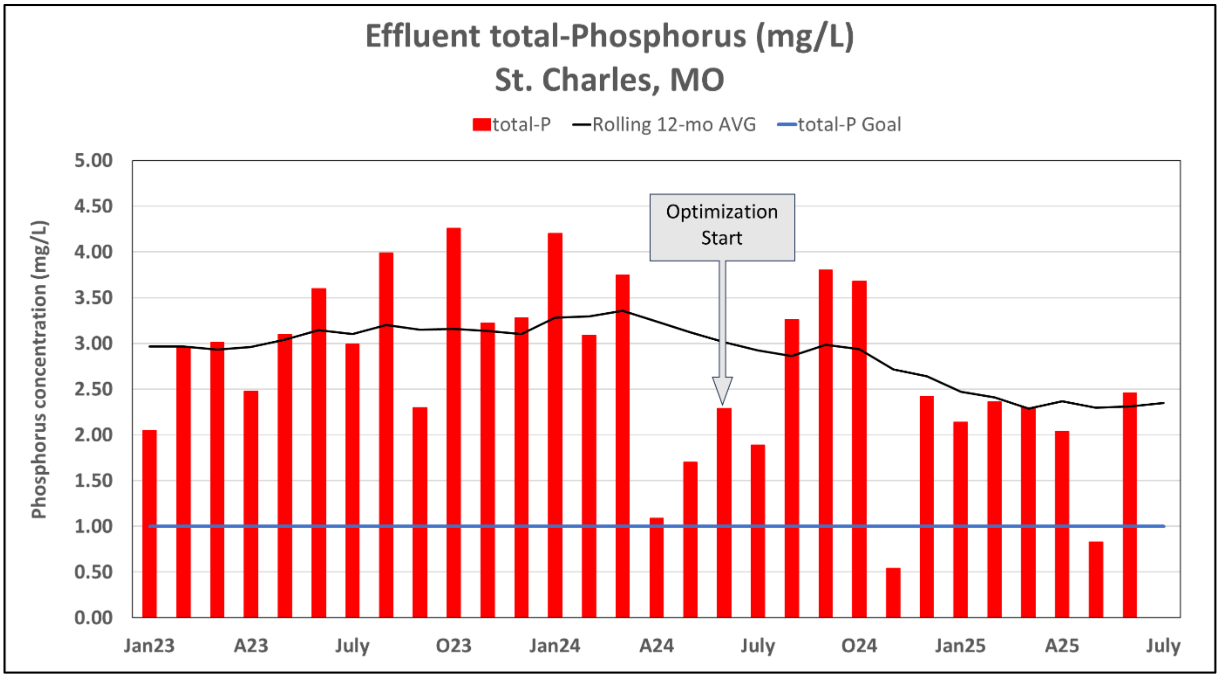
The St Charles Mississippi River Wastewater Treatment Plant operates with a daily average flow of 5.1 MGD versus a design flow of 9.6 MGD. The treatment facility includes a mechanical bar screen, an aerated grit removal basin, three aerated selector basins, six activated sludge aeration basins, two secondary clarifiers, two peak flow clarifiers and ultraviolet (UV) light disinfection. Sludge handling consists of three aerated sludge holding tanks followed by gravity belt thickeners and belt filter presses. Dewatered sludge is landfilled.

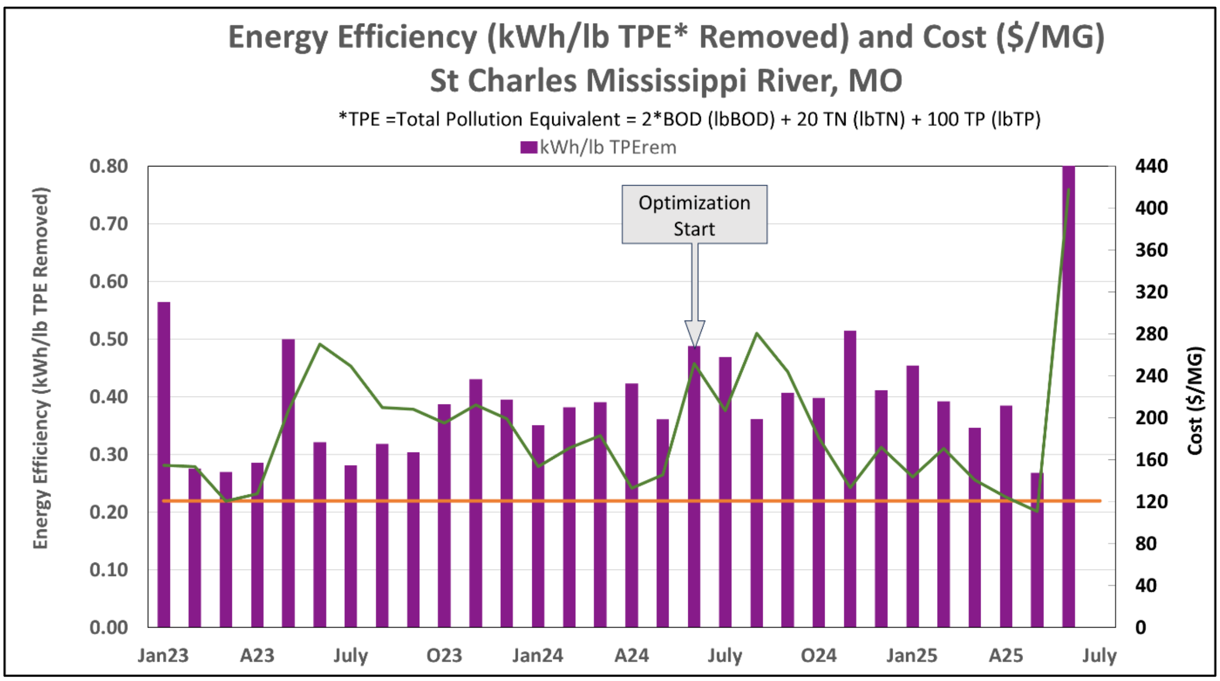
Contractor Information:

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 15 video call meetings with St Charles 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 existing aeration system at the plant makes creation of inline anoxic and anaerobic zones a challenge to create. The blowers appear to be oversized for current needs. The operators run the VFDs on the blowers at their lowest levels and still have excess air. Air drops in either the selector basins or CMAS basins must be turned down/off manually to reduce aeration. There are real concerns about damage to blowers by shutting down too many air drops at one time.

The WWTP was lightly loaded organically during the optimization period (average BOD of 137 mg/L). The selector basins appeared to remove much of the influent BOD, so there may not be enough food left in the CMAS basins to fully denitrify.

The air-ON, air-OFF cycles for the selector basins were not effective primarily because of the serpentine walls in the basins. The walls caused solids to build up to the point they were not adequately mixed following air-OFF cycles in the basins.

The air-ON, air-OFF cycles for the CMAS basins were not effective primarily because manual operation of the air drop valves was required and solids built up in the front (low aeration area) of the basins. Had each air drop been equipped with electronic-controllable valves, an energy gradient could be established and allow for better mixing. That is a moderately costly upgrade, however.

Sidestream phosphorus removal is a viable option when appropriately sized tankage is available. Sidestream fermenters need to be big enough to provide enough retention time and be septic enough for the generation of volatile fatty acids, but not so septic and not so large as to allow the microbes to decay enough to release too much phosphorus into solution. St Charles appears to have the size of tank and ability to mix solids necessary to allow fermentation to take place and moderately reduce phosphorus. If chemical phosphorus is practiced in the future, any biological phosphorus reduction comes at essentially no cost which can save hundreds of thousands of dollars in chemical costs annually.

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.