# Reducing Operating Costs Through Treatment Optimization: Tampa's Advanced Wastewater Treatment Plant Experience

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The City of Tampa (City) owns and operates the Howard F. Curren Advanced Wastewater Treatment Plant (Plant). The original facility was constructed in the 1950s and provided primary treatment of the City's wastewater prior to discharge to Tampa Bay. Various upgrade and expansion programs implemented by the City over the years have increased the capacity of the plant, provided higher levels of treatment, increased energy efficiency and enhanced cogeneration, improved residuals handling, and met other objectives. Currently, a combination of physical, chemical, and biological unit operations and processes are used to provide a high level of treatment. Treated effluent from the plant is discharged to Tampa Bay, used within the plant for process purposes and for irrigation, or provided to the City's reclaimed water customers through a distribution network. The residuals handling system at the plant receives sludge from the primary settling facilities and the excess solids from the biological treatment stages. The system includes volume reduction, stabilization, dewatering, and drying operations. Treated residuals from the heat drying system are hauled to a fertilizer company for further treatment and blending. Dewatered solids that have not been through the heat drying process are disposed of by land application.

The Plant has a permitted treatment capacity of 96 mil gal per day (mgd) on an average annual daily flow (AADF) basis. The 2011 AADF for the Plant equaled 57.5 mgd. Currently, the permit for the plant issued by the Florida Department of Environmental Protection (FDEP) requires high levels of carbonaceous biochemical oxygen demand ($CBOD_5$), total suspended solids (TSS) and nitrogen removal, as well as dechlorination and post aeration. Furthermore, the FDEP permit sets limits for recoverable nickel and a trihalomethane compound (dichlorobromomethane) and establishes requirements related to effluent toxicity. The major treatment processes of the Plant are shown in Figure 1 and include:

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- High-Purity Oxygen (HPO) Carbonaceous Reactors
- Diffused Aeration Nitrification Reactors (DARs)
- Denitrification Filters

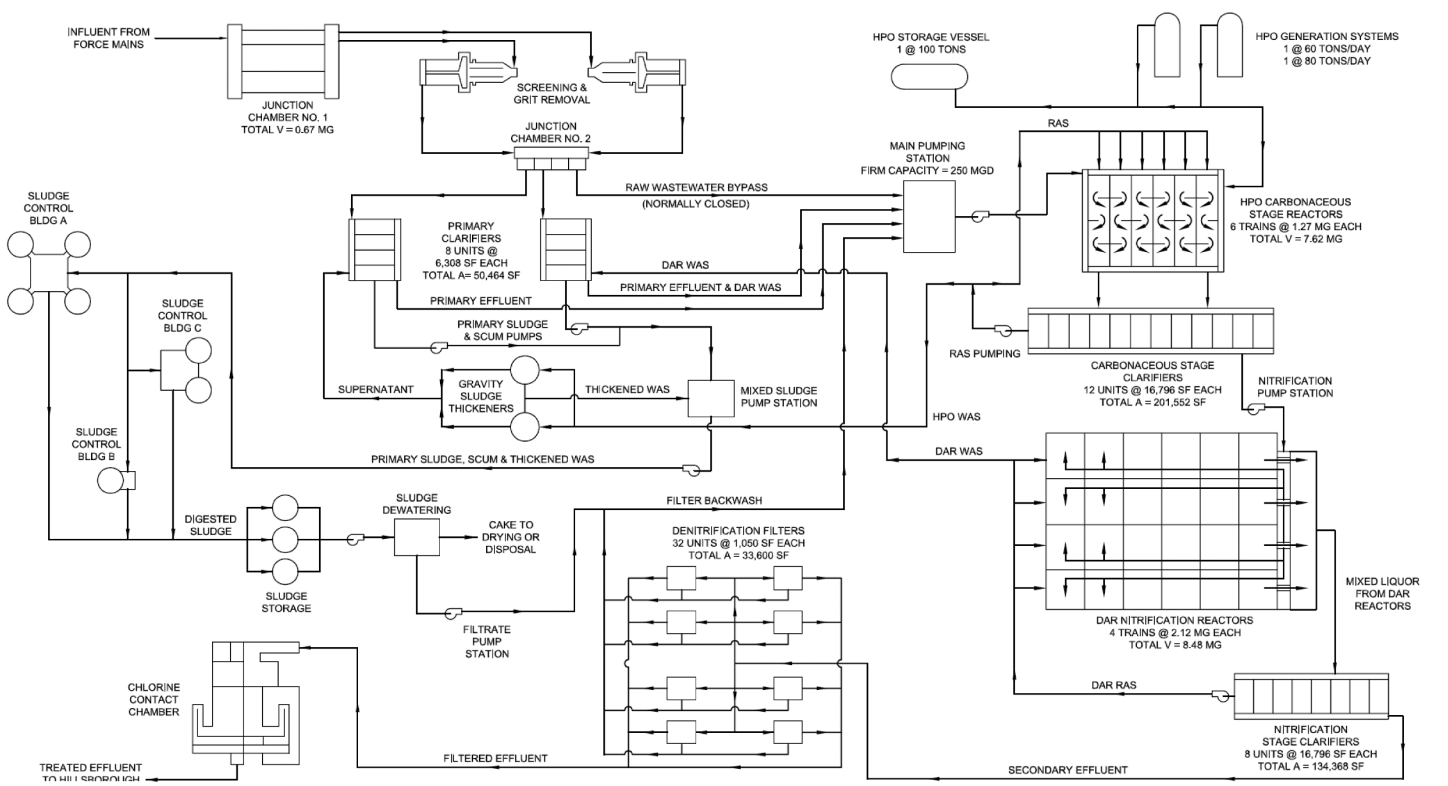


Figure 1. Howard F. Curren Advanced Wastewater Treatment Plant Process Schematic

Many of the treatment technologies employed at the Plant are modern; however, advances in biological nitrogen removal processes offer potential savings in operating costs. Also, other process enhancements and supplementary technologies could offer economic benefits. Since the current flows and loadings are well below design values, it may be possible to modify the treatment process to achieve nitrogen removal and increased efficiencies without building additional structures. Like many public entities, the City is facing significant financial constraints; therefore, potential optimization programs involving relatively small capital expenditures and the savings in operation costs must result in short payback periods. The operating budget for the Plant includes substantial costs for power and the purchase of methanol for the denitrification process. Due to the magnitude of these costs and increasing fiscal pressures, the City authorized Tetra Tech to develop and evaluate specific alternatives that could lead to reductions in operating expenditures. This work was conducted as part of the process optimization feasibility study.

## Process Optimization Feasibility Study

An initial assessment of the Plant identified four general areas where the plant operation could be optimized, resulting in potential energy savings and chemical reduction, and thus, reduced costs, including:

- Alternative 1 - Enhancing anaerobic digestion by increasing primary solids recovery.
- Alternative 2 - Reducing the nitrification requirements in the secondary basin by sidestream treatment of recycled ammonia through the SHARON® process (Alternative 2A) or CAST process (Alternative 2B).
- Alternative 3 - Carrying out suspended growth denitrification in the existing aeration basin to reduce methanol requirements in the denitrification filters.
- Alternative 4 - Evaluating alternatives for optimizing the HPO system.

Alternative 1 explored enhanced primary clarification to increase the solids settling in the clarifiers with a chemical coagulant and sending more solids to digestion. Options evaluated included the addition of iron or aluminum salts upstream of primary settling to increase primary treatment efficiency and cogeneration as a result of increased anaerobic digester loadings. A bench-scale study using ferric chloride was developed by Tetra Tech and conducted by the City's laboratory and operations staff.

Table 1. Economic Sensitivity Based on 2008 Prices

| Parameter | Alternative1: Enhanced Primary Clarification | Alternative 2A: Sidestream Treatment Via SHARON Process | Alternative 2B: Sidestream Treatment Via R-CAST Process | Alternative 3: Anox./Aer. DAR with 10 – 20 MGD Bypass & Suspended Growth Denite | Alternative 4: Temporarily Shut Down HPO Generation System |
|---|---|---|---|---|---|
| Energy Savings | $92,000 - $225,000/ Yr | $64,000 - $158,000/Yr | $67,000 - $165,000/Yr | $86,000 - $125,000/Yr | $258,000/Yr |
| Methanol Savings/ Prod Value | N/A | $215,000/Yr | $224,000/Yr + Prod. Value $281,000/Yr | $368,000/Yr | N/A |
| Additional O & M | $2,358,000/Yr | $62,000/Yr | $408,000 - $718,000/Yr | $43,000/Yr | $10,000/Yr |
| Payback Period | N/A | 17.7 – 25.4 Yrs | 31.6 Yrs (Best Case) | 8.8 – 9.6 Yrs | 1.5 Yrs |

Alternative 2 evaluated use of two technologies for sidestream processes to treat recycled ammonia-nitrogen and thereby reduce the oxygen demand in the main aeration basin. One was the SHARON® process (Alternative 2A), a biological process developed in Europe, and the other was the R-CAST® system (Alternative 2B), a physical/chemical process with recovery of ammonia for use as a fertilizer.

Alternative 3 evaluated denitrification in the existing diffused aeration reactors (DARs) by setting up anoxic zones, thereby reducing oxygen demand in the DARs and chemical methanol needs in the denitrification filters. This is accomplished by creating anoxic zones within the activated sludge treatment process where nitrate can be reduced to nitrogen gas by facultative bacteria. This process modification would be implemented within existing basins and result in lower power consumption and decreased chemical consumption in the subsequent stages of treatment.

Alternative 4 evaluated turning down or replacing the HPO system. The Plant has a cryogenic HPO generation process, with capacity to meet the oxygen demand for the full plant capacity. Since the current oxygen demand is less than the design capacity, excess HPO is being generated. This alternative evaluated turning off the HPO system and using mechanical aeration within the various reactors to provide the oxygen needed for $CBOD_5$ removal in the initial stage of treatment.

The costs associated with the different alternatives were developed utilizing the 2008 electrical and methanol costs. Additionally, the payback period for the proposed alternatives was calculated, as shown in Table 1.

Alternative 3 appears marginal from an economic standpoint at current price levels for power and methanol; however, the analysis included costs for a new floor-cover-diffused aeration system and the installation of an automated aeration control system. The replacement of the aeration system should be considered normal renewal and replacement and an automated aeration system would be a typical feature for such a large plant. If these two costs are removed from the analysis, suspended growth denitrification is very cost-effective, resulting in a payback period of less than two years. Savings associated with this option are anticipated to be approximately $400,000 per year.

For Alternative 4, the existing HPO generation system is producing significantly more oxygen than needed to provide removal of $CBOD_5$. This situation results from a limited turndown capability and there does not appear to be a simple and effective means of modifying the HPO generators to correct the situation. If the HPO generation systems were to be shut down, the mechanical aerators within the HPO train can be used to provide aeration in a conventional manner; however, the tank headspaces will need to be vented.

Based on these findings, it was recommended that the City further evaluate the viability of Alternatives 3 and 4.

## Tampa Takes the Next Step

The evaluation of Alternatives 3 and 4 include the development of a wastewater process model using GPS-X process simulation software. For Alternative 3, the model is used to help identify potential on/off aeration schemes in the DARs in an effort to achieve denitrification upstream of the denitrification filters to decrease methanol use. For Alternative 4, the model is used to check the viability of con-

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verting the HPO reactors to air-activated sludge reactors in an effort to decrease aeration cost and allow for denitrification in the DARs.

**Alternative 3 Modeling**

For Alternative 3, a calibrated GPS-X model was prepared to demonstrate how on/off aeration could be implemented in the DARs to maximize denitrification, as shown in Figure 2. The amount and rate of denitrification is highly dependent on the amount of CBOD available. A bypass around the HPO reactors can supply up to 30 percent of the primary effluent flow directly to the DARs to increase the CBOD available for denitrification. Despite operating the HPO reactors with a low solids retention time (SRT) of less than one day, limited nitrification is achieved in the HPO reactors (typically effluent nitrate concentrations between 6 to 12 mg/L) due to waste activated sludge (WAS) being recycled from the DARs to the HPO reactors. The HPO bypass and limited nitrification in the HPO reactors allow for high-rate denitrification to occur if anoxic conditions are introduced at the beginning of the DARs.

Several variables were modeled to optimize denitrification, including the percent of primary effluent that bypasses the HPO reactors, static anoxic zones, and variable timing of on/off aeration. It was found that the optimal bypass flow was 30 percent of the influent flow rate. Bypass above this percentage resulted in increased effluent ammonia concentrations when operating at a constant SRT. The increased bypass flow changes the bacterial population distribution between facultative and autotrophic nitrifying bacteria. It was found that as more facultative bacteria are grown in the DARs, less nitrifying bacteria are present, unless the mixed liquor concentration is increased, which would result in overloading the clarifiers.

With a 30 percent bypass flow, it was found that the optimal denitrification performance was obtained using an on/off aeration scheme compared to the use of static anoxic zones. Each DAR is divided into six cells that can be operated as different aeration zones. The optimal denitrification performance was found to occur when the first zone was dedicated as anoxic, while Zones 2-5 were operated in an on/off aeration scheme. Zone 6 was continuously aerated to maintain aerobic conditions entering the clarifiers. The on/off timing was modeled using equal on/off cycles of four hours at current loadings. The denitrification performance was found to be 25 percent better using this approach, compared to using two static anoxic zones. The modeling showed that the readily biodegradable influent CBOD was completely consumed by the end of Zone 1, indicating that high-rate denitrification did not occur beyond Zone 1. Denitrification occurred during the off cycles using solubilization of particulate and colloidal CBOD, and endogenous respiration as the carbon sources. Using two static anoxic zones did not provide as much time for endogenous respiration to occur, resulting in less denitrification, which is why it did not perform as well as on/off aeration.

At the current plant loading, the modeling showed that between 6 and 10 mg/L of nitrate could be denitrified in the DAR without effecting nitrification efficiency. Figure 3 shows the denitrification performance under maximum nitrogen concentrations at current flows. By denitrifying in the DARs, less methanol is required in the denitrification filters. The Plant currently doses 2.9 mg of methanol for every mg of nitrate denitrified in the filters. This dose is close to the theoretical minimum of 2.86 mg of methanol per mg nitrate, indicating there is little room for optimizing the methanol dose rate. Denitrifying 10 mg/L of nitrate in the DAR will save approximately $1.1 million annually, based on current methanol pricing of $1.50 per gal. As flows increase at the Plant, additional aeration time will be required to complete nitrification, which will decrease the off-cycle times, resulting in a decrease in savings. In addition to the

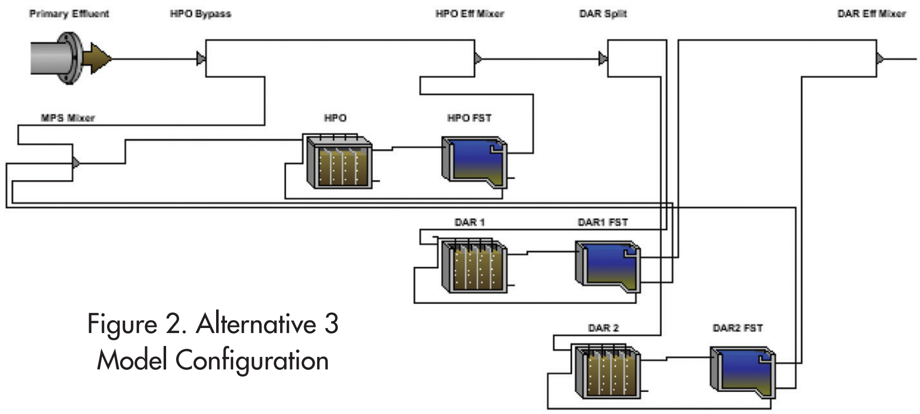


Figure 2. Alternative 3 Model Configuration

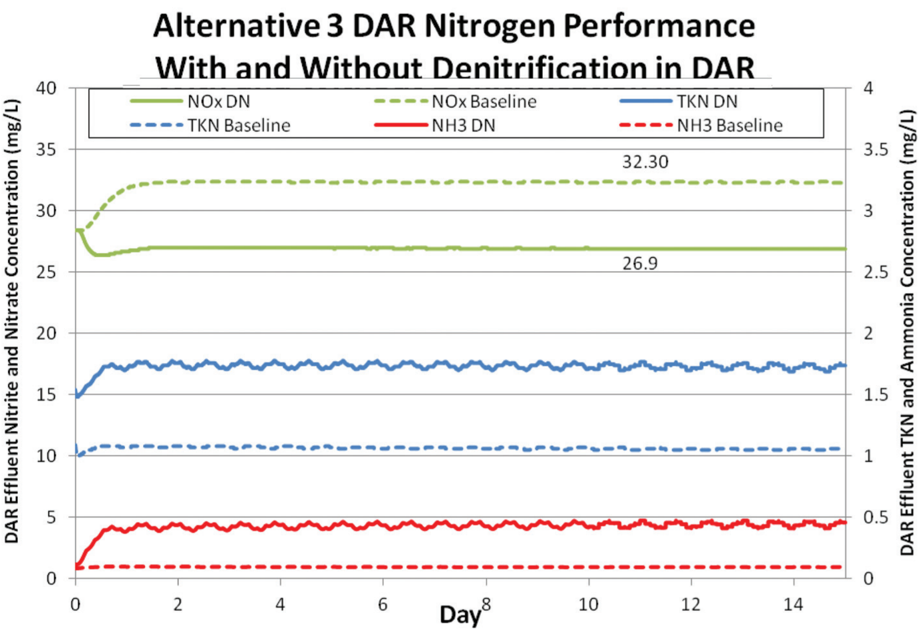


Figure 3. Denitrification Performance for Alternative 3 Using On/Off Aeration

methanol savings, aeration savings would be realized with anoxic oxidation of CBOD in the denitrification process, which is estimated at $81,000 per year.

**Alternative 4 Modeling**

For Alternative 4, the HPO reactors in the GPS-X model were converted to conventional air activated sludge (CAS) reactors, as shown in Figure 4. The modeling showed that for this alternative, the availability of CBOD in the DARs was still the limiting factor for optimizing denitrification. The model was run at conditions that allowed for limited CBOD removal in the CAS reactors by operating at a low 0.5-day SRT and a low DO concentration of 0.2 mg/L, which resulted in relatively high concentrations of CBOD in the DARs. It was found that operating the DARs using a Ludzack-Ettinger (LE) process (static anoxic zone at the head of the DARs without mixed liquor recycle) resulted in denitrification of 12 to 16 mg/L of nitrate in the DARs, while using an on/off aeration control resulted in only denitrifying 8 to 12 mg/L of nitrate. The DAR SRT was maintained at 15 days for both model runs, which resulted in the same effluent ammonia concentration of approximately 0.5 mg/L. Figure 5 shows the denitrification performance for Alternative 4 under maximum nitrogen concentrations at current flows.

The estimated methanol savings for Alternative 4 using current methanol prices of $1.50 per gal increases to approximately $1.65 million a year due to additional denitrification in the DARs. In addition to methanol savings, Alternative 4 will realize significant aeration savings. The net reduction in power consumption anticipated with this alternative is approximately 3,680,000 kWh/year, which would decrease greenhouse gas emissions by over 2,900 tons/year. Cost savings under this scenario are expected to equal approximately $250,000 a year and the capital investment would be relatively small.

On/off aeration had better denitrification performance for Alternative 3, but it did not have better performance for Alternative 4. For Alternative 4, there was adequate CBOD available for denitrification throughout both anoxic zones in the LE process. While overall denitrification performance was better, there are several concerns using this approach. Denitrification within the DAR clarifiers might be a problem, considering there will be relatively high concentrations of nitrate going to the clarifiers, with an increased oxygen uptake rate due to more CBOD removal in the DARs. While the model predicted good overall performance with the highest denitrification for Alternative 4, operating the HPO as CAS reactors with low SRT and low DO could result in poor settleability. Predictions of changes in settleability cannot be accurately modeled; therefore, a pilot demonstration should be performed to demonstrate that good settleability can be maintained in both the CAS and DARs.

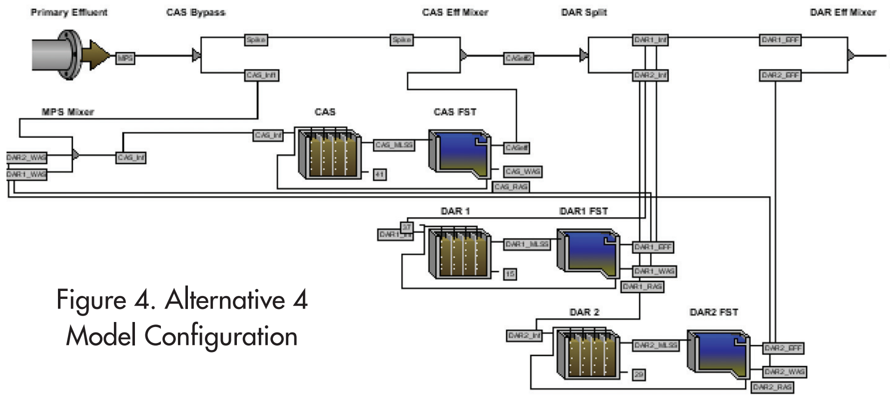


Figure 4. Alternative 4 Model Configuration

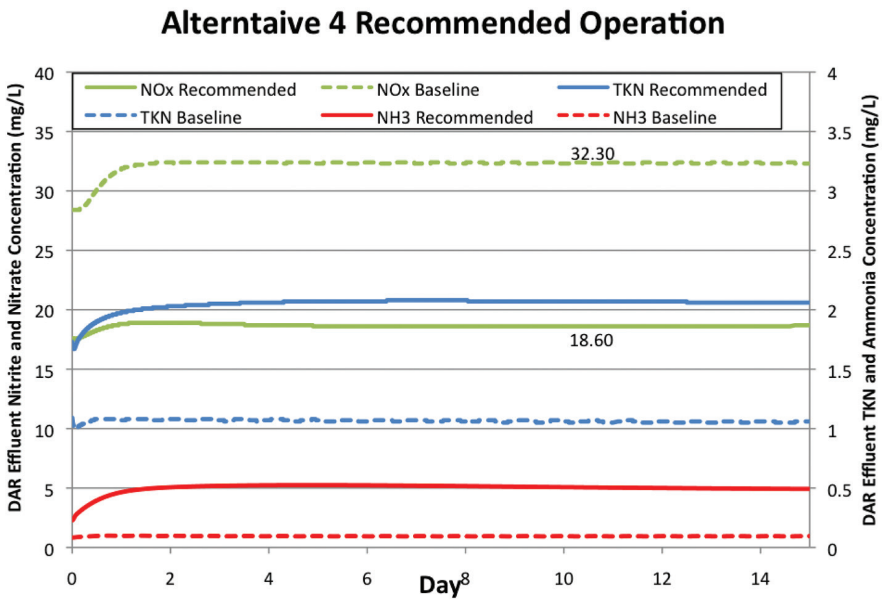


Figure 5. Denitrification Performance for Alternative 4

## Tampa Plans for Implementation

Treatment plants are designed to operate at a design capacity that is typically higher than current flow and loading conditions. While plants are underloaded, there is usually ample opportunity to optimize the process and operate with a different mindset when at capacity. The Plant is currently loaded at about 60 percent of design capacity. The City has taken a systematic approach of performing studies and evaluating alternatives, and has begun to implement the best optimization strategies by integrating the necessary improvements within planned capital replacement projects.

The aeration diffusers in the DARs need to be replaced. The design of the aeration diffusers in the DARs will incorporate the ability to operate in on/off aeration mode as described in Alternative 3. This will allow the City to take advantage of some methanol savings through denitrification in the DARs while the HPO system is in operation. The City is still evaluating the possibility of temporarily converting the HPO reactors to CAS reactors while the plant is underloaded to maximize denitrification upstream of the denitrification filters as described in Alternative 4. The new aeration system in the DARs will be designed to incorporate such a conversion if it is made in the future. Implementing either alternative will result in significant operational savings that can be used to fund future optimization and capital improvement projects in the future.