

---

## **Technologies for Enhanced Nutrient Removal at the Austin Water Utility Pearce Lane Wastewater Treatment Plant**

SR-11-12, June 10, 2011

Ed Peacock, P.E., Chris Herrington, P.E., Mike Kelly, P.E., Mike Personett  
Environmental Resource Management Division

### **Abstract**

*Medium-sized package wastewater treatment facilities are useful tools as intermediate steps in long term regional treatment system planning. Funding for such systems is typically through service agreements with developers and is determined far in advance of permitting with the TCEQ. The Pearce Lane WWTP (300,000 gpd) was designed to meet minimum treatment levels required by the Colorado River Tributary Rules (30 TAC 311(e)) and will discharge into Dry Creek. However, monitoring of Dry Creek and comparison to other tributaries in the area indicate that nutrient levels in the effluent should be lower than that permitted. Agreements with the developer of this project may preclude design of facilities to meet these lower nutrient levels. Processes to achieve very low nutrient levels were investigated and outlined for this plant in an effort to potentially upgrade the facility in the future, or to provide information for additional discharges into similar receiving waters.*

### **Introduction**

On May 3, 2011, staff of the Watershed Protection Department (WPD) met with Austin Water Utility (AWU) staff to discuss the potential to modify the design of the Pearce Lane WWTP to achieve higher levels of nutrient removal relative to the requirements of the draft Texas Pollutant Discharge Elimination System (TPDES) permit for the facility. This meeting was a follow-up to a memorandum from WPD, dated April 13, 2011, which presented the WPD staff evaluation of the potential impacts of the discharge on the quality of the receiving water and on documented mussel populations in Dry Creek. In that memorandum, WPD staff requested AWU to consider design and operation of the new plant to achieve total nitrogen (TN) and total phosphorous (TP) removal at the lowest feasible concentrations and consider the use of ultraviolet (UV) disinfection.

Improved nutrient removal in the initial phase of the Pearce Lane facility would be optimal not only to minimize degradation of Dry Creek, but also to proactively anticipate future instream nutrient criteria under development by the Texas Commission on Environmental Quality (TCEQ) and the U.S. Environmental Protection Agency (EPA). For example, EPA has published a draft chronic numerical criteria for ammonia for freshwater where mussels are present of 0.26 mg/L NH<sub>3</sub>-N at standard pH and temperature (EPA 2009). Additionally, because of nutrient spiraling effects (Fisher et al 1998), degradation of streams from continued high nutrient loadings may require long periods of time to correct once the nutrient point source has been reduced or eliminated. Furthermore, incorporating enhanced nutrient removal into the initial design of the Pearce Lane facility would provide valuable experience with the operation of such a facility at a relatively small scale.

It is understood that the City's agreement with the developer for this facility was negotiated and approved more than two years ago, and that any changes to this agreement that increase either the capital or the O&M costs of the Pearce Lane facility will be problematic. Accordingly, WPD is not seeking to alter the draft TPDES permit for the facility but is interested in assisting AWU with an evaluation of the impacts of the discharge once the facility is operational. WPD is also interested in collaborating with AWU to evaluate processes and technologies for enhanced nutrient removal. Each of these topics is briefly discussed below.

## **Water Quality Modeling**

Questions were raised during the May 3<sup>rd</sup> meeting concerning the WPD findings with regard to the potential impacts of the planned discharge in the absence of a more thorough analysis of the receiving water. WPD staff have applied EPA's Water Quality Analysis Simulation Program (WASP) to evaluate a number of TPDES discharge permits, but have not previously calibrated a WASP model for a Blackland Prairie stream with conditions similar to Dry Creek. With approximately two person-months of staff time, existing WASP models could be adapted by WPD staff for application to Dry Creek. This would provide a method, consistent with widely accepted practices (King 2009), to estimate what actual total nitrogen and phosphorus limits will be necessary to prevent water quality degradation. However, to estimate operational effluent quality limits with confidence, water quality sampling will be required for model calibration. Field sampling would include deployment of periphytometers, instream water quality sampling, and assessment of periphytic algae abundance and biomass nutrient ratios. Pending alleviation of current drought conditions, the field study would take approximately 12 months and would incur approximately \$5,000 in laboratory analytical costs. WPD can contribute the expertise and labor required for such a study but would look to AWU for funding for the costs of laboratory services.

## **Water Quality Monitoring**

In lieu of additional modeling analysis in advance of the construction of the Pearce Lane WWTP, and assuming no further design modifications for enhanced nutrient removal, it was agreed that conditions in Dry Creek should be monitored and evaluated before and after the facility is in service. Sampling should be conducted with an upstream/downstream approach relative to the wastewater treatment plant outfall in two periods, before and after effluent discharge to the creek begins. If comparative monitoring reveals significant water quality degradation due to nutrient loads or disinfection practices, it was also agreed that upgrades to the plant will be considered in advance of TPDES permit renewal. In general terms, a water quality monitoring program for Dry Creek would include three primary components:

- Surface water quality monitoring for nutrients and physio-chemical parameters;
- Benthic macroinvertebrate rapid bioassessment monitoring (Barbour et al 1999); and
- Periphytic algae visual surveys and periphytometer (Matlock et al 1998) assessments.

Surface water quality samples for nutrients (nitrogen, phosphorus), indicator bacteria, total suspended solids and physio-chemical parameters (dissolved oxygen, conductivity, pH, temperature and stream flow) should be collected across the range of seasonally variable climatic conditions (TCEQ 2008). In the absence of extreme drought conditions, this can be accomplished with monthly sampling for at least one year in each condition (before wastewater discharge, after wastewater discharge) at two sites (upstream of the discharge, downstream of the discharge) to be evaluated. Samples should be collected under non-stormwater runoff influenced conditions. Use of a control site proximate but upstream of the wastewater treatment plant outfall, in addition to a site downstream of the outfall would enable paired comparison statistical testing thus reducing background noise effects (Helsel 2005) if general site

characteristics are similar. Power analysis (Rosner 2005) using existing WPD data from Dry Creek at Pearce Lane estimates that 12 sample events would enable statistically significant detection of a 0.1 mg/L increase in mean ammonia, a 0.4 mg/L increase in mean nitrate and a 0.05 mg/L increase in mean orthophosphorus at a type I error rate of 0.05 and a power of 0.80. Based on a relative comparison of mean values and predicted effluent concentrations versus trophic state boundaries (Dodds et al 1988), these statistical thresholds should enable detection of significant water chemistry degradation. At current WPD analytical costs, laboratory analysis of each water quality sample costs \$102 and for 48 water quality sampling events and 6 quality control samples the total cost would be \$4,896.

Both traditional benthic macroinvertebrate monitoring by rapid bioassessment protocols (Barbour et al 1999) and monitoring of freshwater mussel (Unionidae) populations would provide additional quantification of the potential impacts of nutrient enrichment or toxic effects at a broader ecological scale. Benthic macroinvertebrate and mussel surveys should be conducted during the Index Period (March-October) as defined by the Texas Commission on Environmental Quality (TCEQ 2007) when creek flows exceed the 7Q2 (presumed to be 0.1 ft<sup>3</sup>/s). At least three benthic macroinvertebrate surveys should be conducted annually, preferably at the same riffle location downstream of the wastewater treatment plant outfall before and after discharge to avoid any site-specific habitat differences. Changes in benthic macroinvertebrate metrics, including the TCEQ Qualitative Aquatic Life Use Score, and community composition could be used to assess if degradation has occurred. Mussel surveys are qualitative, but should assess changes in the density and spatial coverage of at least the first mussel bed downstream of the wastewater treatment plant outfall before and after discharge commences. Impacts from wastewater effluent may be most acute on early mussel life stages (Goodreau et al 1993), and thus may not be evident in mussel populations for long periods of time depending on recruitment rates. There are no associated analytical costs, only WPD labor in sample collection, taxonomic identification and analysis.

Periphytic (attached) algae communities, as the primary producers of aquatic systems, will be the first to respond to nutrient enrichment. Visual surveys of algae composition, cover and thickness should be conducted by WPD standard methods involving sub-sampling at fifty 1 foot square areas centered along a zig-zag pattern transect crossing the stream in the sampling reach as adapted from Mabe (2007). Visual surveys should be conducted in conjunction with each water quality sampling event, and involve no additional analytical costs. Analysis of variance for changes in algae composition, cover and thickness can be performed before/after discharge or between upstream/downstream sites. Periphytometers should be deployed to determine the limiting nutrient, attempt to establish nutrient concentration thresholds at which rapid changes in algal growth rates occur and to gage the current productivity of the site by the Lotic Ecosystem Trophic Status Index (LETSI) (Matlock et al 1999). A periphytometer should be deployed before and again after the discharge commences during baseflow conditions for a 2-week period, preferably in the spring, with 40 replicates per unit. Chlorophyll-a will be extracted and measured from the filters associated with each replicate, at an analytical cost of \$28 each and a total analytical cost of \$2,240. LETSI values are a quantitative measure of the maximum primary productivity of the system relative to current ambient conditions and can be used to quantify the amount of change in algal growth directly caused by enrichment from the wastewater effluent.

Again, WPD could provide the expertise and labor required for the monitoring program but would request funding from AWU for laboratory services in the approximate amount of \$7,100.

## **Advanced Nutrient Removal Processes**

Questions were also raised in the May 3<sup>rd</sup> meeting with regard to the availability of proven processes and technologies for advanced nutrient removal and the estimated costs, both capital and O&M, associated

with such technologies. In response, WPD staff agreed to conduct a reconnaissance-level review of potentially feasible processes and technologies that are potentially applicable for advanced nutrient removal at the Pearce Lane WWTP. Further detailed review and evaluation of the available processes and technologies should be provided by experienced wastewater treatment plant engineers if application of such technologies is to be seriously considered.

The U.S. EPA's *Municipal Nutrient Removal Technologies Reference Document (September 2008)* provides a comprehensive review of available nutrient removal technologies. Only technologies that met two criteria were included in this review: 1) those for which at least one-year of full-scale operating data is available and 2) those that have detailed capital and O&M cost data. From this review and based on future retrofit of the Pearce Lane WWTP, there appear to be two technology options to meet nutrient limits of 0.1 mg/L TP and 3.0 mg/L TN:

**1. Nitrifying activated-sludge reactor retrofitted with two-point alum addition for phosphorus removal plus a denitrification filter**

This type of retrofit would take advantage of the nitrification already required by the Colorado River Tributary rules and add discrete chemical feed for precipitation of phosphorus and an additional basin for denitrification and high-performance filter for additional phosphorus removal. Advantages of this option include relatively simple control system, good performance, and compact area compared to other denitrification processes. Also, existing filters to reach current permit BOD and TSS removal levels can sometimes be used as denitrifying filters. The disadvantages are the potential costs of new filter basins, increased sludge generation, less efficient removal of solids, larger footprint overall and carbon source requirements (commonly methanol).

**2. Conversion of an activated-sludge system to a 5-stage Bardenpho process with chemical addition for polishing phosphorus and a tertiary filter.**

Conversion of activated sludge to 5-stage Bardenpho requires an anaerobic and anoxic basin in advance of an aerobic tank that recycles nitrified mixed liquor to the anoxic basin and discharges to another anoxic basin and aerobic tank before gravity settling or filtration. Advantages for this system include the added flexibility of having a tertiary clarifier/filtration, multiple feed points for chemical addition, a good filter system, and prevention of secondary nutrient release. Disadvantages are the need for two segregated anoxic basins and potential need for carbon source. A successful conversion is noted to have been made in Clearwater Florida and typical costs are 50% over a new unit with the same capacity. This includes the addition of walls and baffles to segregate anoxic zones, additional tank capacity, additional piping and recirculation pumping, and additional secondary clarification and blower capacity, as well as material and energy costs.

Cost estimates for each of the options can be extrapolated from the EPA guidance document (Table 1). Because the Pearce Lane WWTP is being designed to achieve effluent quality of 5.0 mg/L BOD, 5.0 mg/L TSS, 2.0 mg/L NH<sub>3</sub>-N, and 1.0 mg/L TP, retrofit options may be more or less costly than reported values. Other options for expansion of facilities with higher effluent flow volumes are also detailed in the EPA (2008) guidance as well as many intermediate treatment level designs. By comparison, the Marshall Street WWTP was constructed in Clearwater, Florida, to meet annual TPDES permit limits of 3 mg/L total nitrogen and 1 mg/L total phosphorus, and achieved an annual average 2.23 mg/L TN and 0.11 mg/L TP with a 5-stage Bardenpho process followed a sand filter with alum addition at a unit capital cost of \$2.95/gpd albeit with a 10 MGD design flow (EPA 2008). Higher unit costs might be expected for a much smaller facility such as the Pearce Lane WWTP. In any case, based on estimates from the

EPA guidance document, the capital cost of this retrofit would range from \$531,000 to \$735,000. For the AWU Taylor Lane WWTP, an estimate for biological nutrient removal in the initial 0.5 MGD phase was \$6.7M, which included a cost increase of only \$362,400 (approximately 5%) over conventional activated sludge treatment (Bury and Partners, 2009).

Table 1 - Estimated Costs for Nutrient Removal Retrofits

Option	Capital Costs (\$/gpd)	O&M Costs (\$/MG treated)	Life Cycle Costs (\$/MG treated)
2-point alum, denitrifying filters	1.77	817.8	1238
5-stage Bardenpho with alum and filters	2.45	367.5	952.5

A third potential option for enhanced nutrient removal from the Pearce Lane WWTP would be to “polish” effluent through a constructed free water surface wetland or vegetated subsurface flow system (“rock-reed filters”). This option is well described in EPA guidance (2000). From case studies, constructed wetlands have maximum documented nutrient removal efficiencies in the ranges expected to protect water quality in Dry Creek. Wetlands have an added benefit of providing additional wildlife habitat and, because only periodic maintenance is required, overall O&M costs can be substantially less than for conventional wastewater treatment facilities. However, nutrient removal may vary seasonally and performance can be variable (EPA 1988, EPA 1993). Under some conditions, constructed wetlands can actually export nutrients. Vegetated subsurface flow systems are generally more expensive than free water surface systems, but isolate effluent from mosquitoes and humans.

The costs associated with constructed wetland treatment facilities are highly dependent on the amount and cost of land required and the degree of alteration necessary. Not including land acquisition costs, constructed free surface wetland costs have been estimated to range up to \$2.63/ft<sup>2</sup> with an estimated average \$0.02/ft<sup>2</sup> for annual O&M (adjusted to 1997 dollars, ENR CCI = 5854) (EPA 2000). Based on a preliminary design exercise suggested by EPA (1988), the hydraulic loading rate to a free water surface wetland to achieve total nitrogen effluent concentrations below 5 mg/L must be less than 99,894 gal/acre-day. This translates to a total required surface area of approximately 3.0 acres for a 0.3 MGD facility. This would result in a \$343,688 increase in facility capital cost but only \$2,614/year O&M cost increase.

As a final note, land application of effluent for beneficial reuse has proven to be effective in terms of nutrient removal to protect water quality reliably when applied appropriately (EPA 2008). By comparison, all biological/chemical processes for enhanced nutrient removal can exhibit substantial variability in effluent quality (WERF 2011). When substituted for fresh or potable water supplies, reuse of effluent also extends available water supplies. Costs of irrigation facilities and dedication of land for reclaimed wastewater use make cost estimates difficult for these facilities. However, figuring the acreage needed for a similar sized plant, this would add approximately 137 acres or roughly \$685,000 in land acquisition costs. Added to these costs would be irrigation piping, sprinkler heads, storage ponds, and tailwater controls. Therefore, a significant price would be paid for land application reliability.

## Conclusions

Conclusions from this desktop evaluation are as follows:

- Due to the characteristics of Dry Creek, nutrient removal to very low levels (3 mg/L TN, 0.1 mg/L TP) would likely prevent water quality degradation based on comparison to other wastewater discharges and periphytometer testing in somewhat similar streams.
- Water quality modeling could be conducted to arrive at a more accurate and precise treatment level if a year of calibration data were to be obtained.
- Since the agreement with developers of the Pearce Lane WWTP does not require more advanced nutrient removal capabilities, it is unlikely that this can be accomplished in the first phase of construction.
- A variety of retrofit opportunities exist to meet very low nutrient levels with moderate costs in comparison to the initial capital expenditures for conventional activated sludge facilities.
- It may be possible upon renewal of the permit in five years with financial planning by AWU to retrofit to the Pearce Lane WWTP for advanced nutrient removal. The target nutrient concentrations would be better defined after water quality modeling has been completed.

## Recommendations

Given the above conclusions, the following recommendations are offered:

- Accept currently proposed treatment limitations from TCEQ to provide the highest degree of flexibility for plant operators possible under existing regulations.
- Construct facility as permitted with pumping and piping modifications as feasible to allow more economical retrofit in the future.
- Plan financially for retrofit of the facility to very low nutrient levels at the end of the first term of the TCEQ permit.
- Conduct water quality monitoring and modeling to ascertain effluent limits that will protect Dry Creek.
- Design retrofit and subsequent phases of plant construction to meet treatment levels consistent with water quality modeling results.
- Incorporate advanced nutrient removal in the design of future AWU package plants when WPD water quality modeling and monitoring indicates advanced nutrient treatment is necessary to prevent water quality degradation.

## References

Barbour, M.T., and J. Gerritsen, B.D. Snyder, J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water.

Bury and Partners, 2009. Taylor Lane Wastewater Treatment Plan Wastewater Treatment Alternatives Workshop Presentation. Table 18. November 4, 2009.

Dodds, W.K. and J.R. Jones, E.B. Welch. 1998. Suggested Classification of Stream Trophic State: Distribution of Temperate Stream Types by Chlorophyll, total Nitrogen and Phosphorus. *Water Resources* 32(5): 1455-1462.

Fisher, S.G., and N.B. Grimm, E. Marti, R.M. Holmes, J.B. Jones Jr. 1998. Material spiraling in stream corridors: a telescoping ecosystem model. *Ecosystems* 1(1): 19-34.

Goodreau, S. E., and R. J. Neves, R. J. Sheehan. 1993. Effects of wastewater treatment plant effluents on freshwater mollusks in the upper Clinch River, Virginia, USA. *Hydrobiologia* 252: 211-230.

Helsel, D.R. 2005. *Nondetects and Data Analysis: Statistics for Censored Environmental Data*. John Wiley & Sons, New Jersey.

King, R.S. 2009. Linking observational and experimental approaches for the development of regional nutrient criteria for Wadeable streams. Final Report for Section 104(b)(3) Water Quality Cooperative Agreement #CP-966137-01 to US EPA Region 6.

Mabe, J.A. 2007. Nutrient and biological conditions of selected small streams in the Edwards Plateau, Central Texas, 2005-2006, and implications for development of nutrient criteria. US Geological Survey Scientific Investigations Report 2007-5195. 46 pp.

Matlock, M.D., and M.E. Matlock, D.E. Storm, M.D. Smolen, W.J. Henley. 1998. Limiting nutrient determination in lotic ecosystems using a quantitative nutrient enrichment periphytometer. *Journal of the American Water Resources Association* 34(5):1141-1147.

Matlock, M., and D. Storm, M. Smolen, M. Matlock, A. McFarland, L. Hauck. 1999. Development and application of a lotic ecosystem trophic status index. *Transactions of the American Society of Agricultural Engineers* 42(3):651-656.

Rosner, B. 2005. *Fundamentals of Biostatistics*, 6<sup>th</sup> edition. Cengage Learning.

Texas Commission on Environmental Quality (TCEQ). 2007. *Surface Water Quality Monitoring Procedures Manual, Volume 2: Methods for Collecting and Analyzing Biological Assemblage and Habitat Data*. RG-416.

Texas Commission on Environmental Quality (TCEQ). 2008. *Surface Water Quality Monitoring Procedures Manual, Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment and Tissue*. RG-415.

U.S. Environmental Protection Agency (EPA). 1988. *Design Manual: Constructed Wetlands and Aquatic Plant Systems for Municipal Water Treatment*. EPA/625/1-88/022. 92 p.

U.S. Environmental Protection Agency (EPA). 1993. *Constructed Wetlands for Wastewater Treatment and Wildlife Habitat: 17 Case Studies*. EPA 832-R-93-005. 219 p.

U.S. Environmental Protection Agency (EPA). 2000. *Constructed Wetlands Treatment of Municipal Wastewaters*. EPA/625/R-99/010. 166 p.

U.S. Environmental Protection Agency (EPA). 2008. Municipal Nutrient Removal Technologies Reference Document. Volume 1 – Technical Report. EPA 832-R-08-006. 268 *p.*

U.S. Environmental Protection Agency (EPA). 2009. Draft 2009 Update Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater. EPA-822-D-09-001. 192 *p.*

Water Environment Research Foundation (WERF). 2011. Nutrient Management Volume II: Removal Technology Performance and Reliability. Final Report.