# APPENDIX D

## Case Studies

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These studies are presented to provide a sense of the range of challenges that wastewater pond systems designers and operators have faced over the years and some of the solutions that have been put in place.  We include examples of systems from different parts of the country, which must comply with similar regulations though they live in different environmental conditions.

New Hampshire

Rockland

New Hampshire treatment ponds generally operate with a permit to discharge effluent to ambient water during the winter months (November 1 through April 30) and spraying on irrigation fields during the summer. Ponds designed to meet BOD/TSS are increasingly required to meet $NH_3$ limits in the winter.  Studies measured the base level of $NH_3$ coming into the ponds and results suggested that changing the discharge schedule would reduce the number of $NH_3$ limit violations.

Kansas

The Kansas Department of Health and Environment published its Surface Water Nutrient Reduction Plan in December 2004. Referring to a study it conducted in 2002, the KDHE reaffirmed its support of wastewater treatment ponds as the only feasible treatment technology for many small Kansas towns and attested to their effectiveness in removing nutrients (T*N* by 65% and T*P* by 55%).

California

Los Banos

A small city (population 40,000) in the Central Valley of California was a candidate for a study using solar-powered water circulators (Solarbee®) to evaluate effectiveness and potential savings in energy from this source if new water quality standards are added to its permit. The study provided support for the effectiveness of the treatment system.  Another study examined the impact of the release of effluent on agricultural fields over time.

Arkansas

The Wastewater Treatment Ponds in Arkadelphia, AK have been in operation since 1968.  In 1994, with the addition of a small Lem-Tech duckweed system after the last pond, the system consistently meets discharge limits year round.

## New Hampshire

Meeting Ammonia Requirements by Reviewing Nutrient Values against Discharge Operation Schedules


### Summary

A wastewater treatment pond system consisting of two facultative ponds (2.6 MG) and one storage pond (18 MG) serving a county jail and nursing home were constructed in 1990 and designed to meet $BOD_5$/TSS of 30/30 mg/L. In 1996, $NH_3$ limits of 6.1 mg/L monthly average with a 12.2 daily maximum. The storage pond was permitted to discharge treated effluent to a small stream from October to April. Total Kjeldahl *N* (TK*N*) and $NH_3$ in the influent increased from 28 mg/L to 45 and 8 mg/L to 21, respectively from 1996 to 2010. Water conservation and use of kitchen disposals is thought to be the reason for the increase. An operational decision to change the timing of the initiation of discharge from January to November brought the facility into compliance for $NH_3$.


### Introduction

Rockingham County Complex, Brentwood, New Hampshire operates a three-cell aerated pond system dedicated to serving a county jail and nursing home. The ponds were constructed in 1990 and were designed to meet typical secondary treatment standards of 30/30 mg/l for $BOD_5$ and TSS. The plant was originally designed to treat a flow of 0.67 ML/d (0.178 mg/D and a $BOD_5$ load of 215 kg/d (475 lbs/d). Current flow and loadings are 0.26 ML/d (0.07 mg/d) and 73 kg/d (160 lbs)/d $BOD_5$ (Table 1). No expansions are anticipated and with water conservation measures enacted over the years, it is unlikely design conditions will be met in the foreseeable future.

**Table 1. Discharge Requirements, Rockingham County Complex NH**

| Design flow | Act. flow | BOD/ TSS (mg/L) | Discharge season | $NH_3$ limit (mg/L) |
|---|---|---|---|---|
| 0.67 ML/d 0.178 mg/d | 0.26 ML/ d 0.07 mg/ d | 30/30 | October 1 to April 30 | 6.1 /mo. ave. 12.2 max/d |

The County has an NPDES permit that allows discharge to a very small brook from October 1st through April 30th at an implied flow of 0.085 MGD. They also have a groundwater discharge permit allowing spray irrigation from May 1st through October 31st. The majority of biological treatment takes place in the first two ponds, each having a volume of 2.6 MG. Treated flow is then transferred to an 18 MG storage pond, where it can be held until discharged to the brook or spray irrigated. Due to the design of the valving and piping arrangements, the operator is limited to holding and treating an entire week's worth of flow in the first two ponds during the week, and then transferring that volume of water to the storage pond during the weekend.

In 1997, the County's NPDES permit was reissued with $NH_3$ limits to the brook from October 1st through April 30th of 6.1 mg/l as a monthly average and 12.2 mg/l for a max day. This presented an immediate problem as the system was not designed to remove $NH_3$. Eliminating discharge to the brook altogether would require building another large holding pond and expanding the spray irrigation sites, neither of which was deemed feasible at the time.

**Results**

An initial one year study performed in '96 and '97 showed that the system was capable of producing winter effluent concentrations on the order of 5 mg/l TK$N$ and 3.3 mg/l $NH_3$ at water temperatures < $3^oC$. Summer $NH_3$ levels would go as low as 0.2 mg/l. Influent TK$N$ at the time averaged around 28 mg/l and $NH_3$ 8 mg/l. Biological nitrification was determined to be the primary method for $NH_3$ reduction as demonstrated by the production of $NO_3^-$. Substantial nitrification occurred in the first pond and was brought to completion in the second pond. This continued throughout the summer and well into the fall. The unusually low winter effluent concentrations are thought to be primarily due to dilution in the storage pond.

By October 31st, the end of spray season, the storage pond contained a volume of 4.8 MG of fully nitrified effluent. The second pond continued to support nitrification well into December, until the temperatures decreased to the level of nitrification inhibition and $NH_3$ concentrations increased. As a more $NH_3$ rich water is transferred to the holding pond, the $NH_3$ concentration in the pond and, ultimately, the final effluent, gradually increases to a concentration potentially exceeding 6.1 mg/l. That level was not reached during the initial study.

The plant performed well for the first several seasons under the new permit limits. Beginning in the winter of 2001, however, and lasting through 2005, winter monthly average violations were experienced on a regular basis. January, usually a good month, averaged around 4.5 mg/l $NH_3$. February, March and April averages ranged from 6 to 11 mg/l. There were no violations during the winters of '06 and '07. The violations resumed, however, in '08 and '09. Another study was undertaken to try to determine the cause.

The study showed that the flow and $BOD_5$ loadings remained the same but that the $N$ load had increased considerably. Influent TK$N$ now averages 45 mg/l, up from 28 mg/l, and influent $NH_3$ increased from an average of 8 mg/l in 1996 to 21 mg/l in 2009. It is believed that water conservation measures, in conjunction with the heavy use of garbage disposals in the kitchen area, have led to the increased $N$ loading of the system (Table 2).

**Table 2. TK*N* and $NH_3$ in Pond Influent, 1996 and 2010**

| Influent | TK$N$ (mg/L) | $NH_3$ (mg/L) |
|---|---|---|
| 1996 | 28 | 8 |
| 2010 | 45 | 21 |

The new study showed that the ponds did continue to nitrify, but that the process was now confined to the second pond, and at a slower rate and beginning much later in the summer. As a result, the ponds were unable to handle the increased $N$ load within the system's detention time and resulted in the passing of $NH_3$ to the storage pond and effluent. Dissolved oxygen levels were also found to be too low in the first pond (often < 0.2 mg/l). Insufficient aeration in the first pond could lead to the passing of $BOD_5$ to the second pond, potentially delaying the onset of nitrification. $BOD_5$ must be removed before nitrification can proceed. A review of operational data pointed out the fact that after spray season ends, the operators held all flow for the entire months of November and December and then discharge to the brook in January, February and March, precisely when $NH_3$ concentrations would be expected to be the highest.

During the first year of operating under this plan, discharge to the brook for the months of November and December 2009 resulted in average $NH_3$ concentrations of 1.77 and 1.29 mg/l, respectively. From January 2010 through April, all flow was held until the start of spray season. Supplemental aeration in the first pond has not yet been implemented.

**Discussion**

The major recommendation of this study was to maximize discharge to the brook, within permit limits, during the months when the $NH_3$ was expected to be low, mainly November, December and the first half of January, and rely on holding and spray irrigation for the remainder of the year. This plan, being weather dependent, requires careful planning by the operator to maximize the storage volume of the holding pond to ensure there is adequate room for storage from mid-January to the start of spray season. The study also recommended adding supplemental aeration to the first pond in order to maximize $BOD_5$ removal there, which, in theory, should allow nitrification to proceed faster and be of longer duration in the second pond.

**Conclusion**

This case study illustrates the benefits of system-wide monitoring, close evaluation of flows and loadings, and assessing plant operations to determine the potential for a pond to nitrify. It is unlikely that a continuous flow through pond would meet limits of $< 6$ mg/l in a cold climate without further enhancements, but in an under-loaded pond where the detention time and discharge periods may be manipulated, this may be possible. Further study of those variables may be warranted.

Report by Wes Ripple, New Hampshire Department of Environmental Services. The plant operator is Mark Pettengill (603-679-5335).

**The State of Kansas**

The Case for Ponds in Anticipation of More Stringent Nutrient Limits for Wastewater Treatment System Effluents

Given overall good, consistent treatment and low cost, the Kansas Department of Health and Environment has encouraged communities to build ponds for wastewater treatment. As a result, nearly 80% of all municipal wastewater treatment in the State of Kansas is provided by wastewater pond systems.

In 1994, the Kansas Department of Health and Environment adopted water quality standards that were significantly increased in scope and stringency. Language was indicating that wastewater treatment ponds would be able to meet these standards was not approved by US EPA Region 5. In 1999, the KDHE adopted revised standards that eliminated the reference to ponds and spelled out how ponds would be addressed in the NPDES permitting process. This included a study of pond performance.

Effluent samples from eighteen facilities built in accordance with KDHE's Minimum Standards of Design for Water Pollution Control Facilities were analyzed, including $BOD_5$, $SBOD_5$, $CBOD_5$, $NH_3$, TK$N$, $NO_3$, T$P$, dissolved $P$, fecal coliform and $p$H. Overall, the data indicated that pond systems provide consistently good treatment for $CBOD_5$, $N$ and bacteria. Increase in total $BOD_5$ in late summer, correlating to increase of $NH_3$ and organic $N$, is thought to be due to increasing anaerobic conditions in the sediment, leading to microorganism die-off. KDHE has been evaluating maintenance options to reduce solids in pond effluent.

Similarly, ponds are shown to provide good quality year-round disinfection of wastewater. During the recreation season, best fit curves indicated that fecal coliform will be <200 MPN/100 mL 50% of the time, with 100% of the samples <1700 MPN/100 mL. In the winter, 55% of the samples will be <200 MPN/100 mL and 90% will be <2000 MPN/100 mL. An increase in fecal coliform seen in the late summer correlates fairly well with the increase in $N$.

The issue of greatest concern for the viability of the pond systems in Kansas is the adoption of nutrient criteria by the EPA. The Agency's approach is to develop criteria by ecoregion; Kansas is located in five of those regions. The EPA Region 7 Regional Technical Advisory Group's task is to identify rivers impacted by nutrients, collect water quality data from those rivers, select the upper $25^{th}$ percentile of the nutrient values as ecoregion reference conditions. Where insufficient data exist, the lower $25^{th}$ percentile of the available data from all sites will be used. RTAG recommended criteria for all lakes and reservoirs in Kansas, Iowa, Nebraska and Missouri are 0.70 mg/L (T$N$); 35 µg/L (T$P$); and 8 µg/L (chl $\alpha$). These criteria, it is believed, will be of concern to all types of wastewater treatment facilities, not only pond systems.

The KDHE published the Surface Water Nutrient Reduction Plan in December 2004. It reaffirms its support of wastewater treatment ponds as the only feasible treatment technology for many small Kansas towns and attests to their effectiveness in removing nutrients (T$N$ by 65% and T$P$ by 55%).

The information for this case study is taken from Tate, M.B. et al. 2002 and the Kansas Department of Health and Environment, 2004.

**Los Banos, CA**

Looking at potential for reducing energy costs and long-term impacts of irrigating with pond effluent

Los Banos is community of 40,000 people located in the Central Valley of California. The wastewater treatment facility consists of 234 ha (354 ac) of treatment and storage ponds (167.4 ha/ 354 ac) and spray fields (67.2 ha/ 166 ac). Several studies have been initiated to understand baseline conditions before plans are developed for expansion. Unfavorable economic conditions have slowed the rate of growth, which affected at least one of the studies.

Pacific Gas & Electric, working with the California Wastewater Process Optimization Program (CalPOP), asked the City of Los Banos if it would participate in a study to evaluate and document potential energy savings using Solarbee® technology. Previous projects typically involved the replacement of standard mechanical mixing and aeration systems with Solarbee® units; the Los Banos project involved the introduction of the technology as an alternative to introducing standard mechanical mixing and aeration systems to a large-scale facultative pond treatment system. While the potential savings is speculative, the deployment of the Solarbee® aerators in one treatment and one storage pond did demonstrate their effectiveness in changing the hydrodynamics (reducing stratification of temperature and dissolved oxygen) and provided water quality information.

**Table 3. Los Banos Wastewater Treatment System Process Features**

| **Treatment Process Characteristics** | **Value** | |
|---|---|---|
| | | |
| Average Influent Flow | 3.5 mg/d | |
| Average Influent BOD | 535 mg/L | |
| Assumed Influent $NH_3$ | 25 mg/L | |
| | | |
| Average Recycled Flow (treatment pond effluent) to Plant Headworks | 19.2 mg/d | |
| Average Recycled BOD (treatment pond effluent) to Plant Headworks | 70 mg/L | |
| Combined (Influent + recycled) $BOD_5$ to Ponds | 140 mg/L | |
| | | |
| **Volume/Surface Area** | **Cm(K)/Ha** | **(MG/Ac)** |
| Treatment Pond 1&2 | 471/34.4 | (124.5 / 85) |
| Treatment Pond 5 | 651/28.3 | (172 / 70) |
| Treatment Pond 6 | 738/28. 3 | (195 / 70) |
| Storage Pond 3 | 307/12.9 | (81 / 42) |
| Storage Pond 4 | 609/36.4 | (161 /90) |
| Storage Pond 7 | 723/27.1 | (190.5 / 67) |

The interpretation of water quality results was complicated by the fact that the system process includes constant effluent recycling and redistribution to ponds, as well as differences in pond depths, pond internal loadings, and detention times. Project analysis indicated that the Solarbee®s operated according to their design parameters and met specifications. Specifically, the water column characteristics of temperature, DO, *p*H, and conductivity showed that the ponds with Solarbee®s were better mixed, less stratified, cooler, and had significantly better $O_2$ profiles than the control ponds. It was concluded that the installation of Solarbee® aerators would be a reasonable alternative to the mechanical aeration.

Table 3 provides a facility process summary that presents applicable information collected as part of the pre-project analysis for the treatment facility. Based on influent data from January 2007 to December 2007, the current plant influent loading is 3.5 mgd flow with a yearly average $BOD_5$ concentration is 535 mg/I. However, as is common in plants with food processing influent flows, there is a sustained peak of 600 mg/I influent $BOD_5$ for two months during the year.

Ponds 1 through 7 were monitored for DO, $BOD_5$, TSS, EC and temperature. Supplemental testing included $CBOD_5$, $NH_3$, TK*N*, $NO_2^=$ and $NO_3^-$ (the results are not presented here).

While the comparison of $CBOD_5$ and $BOD_5$ between ponds gave limited information, the ratio of $BOD_5$ to $CBOD_5$, an indicator of the *N* and non-organic $O_2$ demand portion, was fairly consistent in all ponds. In addition, the facility is achieving $CBOD_5$ levels that are non-detect in Ponds 6 and 7 (Table 4). ("The non-detect CBOD results are outstanding for any pond-based system anywhere in the country. Most of the credit goes to a well-maintained and well-operated system operated by dedicated staff…")

**Table 4. $CBOD_5$ (mg/L) in Ponds with Solarbee® Aerators vs. Control**

| | Treatment Ponds | | Storage Ponds | |
|---|---|---|---|---|
| | Solar Bee® | Control | Solar Bee® | Control |
| | Pond 1 | Pond 2 | Pond 6 | Pond 7 |
| Ave | 32 | 26 | 15 | 13 |
| Min | 22 | 13 | 2.5* | 2.5* |
| Max | 60 | 35 | 35 | 24 |

*One/half the detection limit. Actual value is non-detect.

Another study was conducted recently to look at the effect of spraying fields with Los Banos WWTP water (data not provided). The consultant evaluated water level and EC data from new and previously existing monitoring wells around the WWTP, as well as from a network of shallow piezometers maintained by the Central California Irrigation District. Results of this salinity study indicate that (1) unlined irrigation canals are likely influencing shallow groundwater quality, masking the regional salinity gradient, and (2) evapo-concentration may be locally concentrating salts in groundwater. The study also included installation of additional monitoring wells and quarterly sampling of these wells. It is anticipated that these data will be used to demonstrate that the City's wastewater management practices are not adversely impacting the groundwater.

This case study was prepared from *Solar-Powered Circulator Energy Assessment Project, Emerging Technologies Program, Pacific Gas & Electric (2008)* Quantum Energy Services & Technologies, Inc.; *Six Months Report Reviewing Phase One Solarbee® Pilot Program at the City of Los Banos Wastewater Treatment Facility* (2008) (*http://www.Solarbee.com*) and *Salinity Study for Wastewater Treatment Facilities Expansion in City of Los Banos* EKI Consultants (*http://www.ekiconsult.com*)

**Arkadelphia, Arkansas**

The City of Arkadelphia, located on the Ouachita River, with a current population of 11,000, put in a wastewater treatment pond system in 1968. Arkadelphia's wastewater treatment facility consists of 164 acres of oxidation ponds, with the final eleven acres in aquaculture (Lemna Process, see smallest pond in Figure 1). Discharge NPDES limits to the Ouachita River are 30 mg/L $BOD_5$ and 90 mg/L TSS. Average flow through the system is 1.9 MGD with current capability of treating 3.0 MGD.

Sludge was removed from the first pond in 1980. In 1994, a duck weed pond was added to the treatment train to provide consistent TSS, especially in the summer. The operators were advised that they would have to harvest the *Lemna*, using a harvester to break up the clumps of vegetation. In fact, they have never had to use the harvester, as the Lemna breaks up in the fall and decomposes, without causing a significant build up of sludge. The *Lemna* pond is partitioned into a grid system by a series of plastic enclosures. The infrastructure, including plastic sheeting, stainless steel pins, has not needed to be replaced in sixteen years of operation. An added bonus is the number of species of birds visiting the *Lemna* pond to eat the insects that are found there.

Report based on interviews and website information (www.cityorarkadelphia.com).

**Figure 1. Arkadelphia Wastewater Treatment Ponds with Lemna Process (smallest pond).**