ALTERNATIVE TREATMENT AND ENERGY MANAGEMENT SYSTEM TOWN OF WINDHAM WASTEWATER TREATMENT PLANT

FINAL REPORT 10-14
DECEMBER 2009

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Final Report

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NYSERDA Report 10-14

NYSERDA 10882

December 2009

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Abstract

The goal of a more environmentally benign wastewater effluent coupled with a reduced operational budget was verified by this four-month pilot project at the Town of Windham Wastewater Treatment Plant (WWTP). Optimization of upstream unit processes, supplemented by a solar energy component, helped to reverse the practice of energy-intensive downstream treatment in achieving highly polished wastewater effluent. Historically, conventional enhanced wastewater treatment typically includes a grinder, an aeration system, a clarifier, some form of filtration, effluent disinfection, and possibly dechlorination. This conventional system places its major treatment efforts on the most energy- intensive portion of the system, and produces up to 1.2 pounds (lbs) of waste solids for every pound of biochemical oxygen demand (BOD) treated. This proposed system changes the entire process: 80% of the solids and organics will be removed by preliminary and primary treatment in combination with a post-primary filtration system. The piloted system used the proven technologies of primary settling, chemically-enhanced primary clarification by a continuously backwashed upflow sand filtration (CBUSF) system, and coupled those with nitrogen, phosphorus and pathogen reductions in a membrane bioreactor (MBR). With a stabilized mixed liquor suspended solids (MLSS) at approximately 2200 milligrams per liter (mg/L), and a mixed liquor volatile suspended solids (MLVSS) of approximately 1500 mg/L, the aeration requirements for the system were significantly less than that of a conventional activated sludge system. Biological sludge production was minimal. MBR effluent quality was excellent: five-day biochemical oxygen demand (BOD_5) and total suspended solids (TSS) values were below detectible levels of 5 mg/L; coliform bacteria were absent; ammonia concentrations were less than 0.1 mg/L; phosphorus concentrations were less than 0.1 mg/L; and turbidity was always less than 0.1 nephelometric turbidity units (NTU).

The wastewater treatment system piloted has wide application for new and retrofit construction. The proposed system's small footprint, coupled with its reduced energy consumption and excellent effluent quality, can benefit numerous watersheds.

Key Words

Membrane bioreactor (MBR), energy efficiency, enhanced nutrient removal, small footprint

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SUMMARY

Within the regulatory communities, the goal of enhanced wastewater treatment relative to nutrient and pathogen removal has always driven technological advances. The ultimate goal of a more environmentally benign wastewater effluent coupled with a reduced energy and operational budget was verified by the currently described four-month pilot project at the Town of Windham Wastewater Treatment Plant (WWTP). To ensure successful dissemination of piloted results to regulatory communities, staffs from two agencies were asked to participate in the project in an advisory role from inception. Personnel from the New York State Department of Environmental Conservation's (NYSDEC) Bureau of Water Resource Management's New York City Watershed Section and the New York City Department of Environmental Protection's (NYCDEP) WWTP Upgrade Program attended project meetings, visited the pilot while in operation, and were updated on results throughout the demonstration. The Town of Windham in Greene County is home to a new WWTP, funded under New York City's Watershed Protection Program for New Infrastructure. The WWTP combines conventional activated sludge unit processes as well as a sand filter-based, microfiltration-equivalent, tertiary component, and complies with all effluent discharge standards. The town is home to a growing recreational and tourism industry, and could benefit from technology that would allow wastewater treatment expansion without additional facilities expansion.

The piloted treatment system used the proven technologies of primary settling, chemically-enhanced primary clarification in a continuously backwashed upflow sand filtration (CBUSF) system, coupled with nitrogen, phosphorus and pathogen reductions in a flat plate membrane bioreactor (MBR). Optimization of upstream unit processes, in which fully 80% of the particulate and soluble carbonaceous material was removed, enabled the immersed MBR system to function as predominantly a nitrification/denitrification system. An immersed MBR system combines the functions of a conventional activated sludge (CAS) aeration system, secondary clarification and tertiary filtration within a single tank. By removing the bulk of the suspended solids and BOD_5 prior to aeration in the MBR tank, the operating MLSS was maintained in the 2,000 to 2,500 mg/L range, rather than the 8,000 to 15,000 mg/L MLSS range of a typical MBR system. This lower MLSS, which consists primarily of the slower growing nitrogen-consuming bacteria, required reduced aeration horsepower to maintain the requisite system dissolved oxygen. Additionally, considerably less biomass was produced by the nitrogen-consuming bacteria, lessening the load on the downstream solids handling systems. The MBR operated at an extended solids residence time (SRT); during this pilot project the system SRT exceeded 100 days. Under such a lengthy SRT, the typical problems of membrane fouling by extracellular excretions of younger sludge were eliminated. This optimization of the upstream unit processes, supplemented by a solar energy component, helped to document reversal of the current trend of energy-intensive downstream treatment in achieving highly polished wastewater effluent.

MBR effluent quality was excellent: BOD_5 and TSS values were below detectible levels of 5 mg/L; coliform bacteria were absent; ammonia concentrations were less than 0.3 mg/L; and turbidity was always

less than 0.1 NTU. Biological phosphorus removal resulted in effluent concentrations of approximately 0.5 mg/L; with chemical sequestering of phosphorus in the MBR tank, effluent concentrations of 0.1 mg/L were easily achieved.

One of the more obvious benefits of this piloted system is its simplicity: the primary clarifier and the CBUSF are easily operated forms of primary treatment. Membrane bioreactor technology was developed in the 1980s and has continued to see increased use in critical watersheds and where water reuse is practiced. Earlier external MBR systems have transitioned to immersed MBR systems, where the immersed flat plate membranes are not adversely impacted by a highly managed food to microorganism (F/M) ratio, or by bulking sludge settling issues. The solids removed from primary clarification and the CBUSF system are easily dewatered; and the biological solids from the MBR system are just a small fraction of that from a CAS system. This operational simplicity allows for a reduced manpower commitment, which combined with the lower energy costs, results in lower operation and maintenance (O&M) costs.

The piloted wastewater treatment system has wide application as new construction and as retrofit of existing treatment facilities. The proposed system's small footprint, coupled with its reduced energy consumption and excellent effluent quality, can benefit numerous watersheds. Across New York State, over 600 wastewater treatment plants serve over 15 million people in 1,610 municipalities. Of these, 323 WWTPs used activated sludge as the treatment methodology; therefore, 53% of the total plants could use this innovative technology. According to the NYSDEC's "Infrastructure Needs Report", dated March 2008, New York's WWTPs are meeting baseline technology limits, yet a growing number are slipping from these limits as their infrastructure ages beyond its expected useful life. Future infrastructure needs will be necessary to protect enhanced water quality standards, as defined by stricter total maximum daily loads (TMDL) standards. Within New York State, 724 waters are on the State's 303(d) List of Impaired Waters that may be candidates for TMDL standards, and the NYSDEC "Infrastructure Needs Report" states, "compliance with TMDL requirements often result in the need to design and construct costly additional treatment infrastructure to supplement existing wastewater treatment facilities", (New York State Department of Environmental Conservation, 2008). With energy reduction and conservation, reduced sludge generation, the tidy footprint, and the ability to reuse existing piping and tankage, along with the long-term lower operation and maintenance costs, this innovative technology could easily find application across New York State as well as nationally. In addition, with the inclusion of such simple, yet effective front-end processes (i.e. fine screen, primary clarification, chemically- enhanced sand filtration), the system could be designed to accommodate a wastewater collection system wherein an infiltration and inflow (I&I) issue is problematic and unresolved.

This innovative treatment system has application to new facilities, but more importantly, has application to the retrofit of existing, under-performing wastewater treatment facilities. As receiving water quality

concerns continue to grow, and with the emergence of an ever- growing list of chemicals and microbial strains of concern, this innovative treatment system affords the user the benefits of enhanced treatment with the flexibility of an easily modified treatment system. With the extremely small footprint of an MBR treatment system, the retrofit of existing facilities can, in most cases, be accomplished within the boundaries of the existing wastewater treatment plant campus. Given the site-specific hydraulics of existing treatment facilities, existing piping, tankage, and utilities can be used in favor of demolition and new construction. This concept saves valuable resources and minimizes the greenhouse gas emissions associated with the production and shipment of all new building materials.

Given the number of plants in New York State, where this technology could be applied and the innovative nature of the project, an adequate amount of outreach was performed during the pilot. The outreach consisted of education, training, a presentation at a technical conference, a press release about the project issued by NYSERDA, and the submission of an article summarizing the results to a technical publication. Delaware Operations extended invitations to visit the operational pilot system to relevant regulators, public officials, and treatment plant operators associated with at least 10 wastewater facilities in the New York City watershed where the technology was applicable. Delaware Operations also provided information to vendors whose equipment was incorporated in the alternative treatment system so that they can now promote the alternative configuration as well.

Section 1

INTRODUCTION AND PROJECT DESCRIPTION

This report summarizes the results of a four-month pilot project study at the Windham WWTP, during which enhanced wastewater treatment under a low energy operations scenario was practiced. The upstream treatment processes were optimized to remove the majority of the particulate and soluble carbonaceous material, after which an immersed membrane bioreactor accomplished nutrient and pathogen removal. The immersed membranes provided microfiltration treatment of biological solids and chemically sequestered phosphate-based particles. The membrane permeate complied with the strictest of effluent standards.

BACKGROUND OF ENHANCED WASTEWATER TREATMENT AND MEMBRANE BIOREACTOR (MBR) TECHNOLOGY

Historically, the goal of treatment of municipal wastewater was "…the protection of public health in a manner commensurate with environmental, economic, social and political concerns" (Metcalf and Eddy, Inc., 2003). Early municipal sewers simply moved wastewater from its source to the closest receiving stream; treatment was by dilution. The first environmental regulation, the 1899 Federal Rivers and Harbors Appropriations Act prohibited the discharge of solids to navigational waters. As population centers grew by the early 1900s, wastewater treatment focused on the removal of floatable and suspended solids, treatment of easily biodegradable organics, and the destruction of pathogenic organisms. By the late 1960s, wastewater treatment plants practiced both primary and secondary treatment. In 1972 the Federal Water Pollution Control Act Amendments (the Clean Water Act) were passed, with the goal of "fishable and swimmable" waters, and a National Pollutant Discharge Elimination System (NPDES) Permit program was established. Since then, additional regulations have required a higher degree of treatment to preserve ambient water quality, based upon the watershed-based receiving stream's assimilative capacity.

Since the early 1980s membrane bioreactors (MBRs) have seen application in treating a variety of industrial wastewaters; and the technology has developed from the pressure-driven cartridge type external to the bioreactor to the vacuum-driven immersed flat plate membrane system. Since the early 1990s, the increase in water reuse applications nationally has promoted the use of various membrane systems, including MBRs. Water reuse applications strictly control the public exposure to wastewater effluent, and membrane systems are known to provide one of the highest levels of treatment by rejecting conventional, nonconventional, and emerging contaminants (Water Environment Federation Press, 2006). As membrane technology has seen wider application in water reuse practices and for direct discharge in critical watersheds, the use of vacuum-driven immersed membranes increased. The emerging application of these immersed membrane systems is for retrofit installations, compared to previously applied tertiary treatment. The benefit of the vacuum-driven immersed membrane systems for retrofit applications include its smaller footprint by combining the functions of a conventional activated sludge aeration system, secondary

clarifiers and tertiary filters within a single tank. The vast majority of the municipal wastewater treatment plants (WWTPs) and wastewater infrastructure constructed and/or upgraded under the 1980s $60 billion Federal Construction Grants program, is reaching or has reached its useful life and is in need of major upgrades. The NYSDEC has identified a $36.2 billion wastewater infrastructure need over the next 20 years for many of the 600+ municipal WWTPs (New York State Department of Environmental Conservation, 2008). Upgrading these facilities will require the judicious use of resources, both financial and spatial.

The upgrading of 103 municipal and private wastewater treatment facilities within the 2,000 square mile New York City watershed, as mandated by the 1997 New York City Watershed Memorandum of Agreement (MOA), is nearing completion. The MOA required that microfiltration-equivalent tertiary wastewater treatment be provided for bacterial and pathogen removal, as well as enhanced nutrient (i.e. phosphorus) removal (New York State Environmental Facilities Corporation, 1997). Both the capital and O&M costs for these enhanced treatment facilities were and are being paid for by the New York City Department of Environmental Protection (NYCDEP). Effluent compliance is very strictly monitored for the typical discharge parameters as well as for turbidity and pathogenic protozoans.

In the absence of the New York City MOA funding initiative, communities requiring enhanced wastewater treatment technologies are forced to evaluate tertiary processes or extensive modifications to their WWTP's primary and/or secondary treatment trains. This evaluation requires thoughtful application of environmental, economic, and societal dictates. The application of MBR technology satisfies the environmental and societal dictates, in that this technology provides barrier treatment to produce an exceptional wastewater effluent. It also satisfies the economic dictates in that it combines aeration, clarification, and filtration all within the same tank, thus saving on process footprint and capital cost.

Operationally, MBR technology has historically required higher electrical consumption due to its higher MLSS concentrations and the concomitant higher aeration demands (Water Environment Federation Press, 2006). In an effort to reduce this electrical demand and shift some of the treatment to upstream unit processes, an innovative approach to treat typical municipal wastewater was developed. This innovative approach was piloted at the Windham, New York WWTP that had recently been constructed as part of the NYC Watershed Protection New Infrastructure Program. The Windham WWTP provided existing treatment processes that could be used in the pilot's design of optimizing upstream processes prior to the introduction of an MBR treatment system and provided an established basis for comparing the piloted technology to an existing state-of-the-art treatment system in one of the nation's most restrictive watersheds.

PROJECT GOALS

The goals of this project, “Alternative Treatment and Energy Management System at the Town of Windham WWTP”, were to document the production of a more environmentally benign wastewater coupled with a reduced operational budget. This was accomplished by optimizing upstream treatment processes, adding MBR technology, reducing energy demand, and adding a supplemental solar energy component. Comparisons between the existing conventional activated sludge/tertiary treatment Windham WWTP and the piloted system were made relative to energy demand, biological solids production, chemical usage, and operational constraints.

Section 2

METHODOLOGY

EXISTING WINDHAM WWTP

The Windham WWTP is permitted for a monthly (30- day average) flow of 0.445 million gallons per day (mgd). Raw wastewater from the sanitary sewer system enters the WWTP at the influent pump station where it is pumped to the influent head works building. Influent wastewater passes through a Parshall Flume and ultra-sonic flow-measuring device on its way to the Muffin Monster® and Auger Monster® for grinding and screening purposes. The raw wastewater flows to a splitter box where it can be diverted to one or both of the primary clarifiers (49,000 gallons each) for preliminary separation of solids. Sludge from the primaries is pumped to the aerated sludge digester for further processing. The wastewater from the primary clarifiers flows to an aerated influent channel where several flow options are available. The flow normally enters the equalization (EQ) pump station where it is pumped at a pre-determined rate to one or both of the aeration tanks. Should the incoming flow exceed the pre-determined pump rate, the pump station overflows into the (EQ) basin. Coarse bubble diffusers aerate the 150,000 gallon EQ basin to ensure complete mixing.

Figure 2-1
Town of Windham WWTP

Equalization pumps transfer wastewater from the EQ pump station to a splitter box where the flow can be diverted to one or both of the aeration basins in the biological process. The secondary treatment is an extended aeration, activated sludge process that consists of two 240,000 gallon aeration basins with fine bubble diffusers and two 105,000 gallon secondary clarifiers. Solids from the secondary clarifiers not returned to the aerations basins are pumped to the aerobic sludge digester for further processing.

The secondary effluent flows by gravity to the continuously backwashed upflow dual sand filtration (CBUDSF) system for tertiary treatment. Polyaluminum chloride (coagulant) and sodium hypochlorite are injected into the waste stream for phosphorus removal and disinfection. The system has three filtration trains that consist of two 50 square foot (sq. ft.) sand filters (a deep bed and a shallow bed) installed in series. The backwash (reject) from the CBUDSF flows into the site lift station where it is pumped back to

the head works building and mixes with incoming wastewater post Parshall flume and ultrasonic flow meter. An in-line effluent turbidimeter and particle counter continuously monitor effluent quality. After dechlorination through the addition of sodium thiosulfate, the final effluent flows to the Batavia Kill, a class C(T) tributary of the Schoharie Creek, and ultimately into the Schoharie Reservoir.

The sludge generated from the primary and secondary clarifiers is held in a 121,000 gallon aerated sludge digester. It is decanted and pumped to a one-meter belt press where it is dewatered and transferred via conveyor to a container for transport to the landfill. The filtrate (water phase) from the belt press and wash water is pumped back to the head works building where it is mixed with incoming wastewater, post Parshall flume and ultrasonic flow meter.

PILOT EQUIPMENT DESCRIPTION AND LAYOUT

The piloted system at the Windham WWTP consisted of primary clarification, chemically-enhanced sand filtration, nutrient removal, and microfiltration through a 0.4 micron flat plate membrane bioreactor (MBR).

Flow from the Windham WWTP's primary clarifier was pumped to the seven-square foot continuously backwashed upflow sand filtration (CBUSF) unit at an application rate of between 2.1 and 2.5 gallons per minute per square foot (gpm/sq.ft.), or between 21,168 and 25,200 gallons per day (gpd). Influent to the CBUSF was injected with a low dose of sodium hypochlorite to prevent biofouling; residual chlorine levels of sand filter effluent were typically less than 0.1 mg/L to protect the biomass in the MBR system. The addition of polyaluminum chloride (PACl) for coagulation was done at an approximate 10 parts per million (ppm) active Aluminum (Al) dosage rate. The one-meter deep sand filter used 1.4 millimeter (mm) silica sand. All filtered effluent from the CBUSF system in excess of that required for the membrane bioreactor system was discharged via gravity to the headworks of the Windham WWTP. The reject waste from the CBUSF system likewise flowed by gravity to the headworks of the Windham WWTP.

From the CBUSF, filtered effluent entered a 50-gallon tank, which served as the reservoir for the Kubota flat-plate membrane bioreactor. From this reservoir, flow entered the float-controlled 41-gallon anoxic tank, then into the 83-gallon pre-aeration tank, and then the bioreactor tank that housed the 0.4 micron flat-plate membrane. There were four, 1.18 sq.ft. flat-plate membranes within the 72-gallon bioreactor.

The design flux of this pilot system is 14.6 gallons per day per square foot (gpd/sf), or a permeate production rate of approximately 70 gpd at a minimum water temperature of 15º Celsius (59º Fahrenheit). For this project, the pilot permeate production rate was approximately 35 gpd for a flux rate of 7.3 gpd/sf; wastewater temperatures ranged from 8.0º Celsius (46.4º Fahrenheit) to 17.9º Celsius (64.2 ºFahrenheit). The MBR permeate was sampled at a location on the discharge side of the permeate pump for both in-house process control testing and certified laboratory testing. All permeate flow was eventually returned to the headworks of the Windham WWTP.

Figure 2-2
Alternative Treatment and Energy Management System
CBUSF Treatment Unit and MBR System

The Kubota MBR pilot uses four flat-plate type 203 membranes. Each membrane is 316 mm in length, 226 mm wide and 6 mm thick with a cartridge surface area of 0.11 square meters (m^2) (1.18 sq. ft.). The membrane cartridges are composed of sheets of polyethylene ultrasonically welded to support panels. The membrane mean pore size is 0.4 microns, with an effective pore size down to 0.1 micron. The smaller membrane effective pore size results from the biofilm, which has been characterized as a dynamic membrane protecting the membrane material from fouling and creating a secondary densely packed barrier to pathogen breakthrough. The Kubota pilot also includes a control panel with timers, as the MBR operates in a one-minute back pulse mode for every nine minutes of operational time (i.e. a 1,296-minute operating day as compared to the actual 1,440-minute day).

PILOT START-UP, OPTIMIZATION AND GENERAL OPERATION

During the period from September through December 2008, the project team initiated securing and installing the equipment necessary to complete the pilot project. An assessment of the physical layout of the system was completed once all of the equipment was on site; equipment placement was determined by site constraints (i.e. gravity wastewater feed to the pilot wherever possible, ambient temperature protection for sensitive equipment electrical connections, recycle stream discharge, etc.). The CBUSF was installed along the Windham WWTP's concrete equalization tank wall, adjacent to the garage. The CBUSF was housed within a temporary insulated structure, warmed by the filter's air compressor excess heat and a small ceramic heater. The Kubota membrane pilot system was housed within the WWTP's heated garage area. On December 16, 2008, the project kickoff meeting was held at the Windham WWTP. Attendees at the meeting included: an engineer, manager and operators from Delaware Operations responsible for pilot

design, installation, sampling and analysis, marketing, project management, and reporting. Also present was the project manager from NYSERDA and in an advisory role two staff members from NYSDEC's Bureau of Water Resource Management's New York City Watershed Section and three staff members from NYCDEP's WWTP Upgrade Program. Discussions at that meeting included a review of the project team's scope of work, recommendations from the regulatory agency personnel on project scope modifications, and a tour of the pilot.

During the initial start-up period of the MBR, the permeate flow was reduced by approximately half to allow the mixed liquor to build up to the manufacturer's recommended design concentration of between 10,000 and 15,000 mg/L. During the January start-up, concentrated return activated sludge from the Windham WWTP was consistently added to the MBR bioreactor in an effort to build the MLSS to this design range (i.e. 10,000 to 15,000 mg/L). On January 8, the MBR bioreactor was initially seeded with MLSS of 5570 mg/L. By January 16, after several more seeding campaigns, the MLSS was down to 3,400 mg/L and the system was nitrifying successfully. Effluent ammonia concentrations were well below 0.7 mg/L from influent levels as high as 34.0 mg/L. A one-time addition of less than 250 milliliters (mL) of soda ash was required to maintain neutral pH levels and adequate alkalinity levels; effluent pH values remained consistently above 7.0. By January 31, the MLSS within the MBR bioreactor was down to 2,240 mg/L, where generally it remained for the duration of the pilot project. Weekly sampling events confirmed the stability of the biomass throughout the four-month pilot project. This biomass consisted almost exclusively of nitrifying bacteria, the growth rate of which is considerably slower than that of the carbonaceous consuming bacteria.

During this first month of operation, typical operational issues surfaced. One of the biggest obstacles encountered was the continuing period of extremely cold temperatures. Ambient temperatures were as low as -26° Celsius (-15° Fahrenheit), with influent wastewater temperatures as low as 7°Celsius (44.6°Fahrenheit). Once the sand filter effluent entered the reservoir inside the heated garage, the temperature increased to a minimum of 10° Celsius (50°Fahrenheit). The final permeate was typically no less than 16° Celsius (60.8° Fahrenheit). Winterization of the CBUSF system required some minor modifications (i.e. heat tracing some of the chemical feed and air lines). As for the MBR system, the earliest young biomass and cold water temperatures resulted in a sticky, gelatinous material adhering to the membranes. This problem was observed within the first full week of system operation, and was easily resolved by a combination of water scouring of the membranes, or an overnight soaking of the membranes in a weak solution of sodium hypochlorite.

On March 9, the anoxic tank was renamed the pre-aeration tank, and the former pre-aeration tank was taken off -line. The reason for this was the inability to obtain anoxic conditions within the former anoxic tank due to the high concentrations of dissolved oxygen in the MBR tank and the high recycle rate. The change

in operational mode had no discernible effect on permeate quality, MLSS concentrations or characteristics, or dissolved oxygen concentrations. The transmembrane pressure (TMP) across the flat-plate membranes was continuously monitored to detect any increase in pressure resulting from solids/biofilm buildup on the membrane surface. During the early weeks of the project with a young biomass and colder wastewater temperatures, the membranes were removed and cleaned several times; this was done as a precautionary measure as the younger biomass created a gelatinous mat on the membrane surface. There was a slight build up of a slime layer on the membranes, and this was easily hosed off. Throughout the remainder of the pilot project, no clean-in-place (CIP) cleaning using sodium hypochlorite and acid was required on the membranes. The TMP readings, while typically near zero, did show some increases not attributable to biomass fouling. A faulty TMP pressure gauge was suspected, and a new gauge was installed on March 19. After the new gauge was installed, TMP readings remained at zero except for two events immediately after installation of the new gauge.

PILOT DATA ACQUISITION – PROCESS CONTROL AND LABORATORY ANALYSES

An industry standard for enhanced wastewater treatment is microfiltration, which produces an effluent compliant with potable water clarity standards. Therefore, the effluent quality from both the conventional and alternative treatment streams had to be in accordance with New York State Department of Environmental Conservation (NYSDEC) intermittent stream limits, which are defined as those shown in table 2-1:

Table 2-1

NYSDEC Intermittent Stream Limits

Parameter	*Limit*
Biochemical Oxygen Demand (BOD_5)	5 mg/L
Total Suspended Solids (TSS)	10 mg/L
Ammonia (NH_3)	2.0 mg/L
Fecal Coliform	200/100 ml
Dissolved Oxygen (DO)	>7.0 mg/L
Phosphorous	0.2 mg/L
Turbidity	<0.5 NTU

Since phosphorus is a parameter identified by many as the controlling nutrient in water impoundments, and turbidity is used as a measurement of clear water and a surrogate for pathogen removal, these two parameters have been added. To ensure the alternative system was capable of producing the same effluent standards as the conventional system, daily process control testing and weekly laboratory analysis were conducted. Daily process control testing on grab samples was performed using equipment provided by Delaware Operations, Inc. at the Windham WWTP. Operational testing done at the Windham treatment facility on a daily basis consisted of the following:

Table 2-2

Alternative Treatment and Energy Management System

Process Control Testing

	Analysis											
Sample Location	***Temp***	***COD***	***NO3***	***Turbidity***	***NH3***	***pH***	***Alkalinity***	***TSS***	***DO***	***Settleable Solids***	***TP***	***Cl2 residual***
Influent	x	x	x	x	x	x		x		x	x	
Primary Clarifier	x	x	x	x	x	x		x			x	
Sand Filter	x	x	x	x	x	x	x	x			x	x
MBR Effluent	x	x	x	x	x	x	x	x		x	x	x
MBR Tankage	x	x	x		x	x	x	x	x			

Twenty-four hour composite samples were collected every Wednesday and Thursday during the four-month sampling and analysis phase of the demonstration. Phoenix Environmental Laboratories, Inc (New York State Department of Health Environmental Laboratory Approval Program #11301), located in Manchester, CT, transported the samples and performed the majority of off-site certified analysis on those collected from the conventional and alternative treatment systems. J. Myers Water Services, Inc. (New York State Department of Health Environmental Laboratory Approval Program #11907), located in Hunter, NY, analyzed the grab fecal coliform samples taken on Thursdays from the conventional and alternative treatment systems. Certified laboratory testing consisted of the following:

Table 2-3

Alternative Treatment and Energy Management System

Certified Laboratory Analysis

	Analysis									
Sample Location	***Alkalinity***	***BOD5***	***Soluble BOD5***	***NH3***	***Nitrate***	***TKN***	***TP***	***TSS***	***VSS***	***Fecal Coliform***
Influent	x	x	x	x	x	x	x	x		
Primary Clarifier	x	x	x	x	x	x	x	x		
Sand Filter	x	x	x	x	x	x	x	x		x
MBR Effluent	x	x	x	x	x	x	x	x		x
MBR Tankage	x				x			x	x	

Section 3

PILOT SYSTEM RESULTS

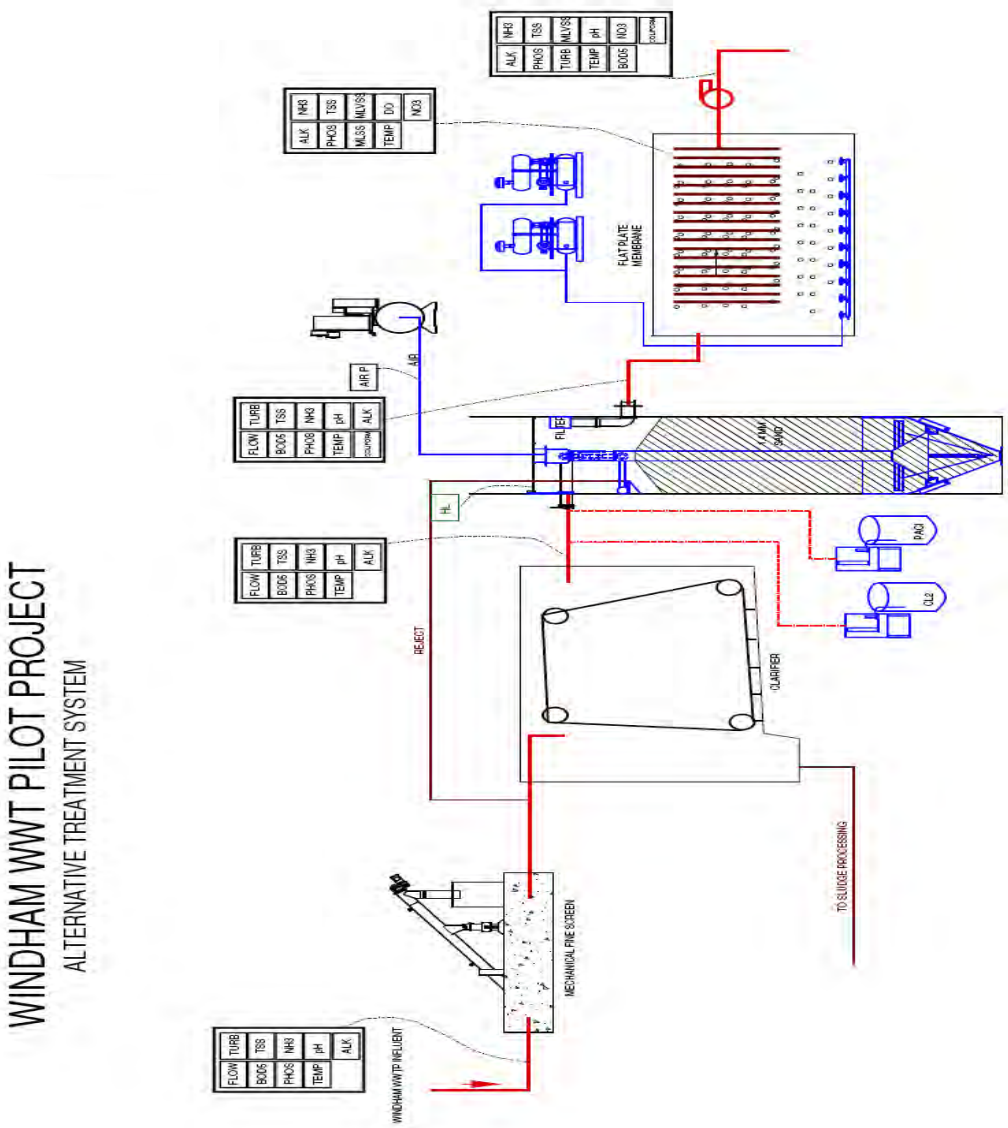
PILOT SYSTEM FLOW REGIME

As discussed in Section 2.2 the piloted system consisted of primary settling, chemically enhanced primary clarification in a CBUSF system, with secondary and tertiary treatment in an immersed flat-plate MBR system. That flow regime is shown in the following diagram. (Note: the Windham WWTP flow schematic is shown in Appendix A):

Figure 3-1

Alternative Treatment and Energy Management System

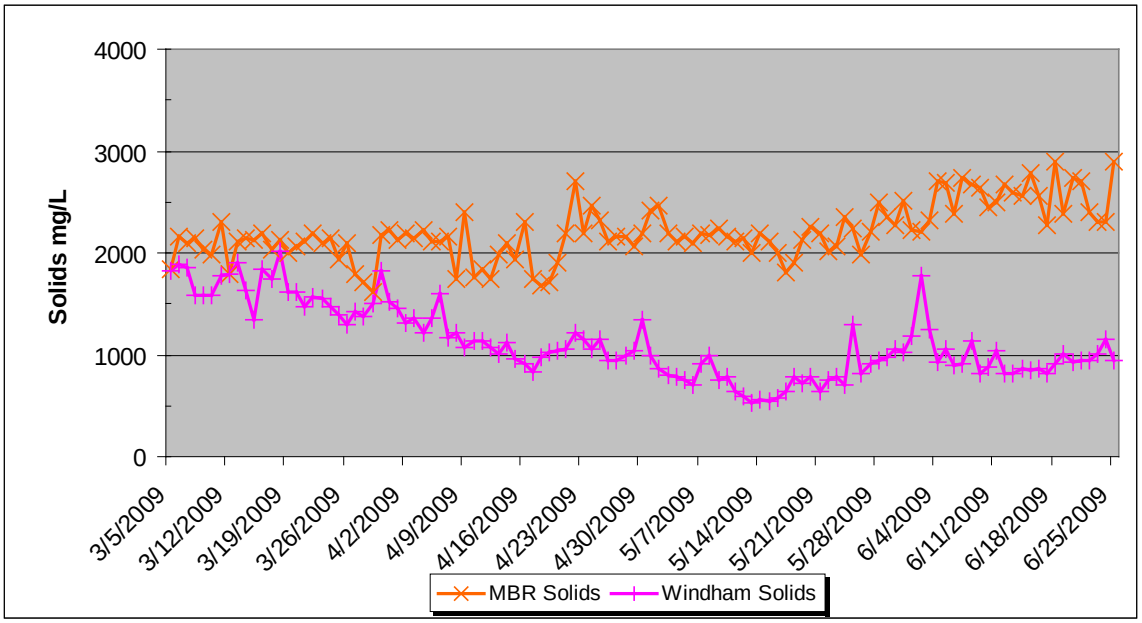
Flow Schematic



MEMBRANE BIOREACTOR BIOLOGICAL SOLIDS

Figure 3-2

Alternative Treatment and Energy Management System and Windham WWTP Biological Solids



Within the MBR tankage the alternative treatment system stabilized at and maintained a MLSS that ranged from 1,620 mg/L to 2,900 mg/L with an average of 2,200 mg/L, as shown in Figure 3-2. A slight increase in solids was witnessed after the addition of PACl for phosphorus sequestering. During the demonstration the Windham WWTP aeration basins had a MLSS that ranged from 530 mg/L to 2020 mg/L with an average of 1,100 mg/L, exhibiting a normal seasonal fluctuation in biological solids concentrations.

Pilot results, on average, showed an 81% reduction in BOD loading and an 88% reduction in TSS loading upstream of the membrane bioreactor as shown in Figures 3-3 and 3-5. In terms of ammonia concentration reduction, the pilot system nitrified successfully from inception. With such high quality effluent (i.e. low BOD, TSS and phosphorus) entering the MBR from the sand filter, the MBR was able to operate primarily as a nitrification system at an average MLSS of 2200 mg/L. Effluent ammonia concentrations were consistently below 0.3 mg/L from influent levels as high as 32.0 mg/L (Figure 3-7 and Figure 3-8).

The objectives for phosphorus removal in this demonstration were to first optimize biological removal to the lowest levels possible; once achieved, chemical sequestering of the residual orthophosphate was then accomplished through the addition of an aluminum-based chemical within the MBR tankage. PACl for phosphorus removal was introduced by hand to the MBR portion of the system on May 20 2009; as shown in Figure 3-10 effluent phosphorus dropped from 0.57 mg/L to <0.02 mg/L.

BIOCHEMICAL OXYGEN DEMAND (BOD_5)

Figure 3-3

Alternative Treatment and Energy Management System

Biochemical Oxygen Demand

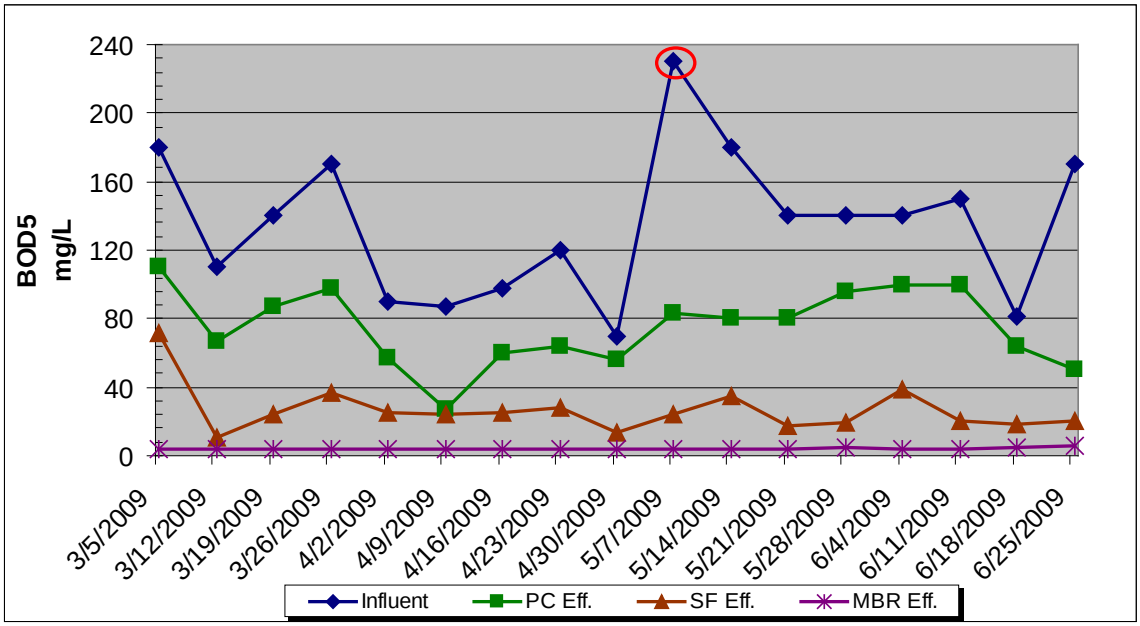
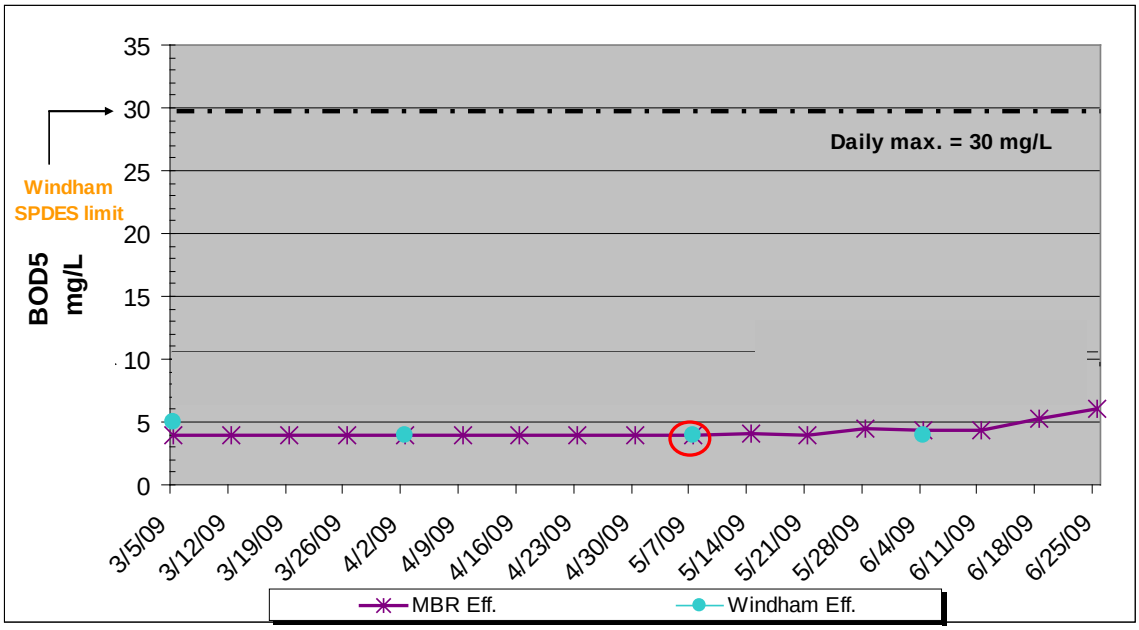


Figure 3-4

Alternative Treatment and Energy Management System and Windham WWTP

Effluent Biochemical Oxygen Demand



TOTAL SUSPENDED SOLIDS (TSS)

Figure 3-5

Alternative Treatment and Energy Management System

Total Suspended Solids

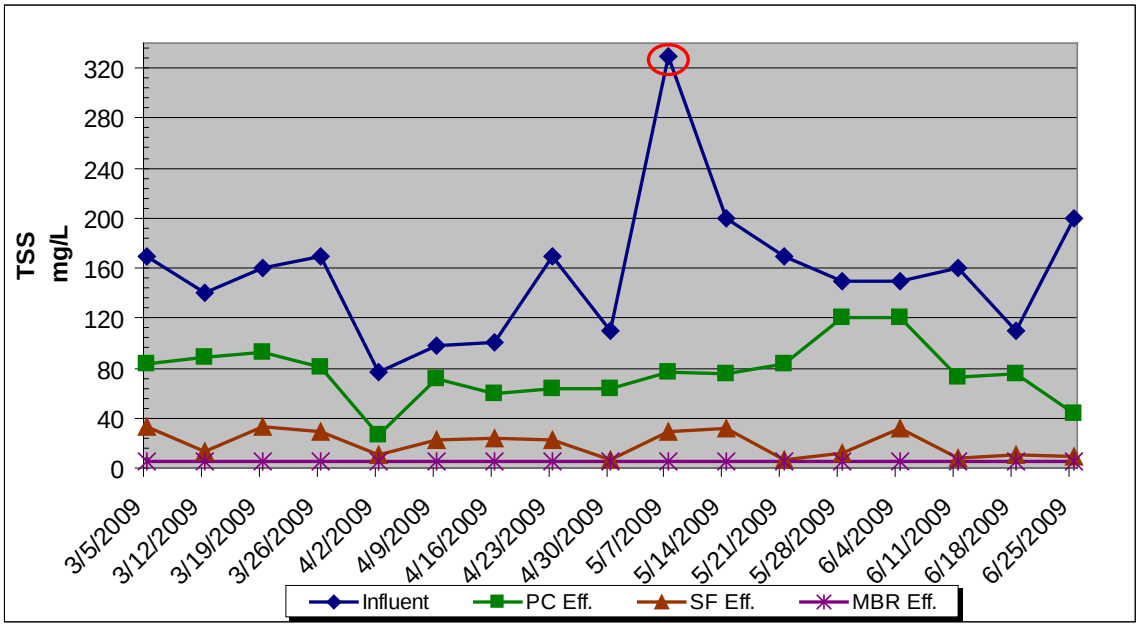
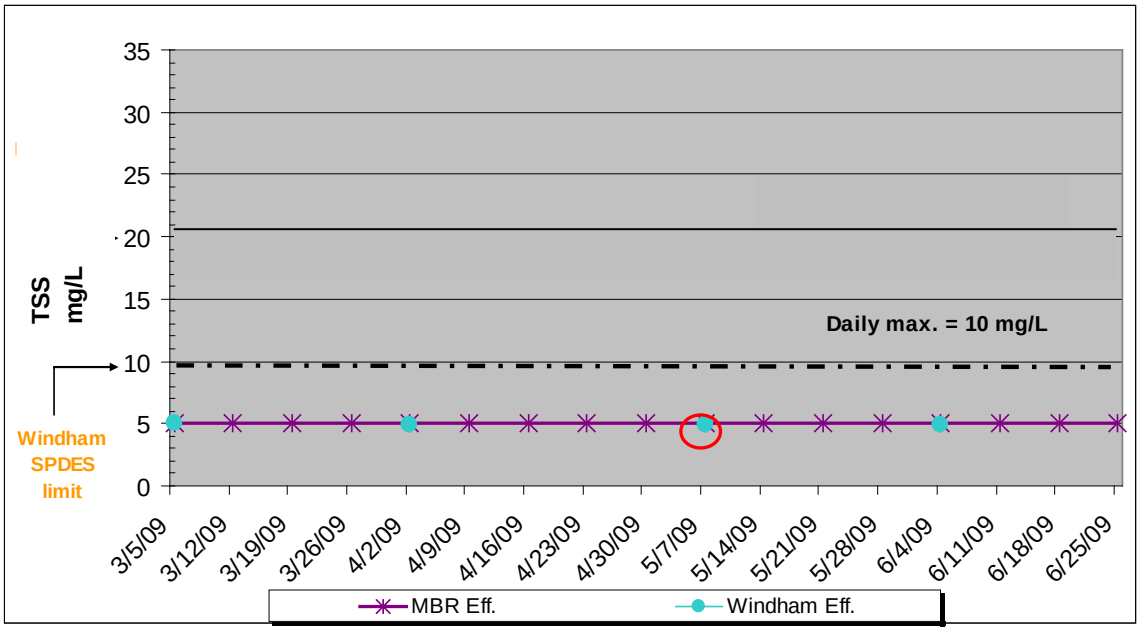


Figure 3-6

Alternative Treatment and Energy Management System and Windham WWTP

Effluent Total Suspended Solids



AMMONIA

Figure 3-7

Alternative Treatment and Energy Management System

Ammonia

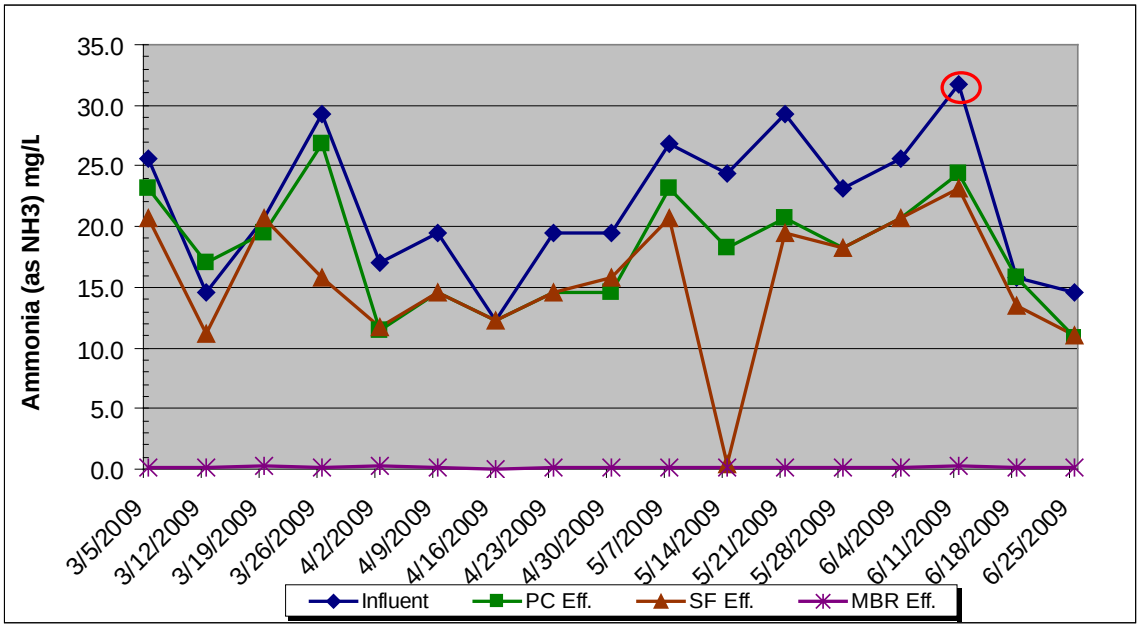
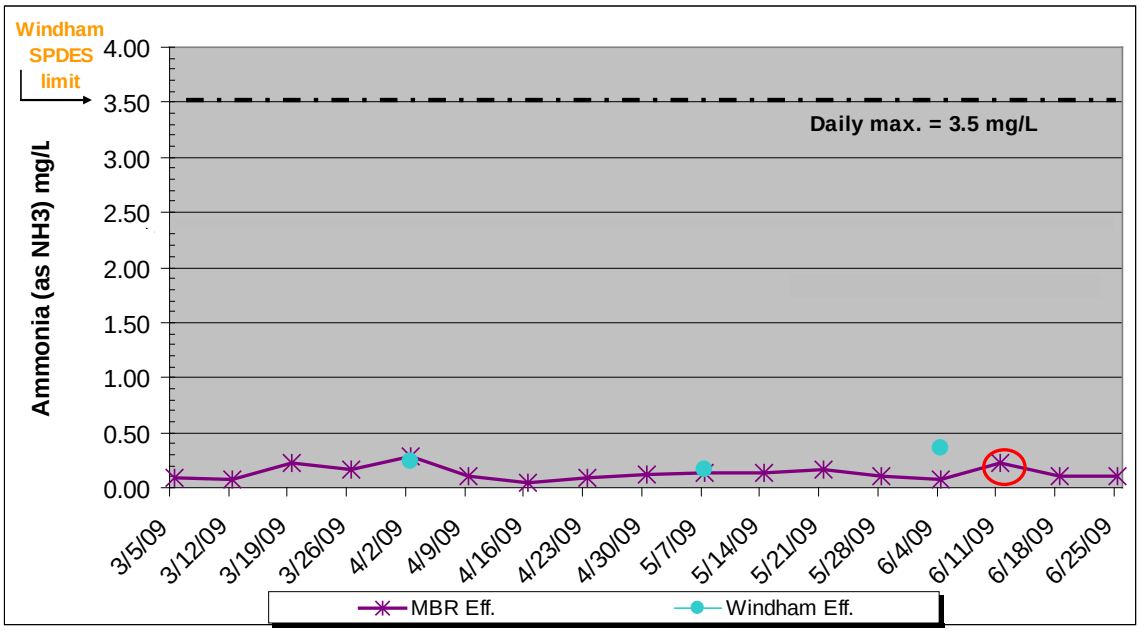


Figure 3-8

Alternative Treatment and Energy Management System and Windham WWTP

Effluent Ammonia



PHOSPHORUS

Figure 3-9

Alternative Treatment and Energy Management System

Total Phosphorus

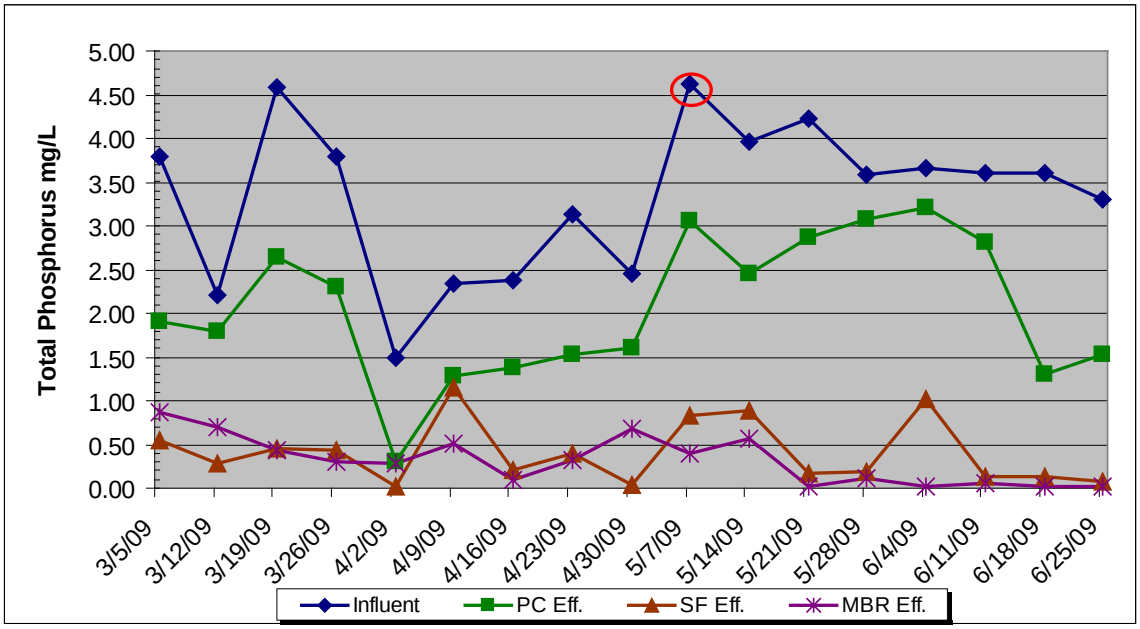
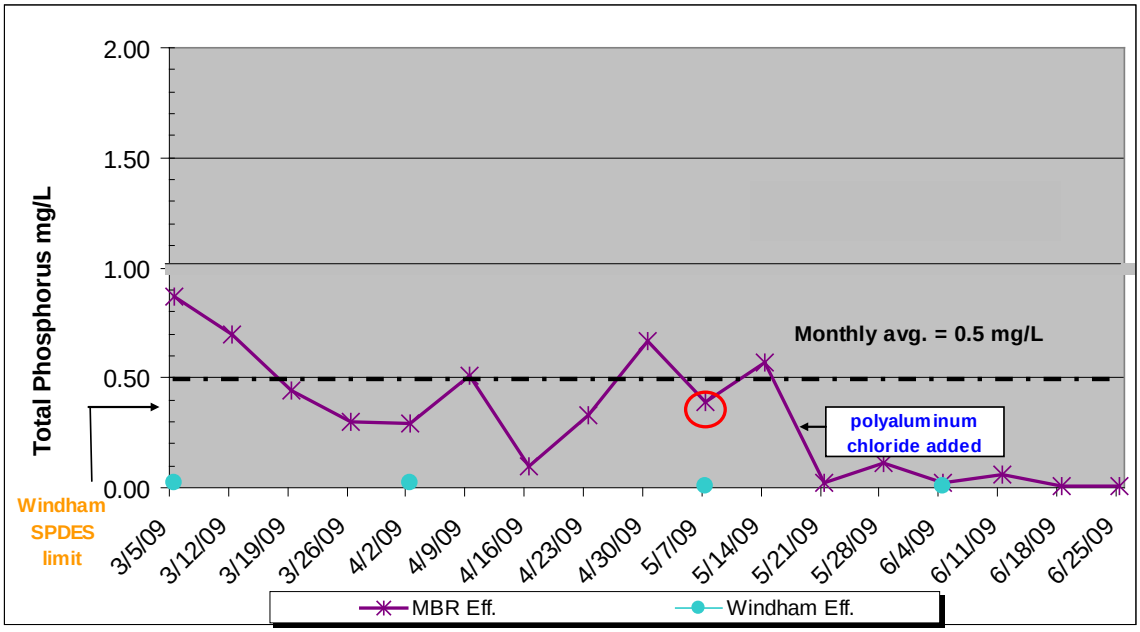


Figure 3-10

Alternative Treatment and Energy Management System and Windham WWTP

Effluent Total Phosphorus



FECAL COLIFORM

Figure 3-11

Alternative Treatment and Energy Management System and Windham WWTP Effluent Fecal Coliform

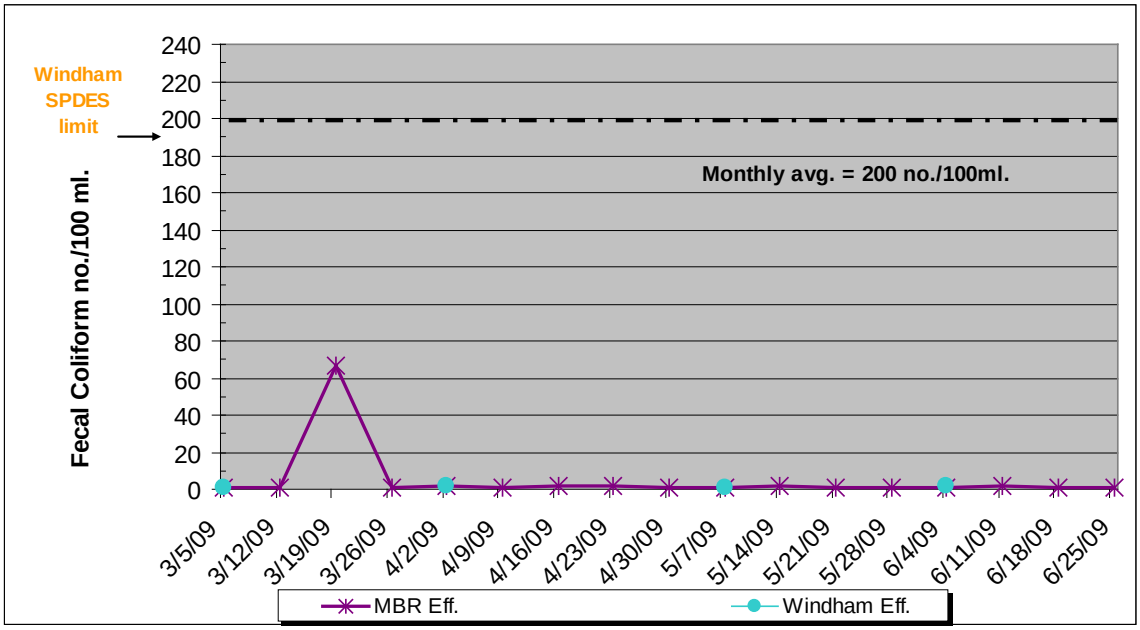
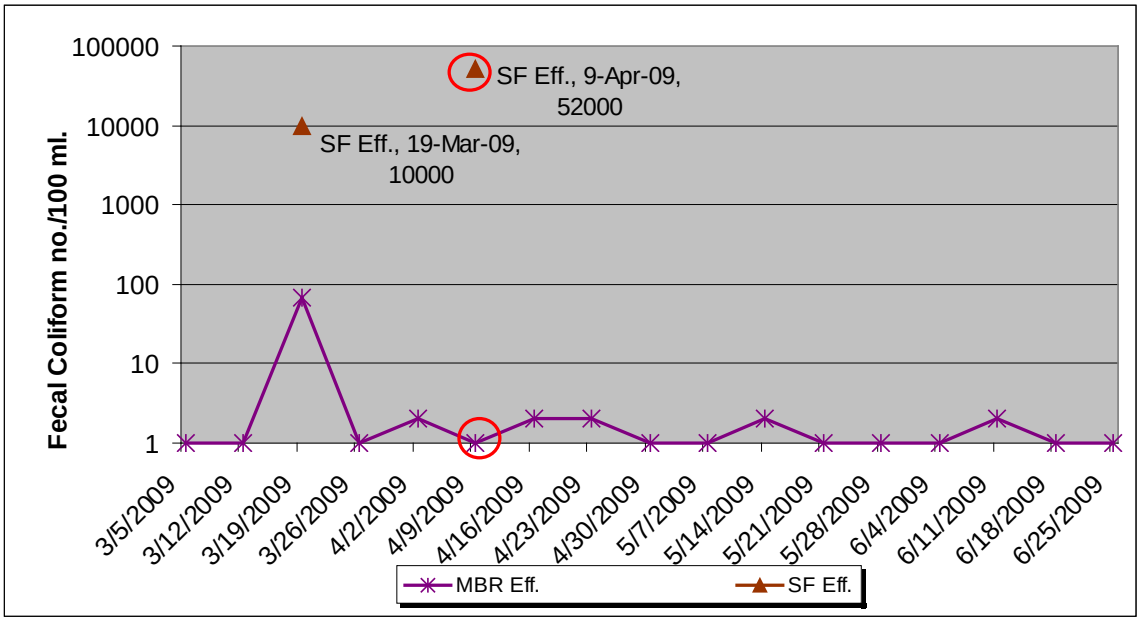


Figure 3-12

Alternative Treatment and Energy Management System Sand Filter and Effluent Fecal Coliform



ALKALINITY AND pH

Figure 3-13

Alternative Treatment and Energy Management System

Alkalinity

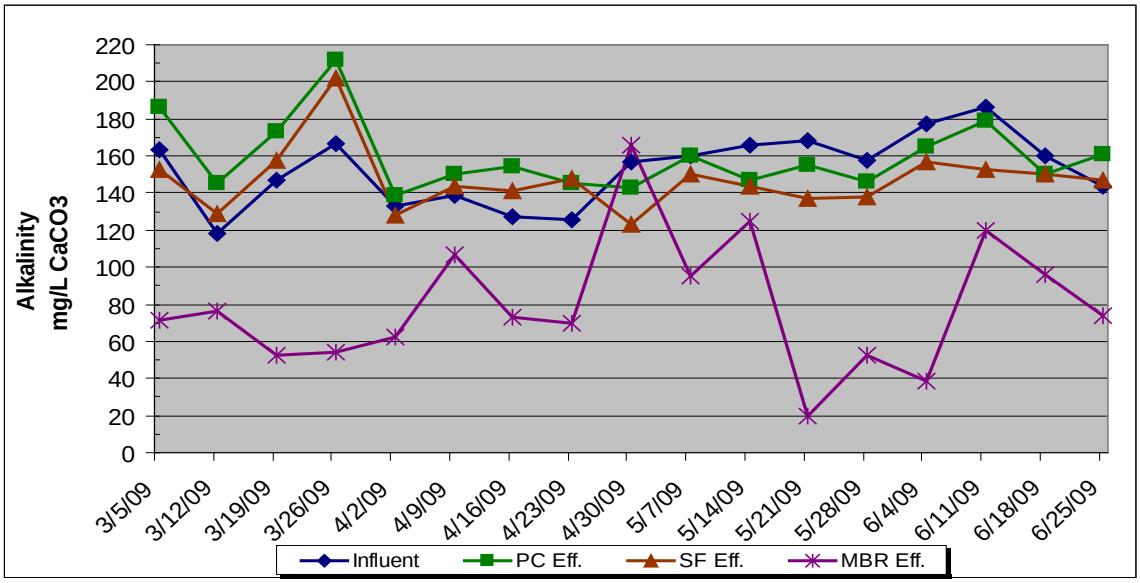
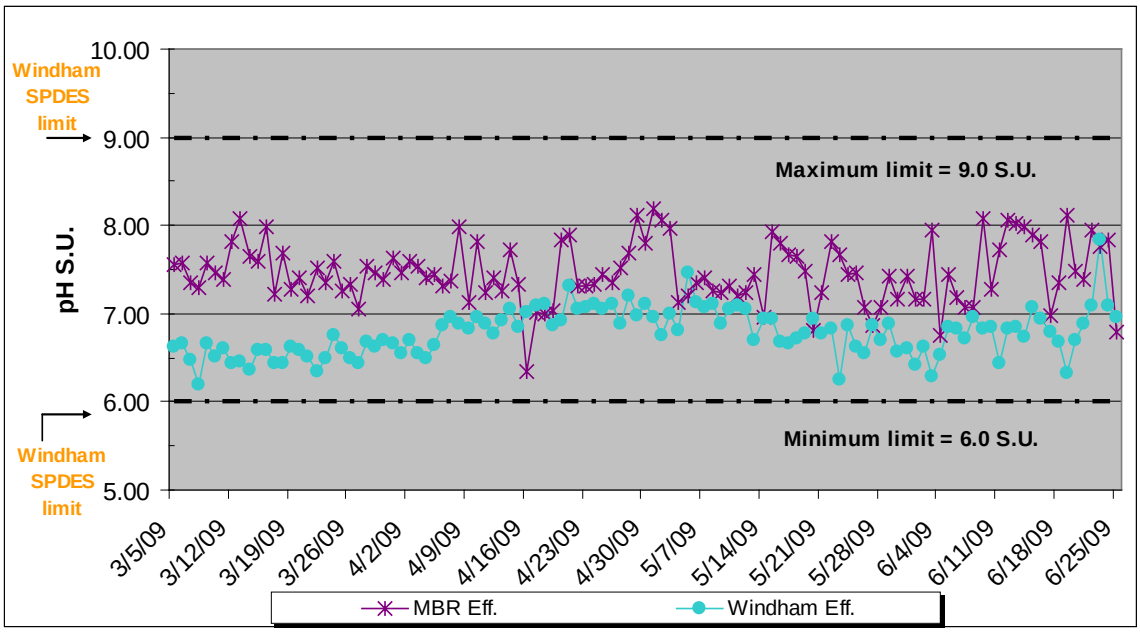


Figure 3-14

Alternative Treatment and Energy Management System and Windham WWTP

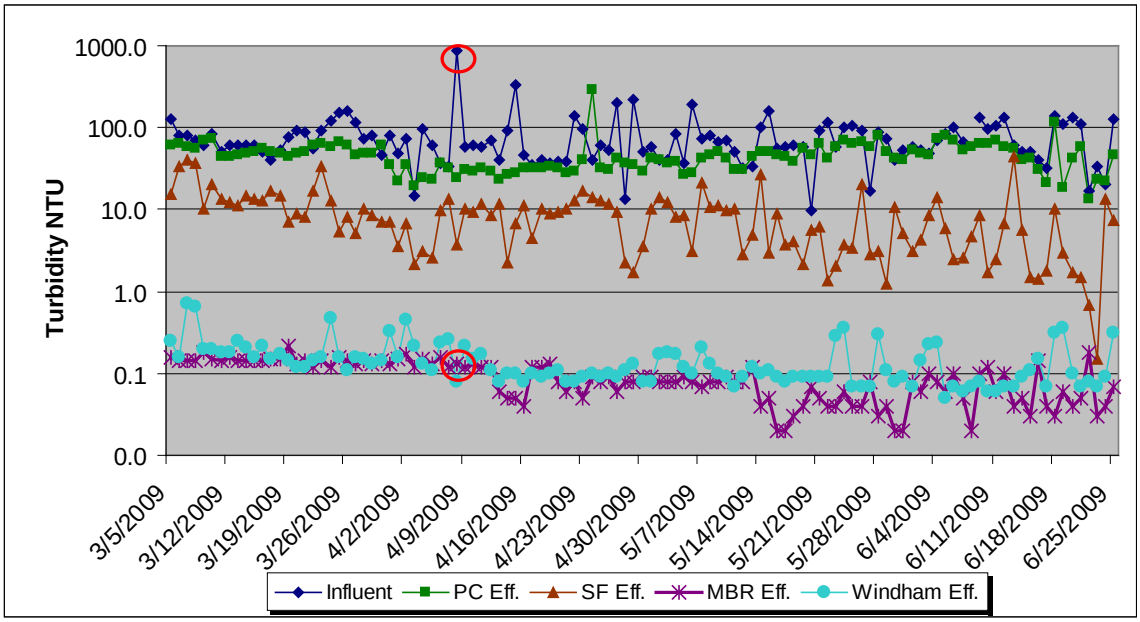
Effluent pH



TURBIDITY

Figure 3-15

Alternative Treatment and Energy Management System and Windham WWTP Turbidity



WASTE SOLIDS PRODUCTION

As previously discussed, the MBR was initially seeded with MLSS of 5570 mg/L in an effort to build up to the manufacturer's recommended design concentration of between 10,000 and 15,000 mg/L. Nevertheless, by the end of January the system had stabilized, and the MLSS was down to approximately 2200 mg/L, where it remained for the duration of the pilot. No solids were ever wasted from the MBR system during the four- month demonstration. The MLSS in the MBR tanks consisted almost exclusively of nitrifying bacteria that have a considerably slower growth rate than carbonaceous consuming bacteria. The only solids removed from the alternative treatment system during the pilot consisted of normal typical operational sludge from the primary clarifier, and in addition, minimal amounts from the sand filter.

ENERGY REQUIREMENTS

It was not workable to isolate the entire alternative treatment system from the Windham WWTP for energy monitoring since some of the treatment phases, including the compressor used for the sand filter, were shared by both. Still, it was feasible to monitor the amperage draw for most of the equipment pertaining to sand filter and MBR operation, and those averages can be found in Table 3-1.

Table 3-1

Alternative Treatment and Energy Management System Average Amperage Draw

Equipment	*Amps*
Sand Filter feed pump	8.5
MBR compressor	1.7
MBR permeate pump	5.7
MBR recycle pump	3.8
Sand Filter chlorine pump	0.3
Sand Filter coagulant pump	0.3

Approximately 23,000 gpd was fed to the sand filter, and a side stream of that was used to feed the MBR system, which had an average permeate flow of 35 gpd. Therefore, a total 20 amps (sand filter compressor excluded) were used to treat the flow for those two operational phases of the alternative system. More energy analysis details can be found in Section 5.4.

TREATMENT SYSTEM PERFORMANCE

Overall, the alternative treatment system performed extremely well and consistently produced effluent within and below the regulatory requirements. The pilot system's ease of operation and reduced on-site operational attention was noted by the operators as well. Through laboratory testing, it was determined that the alternative configuration is certainly capable of producing effluent quality comparable or better than a conventional activated sludge system with tertiary treatment, as is evident in Figures 3-2 through 3-15. The alternative system is also capable of generating effluent quality comparable to a conventional microfiltration facility with a flat plate MBR such as the Village of Dundee WWTP, Dundee, MI, whose performance criteria can be found in Appendix B.

One area of the system's performance that can be improved upon in full scale design is ability to denitrify when mandated by regulatory agencies to do so. The low transmembrane pressure readings, coupled with the low MLSS concentrations, indicated that the MBR biomass was predominantly a nitrifying/denitrifying biomass. Nevertheless, the inability of the pilot system to denitrify was the result of the physical configuration of the tankage, the oversized oxygen supply system, and the high recycle rate. The manufacturer's recommended recycle rate is six- times the finished water production rate or 6Q; this pilot ran at over 9Q. In the absence of a truly anoxic tank (i.e. dissolved oxygen <0.3 mg/L), the facultative aerobic denitrifying bacteria used oxygen as the terminal electron acceptor rather than the desired nitrate and/or nitrite compounds. This pilot-related design limitation is eliminated in full- scale design and operation with adequately sized anoxic tankage and properly sized recycle pumps to achieve a more acceptable recycle rate.

Section 4

FULL SCALE AND RETROFIT DESIGN CONSIDERATIONS

The wastewater treatment system piloted at the Windham WWTP has wide application for both new construction and as retrofit of existing treatment facilities. The proposed system's small footprint, coupled with its reduced energy consumption and excellent effluent quality, can benefit numerous watersheds. The lessons learned from this pilot project, which treated an average of 35 gpd, can be applied to full-scale/retrofit design issues. While exact linear relationships between the pilot work and full- scale operations are not feasible due to economy-of-scale realities, basic relationships are clearly and readily determined. This section discusses various design considerations in retrofitting an existing wastewater treatment facility and builds upon the experiences of MBR suppliers in other retrofit projects. When considering an alternative design, refer to the selection criteria in Appendix C for the evaluation of retrofit options. The Kubota MBR design staff report that fully 80% of their retrofit work was prompted by site limitations of existing facilities. Energy conservation, enhanced effluent quality, lowered O&M costs, and technical support are all considered in any retrofit project; these will be discussed in further detail in the Conclusions and Recommendations section of this report.

As demonstrated over the past 12 years in the New York City Watershed, pristine WWTP effluent has enormous benefits to residents and the environment. The trend toward higher wastewater effluent standards continues with the protection of critical watersheds as well as the increasing reuse of properly treated effluent. The March, 2008 NYSDEC's "Infrastructure Needs Report" focused on the anticipated wastewater treatment needs throughout New York State for the next 20 years; that need exceeds $36.2 billion. The Report notes that those WWTPs built during the 1980s Construction Grants program are clearly nearing or have passed their projected 20-year useful lives. The implications for this piloted innovative technology across the state are obvious. With energy conservation and reduction, reduced sludge generation, the tidy footprint, and the ability to reuse existing tankage and piping, in addition to the long-term lower operation and maintenance costs, this innovative technology could easily find application and help to meet and perhaps reduce that 20-year financial demand. In addition, with the inclusion of such simple, yet effective front-end processes (i.e. fine screen, primary clarification, chemically enhanced sand filtration), the system could be designed to accommodate a wastewater collection system wherein an infiltration and inflow (I&I) issue is problematic and unresolved. When retrofitting existing substandard wastewater treatment facilities, reusing existing tankage contributes to reducing greenhouse gas emissions. The Annual Review of Energy and the Environment states that the cement industry contributes 5% to global anthropogenic CO_2 emissions (Worrell et al., 2001). Thus, it is evident that the reuse of existing, sound concrete structures will benefit the overall CO_2 balance. The reuse of existing tankage also promotes the reuse of existing site piping, saving both materials and established surface finishes.

Another consideration of any retrofit project is the maintenance of existing treatment processes during construction. In most cases, the submerged membranes are lowered into existing aeration tanks, sequentially, so that at all times, treatment is provided to the incoming wastewater flow. With the consolidation of treatment processes within the MBR tankage, older treatment processes may be taken completely out of service (i.e. trickling filters), thus reducing building structures and their concomitant energy demands and stormwater mitigation requirements.

In the retrofit of underperforming WWTPs with the piloted technology, a hydraulic profile of the existing processes would be necessary to determine if and where supplemental pumping of wastewater is necessary. Typically, tertiary wastewater treatment is accomplished by the inclusion of filtration equipment at the end of the existing gravity treatment train, thus necessitating supplemental pumping of the entire flow. Chemically enhanced treatment is typically practiced, producing additional chemical sludge. With the piloted treatment process train, any supplemental pumping would occur early on in the treatment train and would likely be only low head pumping. Biological solids production is reduced, as more of the organic load is removed early on in the treatment train, thus saving in residuals disposal costs. Finally, with the MBR control system, operations staff can monitor systems operation easily in real time.

Section 5

CONCLUSIONS AND RECOMMENDATIONS

ENHANCED NUTRIENT REMOVAL

As is clearly shown in Section 3, the pilot wastewater treatment system produced excellent effluent quality, well in compliance with the strictest discharge standards. Biochemical oxygen demand (BOD_5) effluent values were typically at less than detectible concentrations of 5 mg/L from influent values as high as 180 mg/L. Total suspended solids (TSS) permeate values were likewise at less than detectible concentrations of 5 mg/L from influent values as high as 170 mg/L. Ammonia concentrations were well below 0.3 mg/L. Biologically, phosphorus was removed to approximately 0.3 to 0.5 mg/L, but with chemical sequestering in the MBR tanks, effluent phosphorus levels of less than 0.1 mg/L were readily achieved. Denitrification was not achieved during the pilot project due to the limitations of the system and the inability to maintain a completely anoxic condition (dissolved oxygen < 0.3 mg/L). The piloted system achieved consistently excellent effluent quality, well within even the most stringent effluent guidelines.

ENHANCED PATHOGEN REMOVAL

During the course of this pilot, the MBR permeate was sampled weekly for the presence of fecal coliform bacteria. For all sampling events, the MBR permeate fecal coliform bacteria levels were reported as less than one or two coliform per 100 milliliters of sample (no./100 ml), except for a reported value of 67 no./100 ml on March 19. The validity of this one test is in question, as the coliform test methodology uses a 0.45 micrometer (µm) membrane filter pad to capture fecal coliform. The flat plate MBR membrane has a nominal 0.4 µm pore size, with an effective pore size of 0.1 µm, which theoretically can easily reject fecal coliform bacteria.

Although not specifically tested during this pilot project, the flat plate MBR membranes with a nominal 0.4 µm pore size can reject the pathogenic protozoans *Cryptosporidium parvum* (4 to 7 µm size) and *Giardia lamblia* (7 to 15 µm size). A 2003 study of the ability of the Kubota flat plate MBR membranes to reject viruses (0.05 to 0.3 µm size) indicated a ≥1.1 log removal of injected MS-2 bacteriophage (Adham et al., 2003).

SLUDGE PRODUCTION

During this four-month pilot project, no biological solids were removed from the system. Optimization of the front end processes resulted in an average 81% reduction in BOD loading and an average 88% reduction in TSS loading prior to the MBR tankage. The solids removed in the front end processes consisted of preliminary screenings, primary sludge from the primary clarifier, in addition to the reject stream from the CBUSF unit. During the pilot project, preliminary screenings and primary solids were

handled by the Windham WWTP solids disposal system; the CBUSF reject stream was returned to the Windham WWTP headworks. The biological solids of the MBR system were retained within the pilot tankage for the duration of the project. MLSS concentrations ranged from 1,620 mg/L to 2,900 mg/L and averaged 2,200 mg/L during the four-month pilot project. Inasmuch as the MBR system was operating as a predominantly nitrification system, the cell mass production of the nitrifying bacteria was considerably less than that expected for carbonaceous consuming bacteria. The 2,200 mg/L average MLSS concentrations were maintained for an SRT of over 100 days.

If one looks strictly at the biological solids generation, it is evident that the piloted system drastically reduces the quantity of those solids, and concomitantly reduces the tankage, aeration, and pumping capacity, and the dewatering equipment required to handle and dispose of those generated solids. Primary sludge is generally fairly coarse and fibrous and has specific gravities greater than water; secondary biological solids, conversely, are generally more flocculant, less fibrous, and have specific gravities near that of water (Kerri et al., 1987). Therefore, a greater percentage of primary solids facilitates sludge dewatering, producing a drier cake with less dewatering chemicals. This pilot project documented the remarkable reduction in biological solids production, while still producing an excellent effluent quality.

ENERGY ANALYSIS

A primary goal of this project was to show that the innovative configuration resulted in reduced energy consumption compared to a conventional configuration; primarily by reducing the organic loading to the WWTP's highest energy-demanding process, the aeration system. By optimizing existing front-end processes and adding a coagulant-enhanced organics removal system (i.e. the CBUSF system), the organic load to the MBR system was greatly reduced, allowing for less aeration horsepower and thus lowering the energy consumed. During the pilot, however, even greater energy savings than anticipated were realized. Inasmuch as the MBR system was operating primarily as a nitrification system under a low MLSS loading (i.e. approximately 2200 mg/L), even lower than anticipated aeration was necessary to maintain an adequate dissolved oxygen (i.e. >3.0 mg/L dissolved oxygen), and much less sludge was produced. In fact, no biological solids were wasted from the MBR system during the entire project. The reduced MBR aeration capacity was still sufficient to maintain the requisite air scour across the submerged membranes.

In the following table, energy consumption for a conventional tertiary WWTP, the existing Windham WWTP, and a scaled- up piloted WWTP system are shown. Design flow is for a 0.30 mgd facility. (Note: the Windham WWTP has a permitted limit of 0.445 mgd, but is typically operated below that threshold.) As can be seen from the table, there is a 48% anticipated horsepower savings of the piloted system compared to the existing Windham WWTP; and a 40% savings is anticipated compared to a conventional tertiary WWTP. In this analysis, the Windham WWTP has a 15% higher running horsepower demand than a conventional tertiary WWTP; this is due to larger primary sludge feed pumps, larger compressors to handle the CBUDSF system, and a site lift station.

Table 5-1

Energy Comparisons

	Conventional Tertiary WWTP (0.3 MGD)				*Windham Wastewater Treatment Plant (permit limit = 0.445 MGD, typically less)*				*Scaled-up Alternative Treatment and Energy Management System (0.3 MGD)*			
	Qty.	*HP*	*Connected*	*Running*	*Qty.*	*HP*	*Connected*	*Running*	*Qty.*	*HP*	*Connected*	*Running*
Equalization Blowers	2	10	20	10	2	10	20	10	2	10	20	10
Equalization Pumps	3	10	30	10	3	10	30	10	3	10	30	10
Screen	2	2	4	2	2	5	10	5	1	2	2	2
Primary Drives	2	0.75	1.5	0.75	2	0.75	1.5	0.75	2	0.75	1.5	0.75
Primary Sludge Pumps	2	3	6	3	2	10	20	10	2	3	6	3
Filter Feed Pumps	2	5	10	5	-	-	-	-	2	2	4	2
Chemical Feed Pumps	3	0.25	0.75	0.5	3	0.25	0.75	0.5	3	0.25	0.75	0.5
Compressor	1	10	10	10	1	30	30	20	1	10	10	10
Aeration Blowers	2	40	80	50	3	40	120	50	-	-	-	-
MBR Blowers	-	-	-	-	-	-	-	-	3	15	45	15
Anoxic Mixer	-	-	-	-	-	-	-	-	1	1	1	1
RAS/WAS Pump	3	3	9	6	3	3	9	3	2	2	4	2
Secondary Clarifier Drives	2	0.75	1.5	0.75	2	0.75	1.5	0.75	-	-	-	-
Permeate Pumps	-	-	-	-	-	-	-	-	3	3	9	3
Site Lift	-	-	-	-	2	3	6	3	-	-	-	-
Total HP-HR			172.75	98.00			248.75	113.00			133.25	59.25
Total KWHR			128.87	73.11			185.57	84.30			99.40	44.20

For this project, by off loading fully 80% of the CBOD from the aeration reactor, electrical savings are evident in operational horsepower and connected horsepower. This reduced connected load also helps to reduce the WWTP's monthly electrical demand charge, another cost savings. As for the solar component piloted during the project, it was shown that multiple solar arrays would be required to capture the requisite solar energy necessary to supplement the WWTP. For a proposed 25 kilowatt (kW) solar array at the municipal WWTP, typically 125- 200-watt panels would be required. These panels could be roof or ground mounted at an angle approximately equivalent to the latitude of the host facility (i.e. the Windham WWTP is at latitude 42º North; the panel angle for maximum solar collection would likewise be 42º). The

125 panels would require a surface mounting area of between 2,000 and 2,200 square feet. The proposed 25kW solar array would offer the following annual offsets: 50,148 lbs carbon dioxide, 2,527 gallons of gasoline, and the equivalent of three acres of trees planted.

Figure 5-1

Alternative Treatment and Energy Management System

Solar Generator

ECONOMIC CONSIDERATIONS (CAPITAL AND O&M)

For the construction of new and the retrofit of existing wastewater treatment facilities, a variety of economic factors must be considered. While capital costs are readily apparent during the construction phase, the long-term operation and maintenance costs are chronically a source of expenditure not easily remedied once the construction phase is completed. By focusing on lowering the annual expenditure of operating an effluent-enhanced WWTP, this pilot project clarified the various treatment options paramount to a sustainable and viable wastewater treatment methodology. Simply, by combining the traditional activated sludge treatment train (i.e. aeration, clarification and filtration), the MBR system reduces the overall treatment system footprint and construction cost. In retrofit projects, the reuse of existing tankage and piping for the MBR equipment likewise reduces construction cost. Optimization of front-end processes, where available in retrofit applications, greatly reduces the long term O&M costs due to reduced electrical demands and costs associated with sludge disposal. For new construction, the inclusion of such front-end processes as primary clarification and CBUSF treatment may add to the overall construction load, but affords the WWTP owner system operational flexibility, excellent effluent quality, and lowered long - term O&M costs (i.e. electrical, personnel, chemical and residuals disposal costs).

While difficult to compare equally, recent United States Kubota MBR construction cost data for WWTPs from 0.20 mgd to 6.00 mgd, the capital cost per gallon ranged from $3.00 to $18.29, with an average cost of $8.04 (Enviroquip, 2009). For a 0.30 mgd facility, the construction cost was $7.8/gallon. Operational

costs can likewise vary greatly, depending upon the size of the WWTP, the staffing, regional electrical rate structure, the hydraulics of the collection system, chemical costs, and residuals disposal options. For most WWTPs the most costly items of its annual O&M budget are personnel costs, electrical costs, and sludge management costs. With the proposed treatment technology, it was previously shown how electrical costs can be reduced. As for the personnel costs, reductions can be anticipated based upon the change in treatment technology and the reduced oversight of the biological process. In a conventional activated sludge WWTP, much operator attention is directed to maintenance of the proper food to microorganism (F/M) ratio of the biology, maintenance of proper hydraulic flow characteristics within the treatment vessels, and maintenance of proper settling characteristics of the biomass. With this proposed system, much of the organic and particulate load is removed in the preliminary and primary treatment trains, which can be minimally chemically enhanced. As stated previously, primary sludge is more fibrous and dense, and thus is easier to settle and dewater than secondary biological solids (Kerri et al., 1987). This chemical removal process therefore requires less operator attention. As for the MBR treatment train, the system is controlled via an integrated Supervisory Control and Data Acquisition (SCADA) system, easily monitored, which provides real time operating data. Fewer operators are necessary for the proposed system, and those operators have the advantage of greater real-time response from the operating system. It would be unfair to claim that the proposed treatment system could be completely monitored remotely, since other routine WWTP maintenance and housekeeping duties require the trained eyes of attentive operators. Also, the NYSDEC sets minimum staffing requirements for all WWTPs.

As for chemical costs and sludge removal costs, reductions are also anticipated. Chemical addition points for the proposed treatment process include just two locations. The first is at the CBUSF, with the injection of less than 1.0 mg/L of sodium hypochlorite for the prevention of sand biofouling and oxidation of organic matter. Also at the CBUSF system, approximately 40 mg/L of polyaluminum chloride (PACl) was injected for coagulation of particulate and oxidized organic matter. It must be noted that the injection of PACl far exceeded the requisite concentration due to the sizing of the chemical feed system and the fact that the PACl had to be fed neat. In full scale operation, a dosage rate much lower than that reported in pilot operation is observed. The second chemical injection location is into the MBR tankage for chemically enhanced phosphorus removal. This injection was performed manually due to the limitations of the chemical feed system and the minute amount of PACl required to sequester the 0.4 mg/L phosphorus in the MBR tankage. With the minimal chemical usage within the various treatment trains comes a reduced sludge generation. Solids captured in the preliminary and primary treatment trains account for 81% of BOD_5 and 88% of the TSS, which leaves a greatly reduced organic component for biological degradation within the MBR system. And as shown in this pilot project, the MBR system was operating as primarily a nitrification system. According to Metcalf & Eddy, the solids generation from a nitrifying biomass is approximately 1/3 that of a biomass from a carbonaceous consuming biomass. The end result is less biological solids production and lower sludge handling and disposal costs (Metcalf and Eddy, Inc., 2003).

TECHNOLOGY MARKET ANALYSIS

Membrane bioreactor technology has made significant strides within the last decade. As more watersheds are establishing stricter wastewater effluent standards, and as water reuse is gaining in necessity and popularity, the drive for enhanced treatment is accelerating. With the 1980s Construction Grants Program WWTPs nearing or exceeding their planned useful lives, retrofits at WWTPs will continue to test the host communities and their planning and engineering consultants. This pilot project identified a viable wastewater treatment system that is both capital cost effective and operationally cost efficient. The following matrix looks at how the pilot system compares to other treatment systems:

Table 5-2

Technology Evaluation Matrix

Evaluation Criteria	***Conventional Activated Sludge Process with Sand Filtration***	***Conventional MBR System***	***Alternative Treatment and Energy Management System***
Process flexibility	- MLSS range of 1500 mg/L to 3000 mg/L	- MLSS from 8000 mg/l to 18000 mg/l	- MLSS range from 1500 mg/L to 3000 mg/L
Ability to process fluctuations	- Susceptible to loading/flow upsets	- Performs well in range of loading or flow situations	- Performs well in range of loading or flow situations
Ease of operation	- Process must be monitored closely	- Less process adjustments need to be made	- Operator friendly, less monitoring
Degree of control sophistication	- Requires operator intervention to perform tasks	- Optional complete automation	- Optional complete automation
Operator time	- More operator hours required	- Less operator hours required	- Less operator hours required
Chemical use	- Chemical used for clarification, filtration, nutrient removal, sludge processing, pH adjustment, disinfection	- Chemical used for nutrient removal membrane cleaning, pH adjustment, sludge processing	- Chemical used for filtration, nutrient removal, membrane cleaning, pH adjustment
Long- term repair and reserve	- More equipment with moving parts, requires more maintenance and available parts	- Less equipment and a reduced amount of spare parts on site	- A moderate amount of equipment with moving parts and necessary spare parts
Sludge processing and cost reduction	- If digested a small reduction in processing is possible	- A greater reduction in sludge processing is realized	- Minimal sludge processing is required
Future ability for energy conservation	- A large amount of energy required to operate the facility	- A large amount of energy required to operate the facility	- Half as much energy required for facility operation with an option to supplement with alternative power sources

RECOMMENDATIONS

The stated goals of this pilot project were successfully met, namely that an excellent wastewater effluent can be achieved in an economically and environmentally sustainable manner. The surprising result of this pilot was that once the majority of the particulate and carbonaceous compounds were removed in the optimized upstream treatment processes, the MBR system operated as a predominantly nitrification system under a non-typical MBR low-MLSS concentration scenario. The piloted system produced minimal biological solids under a lowered aeration regime. Savings in electrical, chemical, and residuals disposal costs are achieved in the piloted system.

It is recommended that the piloted system be used in the retrofit of an underperforming WWTP in a critical watershed. The retrofit would comply neatly with the guidelines of New York State's Green Innovation Grant Program: the protection of public health and safety; the protection of environmental resources and water quality; green energy production and the reduction in energy consumption; project sustainability with reference to its capacity for continued financial stability, environmental benefits and the efficient operation and maintenance of the project through appropriate management; and the transferability of new technology. This piloted technology uses proven treatment methodologies in a new and innovative approach to increasingly stringent wastewater effluent standards, economically, and in an environmentally sustainable manner.

REFERENCES

Adham, S., J. DeCarolis and M. Harza (2003) "Final Report-Assessing the Ability of the Kubota Membrane Bioreactor to Meet Existing Water Reuse Criteria," personal correspondence.

Enviroquip (2009) "Innovations thru Experience MBR and PAD-K Systems" seminar, Kingston, NY.

Kerri, K., B. Dendy, J. Brady and W. Crooks (1987) *Advanced Waste Treatment: a Field Study Training Program for the USEPA*, California State University Sacramento Foundation, Sacramento.

Metcalf & Eddy, Inc. (2003) *Wastewater Engineering: Treatment and Reuse*, 4th ed., McGraw-Hill, New York.

New York State Department of Environmental Conservation (NYSDEC) (2008) "Wastewater Infrastructure Needs of New York State," http://www.dec.ny.gov/docs/water_pdf/infrastructurerpt.pdf .

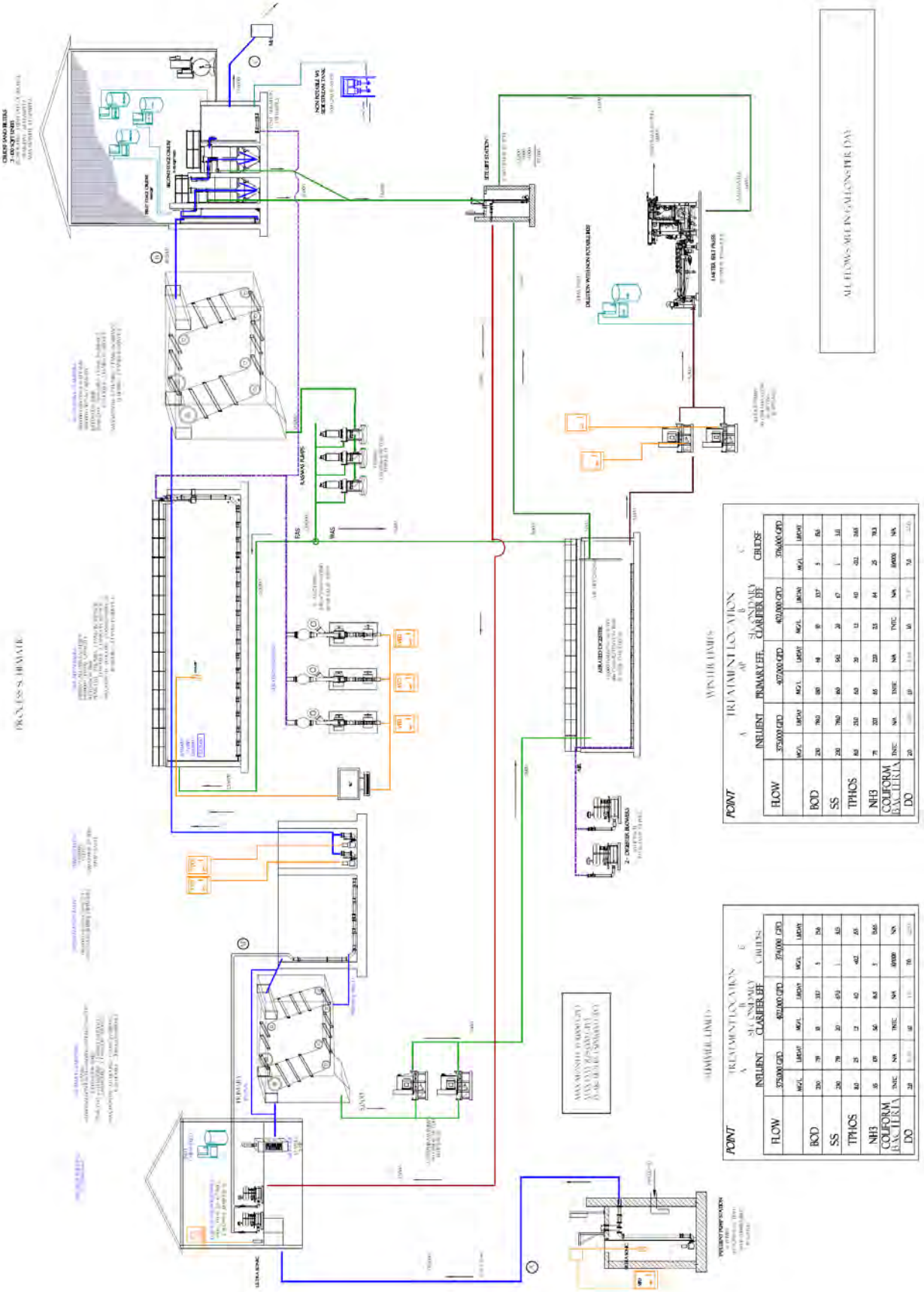
New York State Environmental Facilities Corporation (NYSEFC) (1997) "New York City Watershed Memorandum of Agreement," http://www.nysefc.org/home/index.asp?page=314.

Water Environment Federation (WEF) Press (2006) *Membrane Systems for Wastewater Treatment*, McGraw-Hill, New York.

Worrell, E., L. Price, N. Martin, C. Hendriks and L. Meida (2001) "Carbon Dioxide Emissions from the Global Cement Industry," *Annual Review of Energy and the Environment*, 26: 303-329, http://arjournals.annualreviews.org/doi/abs/10.1146%2Fannurev.energy.26.1.303.

APPENDICIES

Town of Windham Wastewater Treatment Plant



References – U.S. Operational Plants > 0.5 MGD

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  Toledo, OH 43603
  Phone: (419) 473-1121
  ARCADIS FPS

- **Project Information:**

Start-up Date:	July 2005
Design Capacity:	2.0 MGD (1.67 MGD Installed)
Membrane Type:	EK-400
Mode of Operation:	Suction
Peak Hydraulic Rated Capacity:	4.0 MGD (3.37 MGD Installed)
Maximum Month Rated Capacity:	2.0 MGD (1.67 MGD Installed)
Average Annual Rated Capacity:	1.5 MGD
Actual Annual Average Flowrate:	0.5 MGD
Actual Maximum Month Rated Flowrate:	0.7 MGD
Actual Peak Day Permeate Flowrate:	0.8 MGD
Biological Nitrogen Removal:	Yes

Performance Criteria

	Influent	Effluent
BOD	150 mg/l	<10 mg/l
TSS	150 mg/l	<25 mg/l
NH_3	--	<1 mg/l
TIN	15 mg/l	--
TP	3 mg/l	<0.1 mg/l

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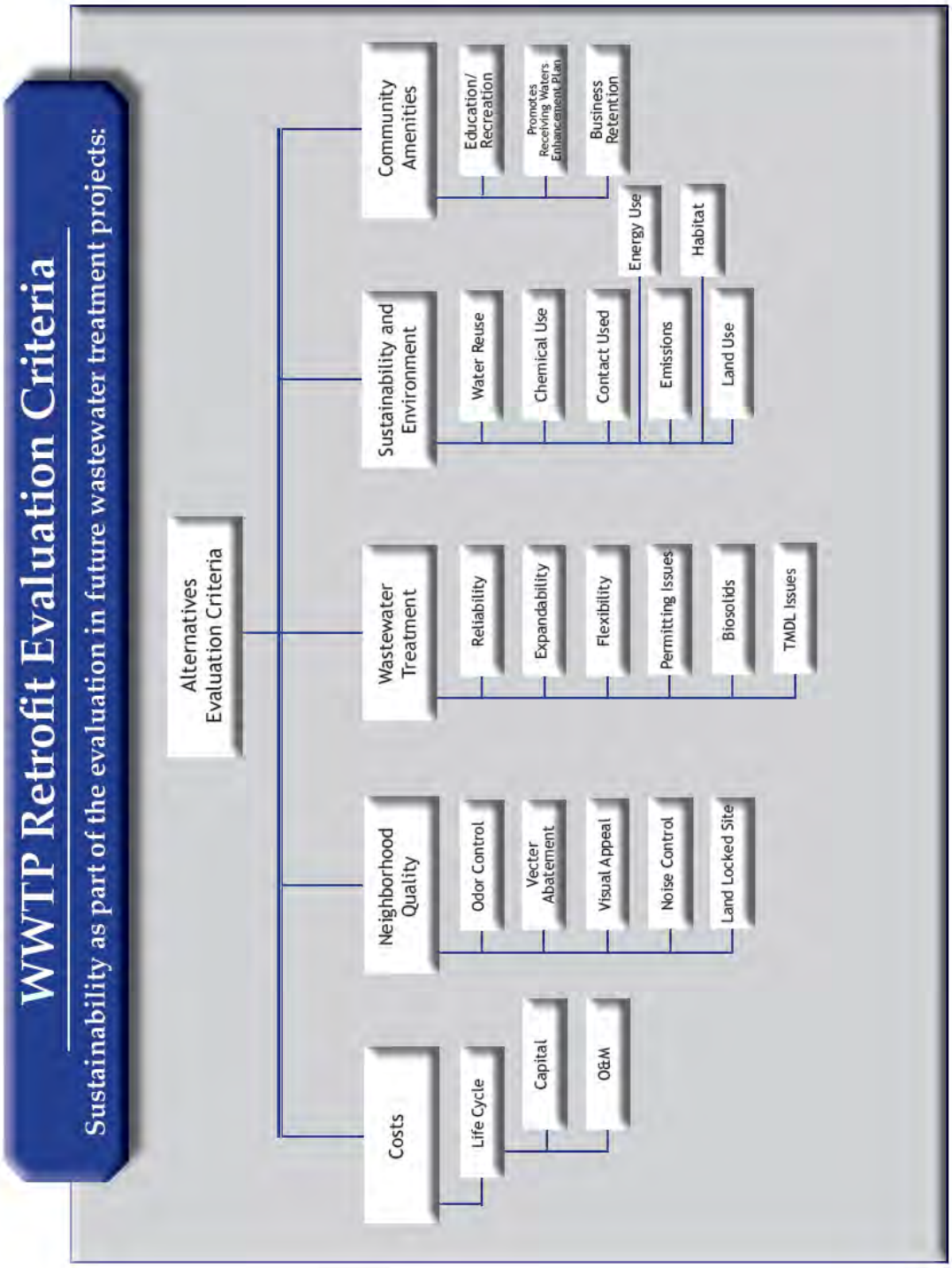
WWTP Retrofit Evaluation Criteria
Sustainability as part of the evaluation in future wastewater treatment projects:
Alternatives Evaluation Criteria
Costs
Life Cycle
Capital
O&M
Neighborhood Quality
Odor Control
Vecter Abatement
Visual Appeal
Noise Control
Land Locked Site
Wastewater Treatment
Reliability
Expandability
Flexibility
Permitting Issues
Biosolids
TMDL Issues
Sustainability and Environment
Water Reuse
Chemical Use
Contact Used
Energy Use
Emissions
Habitat
Land Use
Community Amenities
Education/ Recreation
Promotes Receiving Waters Enhancement Plan
Business Retention

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