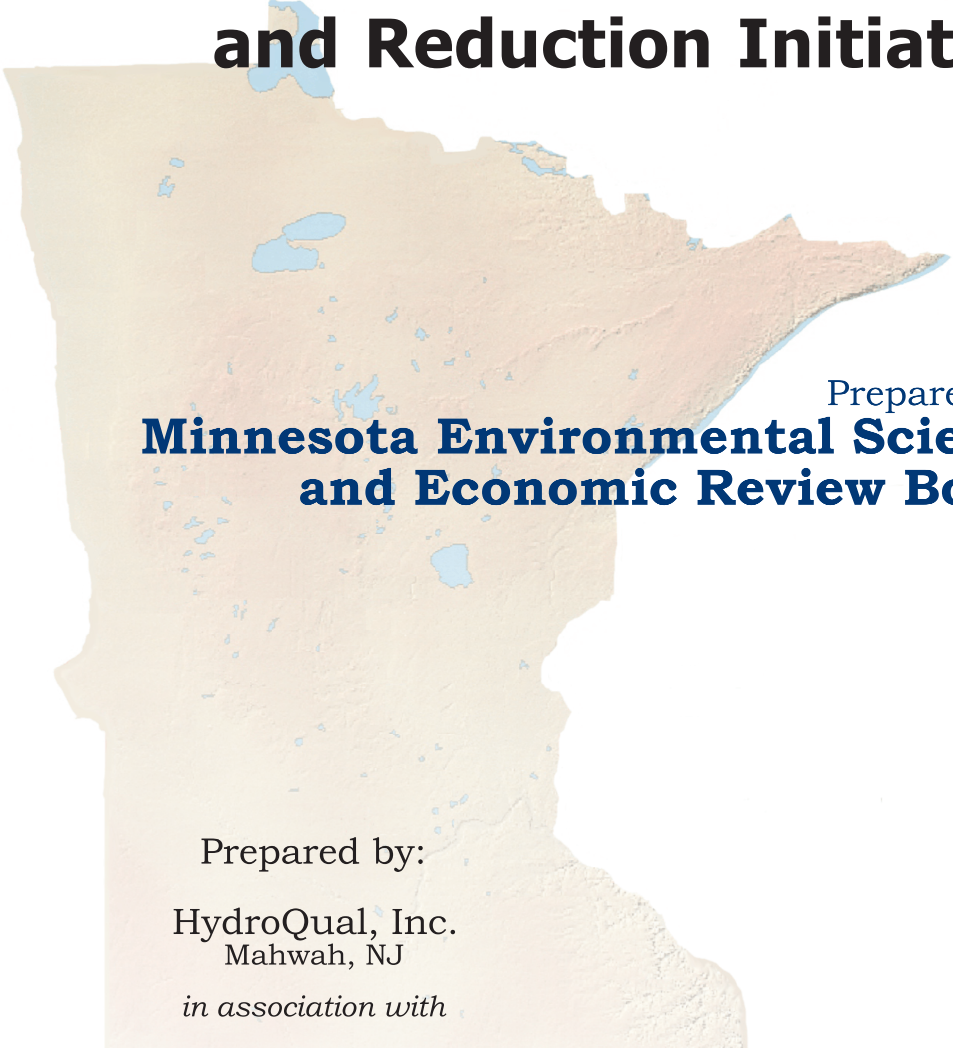
Wastewater Phosphorus Control and Reduction Initiative



Prepared for:

Minnesota Environmental Science and Economic Review Board

Prepared by:

HydroQual, Inc.
Mahwah, NJ

in association with

H. David Stensel, Ph.D., P.E.
University of Washington
Seattle, WA

April 2005
Project No. MESE0001

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Funding for this project was recommended by the Legislative Commission on Minnesota Resources from the Minnesota Environment and Natural Resources Trust Fund

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Nomenclature

A/O	Anaerobic/Aerobic Process for Enhanced Biological Phosphorus Removal (EBPR)
A^2O	Anaerobic/Anoxic/Aerobic Process for Enhanced Biological Phosphorus Removal (EBPR)
Al	Aluminum
$Al_2(SO_4)_3 \cdot 18H_2O$	Alum – Water portion can range between 14 and 18 H_2O
AMSA	Association of Metropolitan Sewerage Agencies
ATP	Adenosine Triphosphate
ATSD	Autothermophylic Sludge Digestion Process
BNR	Biological Nutrient Removal
BOD	Biochemical Oxygen Demand
$Ca(OH)_2$	Lime
$Ca_{10}(PO_4)_6(OH)_2$	Calcium Apatite
$CaCO_3$	Calcium Carbonate
$CBOD_5$	Carbonaceous 5-day Biological Oxygen Demand
Chem	Chemical
COD	Chemical Oxygen Demand
DAF	Dissolved Air Flotation
dia	Diameter
DNA	Deoxyribose Nucleic Acid
DO	Dissolved Oxygen
EBPR	Enhanced Biological Phosphorus Removal
F/M	Food to Microorganism Ratio
Fe	Iron
$Fe_2(SO_4)_3$	Ferric Sulfate
$FeCl_2$	Ferrous Chloride
$FeCl_3$	Ferric Chloride
$FeSO_4$	Ferrous Sulfate
ft^3	Cubic Feet
gpd/ft^2	Gallons per day per square foot
gpd/sf, gpd/ft^2	Gallons per day per square foot
HPO	High Purity Oxygen
HRT	Hydraulic Residence Time
JHB	Johannesburg Process for Enhanced Biological Phosphorus Removal (EBPR)
kg	Kilogram
kg P/capita/yr	Kilograms of Phosphorus per capita per year
lb	Pound
lb/d	Pounds per day
lb/d-1000 ft^3	Pounds per day per 1,000 cubic feet
LCMR	Legislative Commission on Minnesota Resources
MESERB	Minnesota Environmental Science and Economic Review Board
MG	Million Gallons
mg/L	Milligram per liter
MGD	Million Gallons per Day
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids

MPCA	Minnesota Pollution Control Agency
MUCT	Modified University of Capetown Process for Enhanced Biological Phosphorus Removal (EBPR)
$NaAlO_2$	Sodium Aluminate
NH_4-N	Ammonia-Nitrogen
NO_2-N	Nitrite-Nitrogen
NO_3-N	Nitrate-Nitrogen
NPDES	National Pollutant Discharge Elimination System
O&M	Operation and Maintenance
P	Phosphorus
PAO	Phosphorus Accumulating Organism
PCF	Pollution Control Facility
PHB	Polyhydroxybutyrate
PMP	Phosphorus Management Plan
PO_4	Orthophosphate (inorganic phosphorus)
POTW	Publicly Owned Treatment Works
RAS	Return Activated Sludge
RBC	Rotating Biological Contactor
rbCOD	Readily Biodegradable Chemical Oxygen Demand
sBOD	Soluble Biochemical Oxygen Demand
SRT	Solids Retention Time
SWD	Side Water Depth
TF/AS	Trickling Filter + Activated Sludge Process
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
UCT	University of Capetown Process for Enhanced Biological Phosphorus Removal (EBPR)
USEPA	United States Environmental Protection Agency
VFA	Volatile Fatty Acid
VSS	Volatile Suspended Solids
WAS	Waste Activated Sludge
WRP	Water Reclamation Plant
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant

MESERB
Minnesota Environmental Science and Economic Review Board
Using science and economics to improve environmental regulations

April 29, 2005

Bruce A. Nelson, Executive Director
Alexandria Lake Area Sanitary District
MESERB President
2201 Nevada Street
Alexandria, MN 56308-9152

Dear Mr. Nelson:

On behalf of HydroQual, Inc., I am pleased to present to the regular and associate members of the Minnesota Environmental Science and Economic Review Board (MESERB), the Minnesota Pollution Control Agency (MPCA), and wastewater treatment operators throughout Minnesota, the enclosed report, "Wastewater Phosphorus Control and Reduction Initiative."

This report represents the second phase of a three-phase project spanning two years, designed to assist wastewater treatment professionals with identifying and analyzing low-cost, high-efficiency phosphorus reduction options for a variety of wastewater treatment methods and configurations. This project is funded by a $296,000 grant from the Minnesota Environment and Natural Resources Trust Fund, recommended by the Legislative Commission on Minnesota Resources (LCMR) and reflected in Minn. Laws 2003, Ch. 128, Art. 1, Sec. 9, Subd. 07e.

The first phase of the Initiative, involving data analysis for the 22 facilities participating in the study and site tours of 17 of those facilities, began in July 2003 and concluded in October 2004. This report constitutes the second phase of the project. The third phase, involving two seminars for wastewater treatment professionals, is scheduled to be completed by the end of the project's funding cycle in June 2005.

In 2003, the Legislature presented a series of questions to the MPCA, among them "how to best assist local units of government in removing phosphorus at public wastewater treatment plants" (Minn. Laws 2003, Ch. 128, Art. 1, Sec. 166). While MESERB's project predates this directive, I hope this report will provide a valuable analytical tool through which local wastewater treatment engineers and operators can analyze the potential benefits and risks of various phosphorus removal methods as they relate to parameters such as facility size, treatment type, influent characteristics, and available financial resources.

It is important to emphasize that this report focuses on *process*. At its core is a protocol for use by wastewater treatment professionals having some level of familiarity with phosphorus removal methods. Although we try to make the report as user-friendly as possible, some technical understanding of wastewater treatment processes is necessary for the reader to enjoy the full benefits of this protocol and the results it produces for the 17 plants analyzed in this report.

To develop and test the protocol, MESERB directed HydroQual, Inc. to select a total phosphorus effluent concentration of 1 mg/L as a target, and to utilize site characteristics and data from among the 22 participating facilities. Phosphorus removal options and cost estimates discussed in the report were developed by HydroQual, Inc. for purposes of this project, and are not to be considered specific treatment recommendations applicable to any identified wastewater treatment facility. Views expressed in this report are not necessarily those of MESERB or its members, and this report is not intended to advocate for or against any specific policy with regard to phosphorus removal.

Finally, I wish to thank MESERB's consultants with HydroQual, Inc. for their painstaking efforts in researching and preparing this report; the staff at MPCA for their guidance and technical assistance; the LCMR and the Minnesota Legislature for their financial support; and last but not least, the 22 MESERB member communities who contributed time, money and energy to making this report a reality – especially the 17 members who made their facilities and data available for site-specific analyses. Everyone's efforts are very much appreciated.

If you have any questions regarding this report, please contact me at 320-650-2812.

Sincerely,

Ken Robinson

Kenneth Robinson, Public Utilities Director, City of St. Cloud
MESERB Northern Representative and LCMR Project Manager

KRR

Enclosure

EXECUTIVE SUMMARY

BACKGROUND

Phosphorus is an important element in natural water systems because it is an essential nutrient (along with nitrogen) required for the growth of aquatic plants including algae. Its concentration is generally limited in rivers and lakes, whereas carbon and nitrogen are more readily available. Therefore, excessive growth of algae and aquatic plants in rivers and lakes can often be reduced or prevented by limiting the supply of phosphorus alone. Waters with high phosphorus concentrations are often described as eutrophic, in that they are nutrient rich and support excessive algae and aquatic plant growth. Eutrophication affects the dissolved oxygen (DO) concentration in lakes and rivers. Under sunlight photosynthesis by the algae and plants produces oxygen to elevate its concentration, but without light the biological activity associated with plant respiration and decay rapidly depletes the DO concentration to very low levels that are detrimental to aquatic life. Excess algae growth may also create unpleasant taste and odors in water supplies.

The Minnesota Pollution Control Agency (MPCA) has been actively involved in developing control measures to reduce phosphorus discharges from point and non-point sources to the surface waters of the State of Minnesota. In 1996, the MPCA initiated a phosphorus strategy for controlling point and non-point sources of phosphorus involving the following seven action items:

- Develop education/outreach information on environmental impacts of phosphorus;
- Cosponsor basin-wide phosphorus forums;
- Use basin management as the main policy context for implementing the phosphorus strategy;
- Broadly implement Minnesota's point source phosphorus controls;
- Broadly promote lake protection activities;
- Address phosphorus impacts on rivers; and
- Modify water quality standards if necessary.

One of the critical steps in the MPCA phosphorus strategy is the development of Phosphorus Management Plans (PMP) as part of a new or renewed permit. These plans are considered by the MPCA as guidance tools for dischargers to determine the phosphorus contributions from municipal and industrial treatment plants to the surface waters of the State, and, if required, to develop an implementation plan to reduce or remove phosphorus loadings through control measures such as source control, pollution prevention or the implementation of phosphorus removal methods at the treatment plants. As part of the PMP process, the MPCA has established guidelines for implementing a phosphorus control plan based on estimated influent and effluent total phosphorus concentrations. For a given concentration range, the MPCA has defined excessively high phosphorus levels and listed recommended phosphorus control goals. These guidelines are to assist treatment plants in establishing phosphorus control programs.

The Minnesota Environmental Science and Economic Review Board (MESERB) has also been actively involved for a number of years in providing the resources needed to maintain the high quality in the surface waters of Minnesota. In the fall of 2001, MESERB members agreed to develop a Phosphorus Initiative to evaluate municipal wastewater treatment phosphorus reduction efforts and analyze the costs, level of reduction, and associated improvements to water quality. The MESERB participants in the Phosphorus Initiative project included the cities of Breckenridge, Detroit Lakes, Fairmont, Fergus Falls, Glencoe, Grand Rapids, Little Falls, Luverne, Marshall, Moorhead, New Ulm, Red Wing, Redwood Falls, Rochester, St. Cloud, Thief River Falls, Wadena, Warroad, and Winona. Other participants include Alexandria Lake Area Sanitary District, Brainerd Public Utilities, and the Dover, Eyota, St. Charles Sanitary District (Whitewater River PCF). In 2003, MESERB received a grant from the Legislative Commission on Minnesota Resources (LCMR) for the Wastewater Phosphorus Control and Reduction Initiative (Phosphorus Initiative). The project will run from July 1, 2003 to June 30, 2005 and has three phases:

- Site examination and data review of the participating facilities;
- Preparation of a best practices report detailing low-cost, high-efficiency phosphorus reduction methods; and
- Presentation and discussion of the report in two regional seminars.

The technical approach used to address the stated requirements for the three phases involved the evaluation of phosphorus removal options for seventeen (17) selected MESERB wastewater treatment plants that were cost effective, met an effluent phosphorus target concentration of 1 mg/L (the most stringent effluent concentration specified in current MPCA regulations) and would have wide application to treatment plants in Minnesota. To achieve these objectives, the engineering analysis involved the following major tasks:

- Characterize, group and select seventeen wastewater treatment plants from MESERB's 22 participating plants;
- Identify and discuss a range of applicable phosphorus reduction and removal technologies;
- Develop a protocol to systematically evaluate the effectiveness of phosphorus removal alternatives for the seventeen wastewater treatment plants; and

- Identify the most appropriate cost effective phosphorus reduction strategies for the different types of biological treatment processes to meet a monthly average phosphorus discharge target of 1 mg/L.

Phosphorus removal from wastewater treatment effluents requires the transfer of phosphate from the liquid to a solid form, followed by liquid-solids separation and ultimate removal of the phosphorus in the waste sludge. Two methods are used to transfer phosphorus into a solid form: chemical precipitation and enhanced biological phosphorus removal. Both require effective liquid-solids separation to minimize the total phosphorus concentration in the WWTP effluent discharge. For very stringent low effluent discharge concentrations (less than 0.50 mg/L), filtration is used after the secondary clarifiers to remove the phosphorus laden suspended solids concentration to below 2-5 mg/L. Without filtration, effluent phosphorus concentrations in the range of 0.50 to 2.0 mg/L are feasible.

Chemical treatment for phosphorus removal involves the addition of metal salts that react with soluble phosphate and form solid precipitates that are removed by solids separation processes such as clarification and filtration. Phosphate precipitation normally is achieved by the addition of aluminum or iron salts that form sparingly soluble phosphate compounds. These metal salts are most commonly employed in the forms of alum ($Al_2(SO_4)_3{\cdot}18H_20$), sodium aluminate ($NaAlO_2$), ferric chloride ($FeCl_3$), ferric sulfate ($Fe_2(SO_4)_3$), ferrous sulfate ($FeSO_4$), and ferrous chloride ($FeCl_2$). The required chemical dose is related to the remaining liquid phosphorus concentration. At concentrations above 2 mg/L a dose of 1.0 mole Al or Fe is sufficient per mole of phosphorus. For lower phosphorus concentrations in the range of 0.3 to 1.0 mg/L, the dose can be in the range of 1.2 to 4.0 mole/mole, respectively.

Phosphorus removal occurs to some degree as a natural step in biological wastewater treatment through biomass synthesis as heterotrophic bacteria consume organic substances and excess biomass is wasted. An estimate of the bacteria phosphorus content on a dry weight basis is 1.5 to 2.0%. For domestic wastewater treatment with an average influent BOD concentration of about 200 mg/L, the average phosphorus removal efficiency based on biomass synthesis is about 20%. However, starting back in the mid 1970s, biological processes, now termed enhanced biological phosphorus removal (EBPR), were developed and have demonstrated 80 to 90% phosphorus removal by biological means. EBPR processes are designed to culture phosphorus accumulating organisms (PAOs), which are able to take up and store phosphorus at levels greater than required for “normal” heterotrophic metabolic activity in the activated sludge process. In an EBPR process an anaerobic contact zone is added prior to an activated sludge anoxic or aerobic zone. In that zone the PAOs consume organic volatile fatty acids (VFA) contained in the influent wastewater or produced by rapid fermentation of soluble readily biodegradable COD (rbCOD) in the wastewater. In the following aerobic zone the PAOs can take up phosphorus to very low concentrations. The excess phosphorus removed in EBPR processes is directed to storage products in the cells, which have been shown to be able to accumulate phosphorus at levels of 20 to 30% of their dry weight. Removal of phosphorus from the wastewater EBPR processes occurs through two major steps: uptake by phosphorus accumulating organisms and removal, processing, and disposal or reuse of the phosphorus-enriched biosolids produced. The design of EBPR processes needs to address both of these components.

The various conditions and parameters that impact EBPR efficiency can be grouped into three major categories: wastewater characteristics, environmental factors, and design/operating parameters. The wastewater characteristics may be the most important parameter that affects phosphorus removal efficiency. Based on the mechanism described above for phosphorus removal, it is clear that as more VFA is supplied to an EBPR system, more PAOs can be grown and thus more phosphorus removal is possible. The VFA is supplied in two ways to the anaerobic contact zone. It is contained to some degree in the influent wastewater and is generated from fermentation of influent rbCOD in the anaerobic zone. In general, a greater phosphorus removal capacity has been correlated with higher influent wastewater BOD/P ratios, which indirectly assumes that more rbCOD is available as the influent BOD concentration increases. However the fraction of rbCOD in municipal wastewaters will vary, depending in large part on industrial wastewater contributions. General assumptions on EBPR performance, based only on influent BOD/P ratios, may be inaccurate. High phosphorus removal efficiency with effluent phosphorus concentrations of less than 1.0 mg/L has been associated with very high influent BOD/P ratios in excess of 40:1 for domestic wastewaters, but for many wastewaters the ratio is in the 20-30 range.

Environmental factors that could impact EBPR efficiency include temperature and pH. Process design and operating factors included in this evaluation of phosphorus removal include anaerobic contact time, diurnal fluctuations, nitrification, side streams processes, and solids retention time.

APPROACH

The first step in the evaluation of effective phosphorus removal alternatives was to conduct a screening study to select 17 representative wastewater treatment plants from the 22 MESERB participating members in the Phosphorus Initiative project. The objective of the screening process was to select plants with a diverse number of biological treatment processes, located throughout the State of Minnesota and representative of a broad spectrum of the types of treatment plants in Minnesota. The type of plant data collected during the screening process included plant size, type of plant, permit requirements, existing wastewater characteristics, industrial contributions, and sludge handling operations. The plants selected were:

- Alexandria Lake Area Sanitary District Wastewater Treatment Facility (WWTF) - a 3.25 MGD (million gallons/day) activated sludge plant with tertiary treatment and chemical addition.
- Brainerd and Baxter Wastewater Treatment Plant (WWTP) - a 3.13 MGD Rotating Biological Contactor (RBC) treatment plant.
- Detroit Lakes WWTF - a 1.64 MGD trickling filter plant with primary and final clarifiers.
- Faribault WWTF - a 7.0 MGD combined trickling filter and activated sludge system with primary and secondary clarifiers.
- Fergus Falls WWTP - a 2.81 MGD Biological Nutrient Removal (BNR) treatment system.
- Glencoe WWTF - a 1.60 MGD combined trickling filter and activated sludge with primary and secondary clarification and filters for tertiary treatment.
- Grand Rapids WWTF - a 14.3 MGD activated sludge plant with primary and secondary clarifiers and polishing ponds for tertiary treatment.
- Little Falls WWTF - a 2.4 MGD combined trickling filter/activated sludge plant with primary and secondary clarification.
- Marshall WWTF - a 3.3 MGD trickling filter/activated sludge plant with industrial contributions from several food processing plants.
- Moorhead WWTF - a 6 MGD high purity oxygen wastewater treatment plant with an ammonia limit from June to September.
- New Ulm WWTF - a 6.77 MGD activated sludge system with primary and final clarification.
- Redwood Falls WWTP is a 0.824 MGD lagoon system with no industrial contributions and discharges to the Minnesota River.

- Rochester Water Reclamation Plant (WRP) - a 19.1 MGD high purity oxygen treatment system with phosphorus discharge level of 1.0 mg/L and ammonia nitrogen limit of 1.6 mg/L.

- St. Cloud WWTF - a 13 MGD BNR plant with primary and secondary clarification. There are no permit requirements for nitrogen or phosphorus.

- Thief River Falls WWTP - a 2.57 MGD wastewater treatment lagoon system treating several industries.

- Wadena WWTF - a 0.50 MGD oxidation ditch treatment system with primary and secondary clarification and filtration is a tertiary treatment step.

- Whitewater River Pollution Control Facility (PCF) - an 0.80 MGD oxidation ditch treatment system with no primary clarification. The plant has a filter following the secondary clarifiers.

Site visits were scheduled during September and October 2003. The purpose of the site visits was to obtain plant information to become familiar with the operations and capabilities relative to assessing the treatment requirements for effective phosphorus removals. At each site, there was a presentation on the project goals and approach to evaluate phosphorus removal options, a plant tour, a review of plant operations, and the requests for additional plant information.

All unit operations were reviewed during the plant tour including discussions with plant personnel on individual treatment units (e.g., secondary treatment, sludge handling, and disposal, process return lines), plant operations including plant performance and capabilities, design conditions, removal rates, and chemical addition, and existing and future permit discharge limits. For each plant, design and actual flows were tabulated along with the monthly averages of the influent and effluent parameters: BOD ($CBOD_5$), total suspended solids (TSS), total phosphorus (TP) and ammonia-nitrogen (NH_4-N). Permit limits for BOD, TSS, TP and NH_4-N were also presented for each plant. A detailed description of each plant and the conceptual design analyses conducted on the evaluation of phosphorus removal options are discussed in Section 5. The plants were divided into the following eight biological treatment processes: activated sludge, biological nutrient removal (BNR), oxidation ditch, high purity oxygen biological treatment, trickling filter, combined trickling filter and activated sludge, lagoons and rotating biological contactors (RBC).

In this study, a protocol for evaluating phosphorus removal alternatives for representative wastewater treatment facilities was developed and applied in a consistent manner. The process involved defining the facility wastewater characteristics, design loads, and site conditions and preparing preliminary conceptual designs to retrofit existing plants leading to planning level cost evaluations. A result of this approach was the recognition that certain conditions could be identified that favored the selected phosphorus removal alternative and could meet the treatment goal of 1 mg/L at the lowest present worth cost.

The conceptual design protocol was developed in Section 4 and applied to evaluate the phosphorus removal alternatives for each facility in a systematic and consistent fashion. The protocol is presented on Figure ES-1. The conceptual designs considered the wastewater characteristics, the plant layout and sizing of all unit processes, sludge processing methods, the mixed liquor, temperatures, and other treatment requirements such as nitrification. Key steps in the EBPR design were the location and sizing of the anaerobic contact tank, selecting the design solids retention time (SRT), incorporating and sizing an anoxic tank for nitrate removal if nitrification is used, determining the amount of phosphorus removed by the EBPR process, and determining the final effluent phosphorus concentration. Key points in the chemical addition only alternative included biological treatment nutrient requirements, identify chemical dose points, determine chemical dose, and determine chemical sludge production. For cases where the design procedure showed that the EBPR process alone could not meet effluent requirements, chemical treatment design steps were incorporated. These included determining the chemical dose for different chemical addition points and the amount of chemical sludge production. In Section 4, key assumptions and design relationships are summarized.

The basis for the preliminary planning level costs was discussed in Section 4. The cost estimates were based on a compilation of cost information from USEPA reports, trade journals, vendors quotes and internal project data. Section 4 describes the capital costs elements included and not included in the preliminary analysis for the EBPR and chemical precipitation systems, presents a summary of the budgetary O&M costs associated with each phosphorus removal alternative and discusses the planning level capital and O&M cost used in the analyses. Alum was used as the chemical for phosphorus precipitation for all the evaluations to provide consistent comparisons. The operating costs were converted to a present worth cost using a 20-year time period and an average interest rate of 5.0 percent, which was based on the December 2004 Minnesota municipal bond information.

Conceptual designs were developed for each facility in Section 5 so that the performance of the possible phosphorus removal alternative could be evaluated and relative cost determined. The conceptual designs determined required tank volumes, additional reactor mixing requirements, primary, secondary, and chemical sludge production rates, internal recycle rates where necessary, the acceptability of other unit process loadings such as secondary clarifiers, chemical dose requirements, the amount of biological phosphorus removal, and changes in alkalinity concentrations.

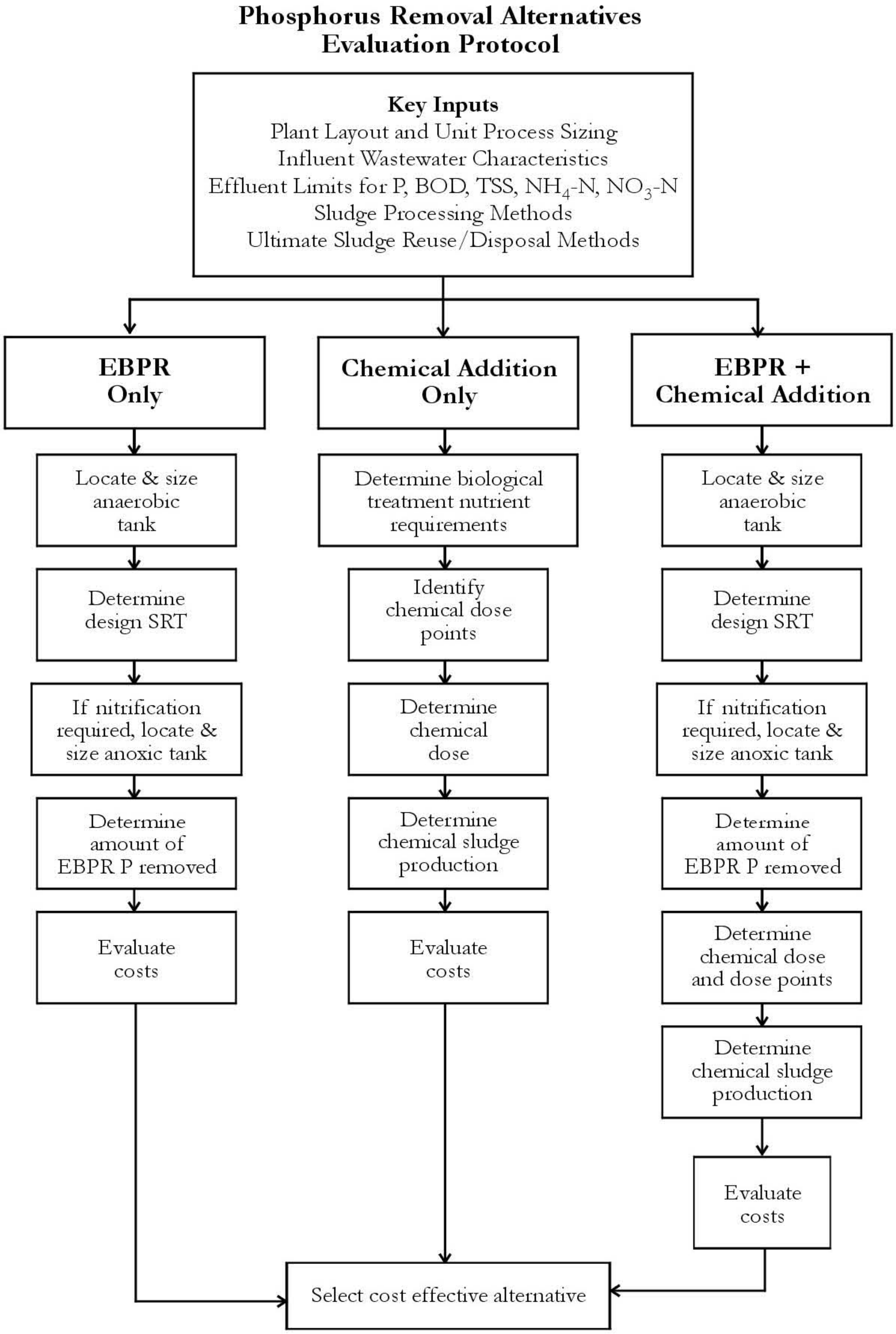

Figure ES-1 – Phosphorus Removal Alternatives Evaluation Protocol

For each type of wastewater treatment plant identified for this study, all reasonable phosphorus removal technologies were identified in Section 5 and evaluated to determine which alternatives were feasible and which were preferred for each of the wastewater treatment facilities identified in this study. All the alternatives involved either chemical addition alone, an EBPR process alone, or a combination of chemical addition and an EBPR process to achieve an effluent concentration goal of 1.0 mg/L phosphorus. Chemical addition could be applied in some way to any of the different types of wastewater treatment facilities, but the feasibility of an EBPR process had to be investigated for each facility. Key issues for the EBPR process included the ability to retrofit the existing plants to accommodate the tankage needed, and the EBPR phosphorus removal efficiency for the particular treatment plant process and wastewater characteristics. The evaluation of phosphorus removal options included an analysis of the cost effectiveness of the conceptual designs developed for each technology. This involved the development of relative costs for each plant to compare the effectiveness of the different phosphorus removal alternatives for a specific site.

For the EBPR process, improved phosphorus removal is possible for EBPR systems by adding readily biodegradable COD generated on site by fermentation of primary sludge, by purchasing sugar or acetate, or by adding chemicals for precipitation. Alum was less expensive than sugar addition for all plant sizes, while fermentation was less expensive than alum when the plant size exceeded 10 MGD. As odor control would add more cost to the fermentation alternative, only alum was considered for chemical addition methods.

FINDINGS

In Section 5 the results of the conceptual design and preliminary budgetary cost analyses are summarized along with a description of the preferred alternative for each wastewater treatment facility. The final alternatives that involved EBPR processes had different variations depending on the site and were either EBPR with the anaerobic tank within the existing aeration basin, EBPR with a anaerobic contact tank constructed outside the existing aeration basin, EBPR with an anoxic tank for denitrification, and any of the EBPR designs with chemical addition to the primary and/or secondary clarifiers. The preferred alternative selected for the suspended growth processes were not just a function of the type of plant but were affected also by the existing system design and wastewater characteristics.

The cost basis for the preferred option is based on the present worth cost comparisons, including capital and operating costs. EBPR systems had higher capital costs and lower O&M cost, and chemical treatment systems had lower capital cost and higher O&M costs. The capital and O&M costs were preliminary estimates developed to evaluate the different alternatives, to provide a framework to allow a comparison of relative costs at a specific site and to assist individual plants to further investigate viable phosphorus removal options.

The EBPR process was the more cost effective phosphorus removal system for six (6) of the 10 treatment systems evaluated (EBPR was not considered a viable option for trickling filters, rotating biological contactors, and lagoon treatment systems). Fergus Falls was not included in the cost evaluation as it was considered a no action alternative, because it is currently meeting a phosphorus discharge limit of 1 mg/L with an EBPR system. The present worth cost analyses showed that the EBPR process was the most cost effective phosphorus removal alternative for the following five plants: New Ulm WWTF, St. Cloud WWTF, Whitewater River PCF, Moorhead WWTF, and Marshall WWTF. The most cost-effective EBPR conceptual designs for these plants were: Moorhead with EBPR and an external anaerobic tank; New Ulm and St. Cloud with an internal modification to the aeration system for an anaerobic zone and chemical addition; Whitewater River and Marshall with EBPR with an external anaerobic tank chemical addition and provisions for an anoxic zone or tank. Except for Moorhead and Fergus Falls, the other 4 EBPR plants would require chemical addition to the secondary clarifiers. Stand-by chemical equipment would be recommended for the Moorhead and Fergus Falls facilities.

Four (4) treatment plants, Alexandria Lake Area Sanitary District WWTF, Wadena WWTF, Rochester WRP and Little Falls WWTF were not selected for EBPR. Alexandria and Rochester are currently meeting a phosphorus limit of 1 mg/L using chemical treatment, and the conceptual design analysis for Wadena and Little Falls indicated that chemical treatment would be the most cost effective phosphorus treatment system.

For five (5) plants (Alexandria Lake Area Sanitary District WWTF, Grand Rapids WWTF, Fergus Falls WWTP, Rochester WRP and Detroit Lakes WWTF), the recommendation was to continue with their present practices. These treatment plants are meeting the monthly average phosphorus permit target of 1 mg/L using current phosphorus control measures. Alexandria and Rochester currently use chemical treatment. Grand Rapids provides nutrient addition on site at the industrial pretreatment area for the nitrogen and phosphorus deficient paper mill wastewater and has the on-site controls required to regulate the concentration of phosphorus entering and leaving the treatment plant. Fergus Falls has an ongoing biological nutrient removal (BNR) treatment system that is meeting its ammonia-nitrogen and phosphorus discharge limits without chemical addition. Detroit Lakes has a combined storage, spray irrigation, and ground water infiltration system with a winter surface discharge after chemical addition for phosphorus removal.

Chemical treatment was the most appropriate phosphorus removal alternative for 10 of the 15 treatment plants evaluated. Two plants, Grand Rapids and Fergus Falls, were not included in the analysis. The evaluation of chemical treatment, as a stand alone phosphorus removal alternative, considered both single and two-point chemical addition. In all cases, the conceptual design analysis demonstrated that two-point chemical addition at the primary and secondary clarifiers would be the most cost effective chemical precipitation system. Two-point chemical treatment would result in lower alum requirements and smaller chemical sludge production. Chemical treatment was the recommended phosphorus removal alternative for the following ten plants: Alexandria, Wadena, Rochester, Detroit Lakes, Faribault, Glencoe, Little Falls, Redwood Falls, Thief River Falls, and Brainerd.

In Section 6, factors that favored EBPR or chemical treatment system alternatives for retrofitting the various types of plants for phosphorus removal were reviewed and design guidelines for retrofit designs for phosphorus removal were summarized for EBPR and chemical treatment systems. Where there was a sufficient amount of soluble BOD available in the influent wastewater, the EBPR alternative was in many cases more cost-effective than the chemical treatment alternative for facilities with some form of activated sludge treatment. For treatment processes without a suspended growth activated sludge process, such as trickling filters, rotating biological contactors and lagoon facilities, chemical treatment was the only viable alternative for upgrading existing systems for phosphorus removal without making major changes in the treatment system design.

The most important factor affecting the EBPR option was the ratio of the amount of readily degradable organic material in the influent wastewater to the amount of phosphorus. The influent BOD/P ratio was used as a general parameter to characterize this parameter for different wastewater facilities. BOD/P ratios of 40 and higher were more favorable for EBPR alternatives. Higher influent BOD/P ratios were needed for EBPR process for wastewater treatment processes that were operated with a longer SRT, had more nitrate recycled to the anaerobic contact zone or had pretreatment processes (e.g. trickling filters) that removed influent soluble BOD. The influent BOD/P ratio can be affected by recycle flows, which can reduce it in some cases to make it more difficult for the EBPR process to meet the effluent phosphorus concentration goal. Facilities with anaerobic or aerobic digestion and sludge dewatering equipment can produce recycle streams with the highest phosphorus concentration and with minimal BOD to essentially decrease the influent BOD/P ratio and increase the amount of phosphorus that the EBPR system has to remove. Some of the Minnesota facilities stored waste sludge without solids dewatering prior to land application of the biosolids, which thus helped to minimize recycle phosphorus loads and provide a more favorable condition for an EBPR process.

Retrofitting existing plants for an EBPR process required a means to provide an anaerobic contact tank with about a 1.0 hour detention time prior to the aeration basin. The aeration basin layout and configuration and capacity at some facilities provided favorable conditions for installing an anaerobic contact basin at less costs. Because the EBPR process generally improves sludge settling characteristics, existing aeration basins could be designed at higher MLSS concentrations, which then led to excess capacity in the aeration basin that could be used for the EBPR anaerobic contact tank. When nitrification was required additional tank volume was needed to provide an anoxic zone for nitrate removal. Systems with excess aeration tank capacity to accommodate anoxic tanks also were more favorable for an EBPR process. For some applications, because of the process configuration, the installation of an external tank for the EBPR anaerobic contact zone was unavoidable. This was the case for facilities with oxidation ditch and high purity oxygen processes.

The option of an EBPR process with chemical addition appeared to be most favored when the EBPR process could provide substantial phosphorus removal, but not enough to meet the effluent phosphorus concentration goal of 1 mg/L based on a monthly average. In these cases, chemical addition for polishing, usually in the secondary treatment process, added a nominal cost to the overall phosphorus removal treatment technology and resulted in a favorable combination. Conditions that favored the EBPR process with chemical addition were a moderate influent BOD/P (25-35) ratio, a higher variability in the wastewater strength, and additional phosphorus from return flows.

For systems with low wastewater strength, as indicated by a low influent BOD/P ratio (< 25), an EBPR process was less effective and chemical treatment alone became the more cost-effective and more reliable alternative. A system with highly variable influent wastewater BOD/P ratios would also have poor or unreliable EBPR performance and thus would favor chemical treatment. Wastewaters with higher alkalinity were more favorable for chemical addition, as there would be less cost for pH control by purchasing alkalinity to offset the alkalinity consumed by the chemical addition. Though not evaluated specifically in this study, systems with excess capacity for handling increased sludge, especially in the primary treatment step, would provide a more favorable condition for the chemical treatment option. Site layout conditions could also increase the cost of constructing necessary facilities for the EBPR process to thus make chemical treatment more favorable. Most systems had convenient locations for chemical addition, either to the primary or secondary treatment steps. Chemical treatment was the only viable option for systems that did not have a suspended growth activated sludge process (necessary for EBPR). Secondary treatment facilities that fit this category were trickling filters, rotating biological contactors, or lagoons.

Because of the above factors, the results of the facility retrofit evaluations showed that for a given type of wastewater treatment facility different phosphorus removal alternatives may be selected at different locations due to site-specific issues. For example, oxidation ditch systems are used at the Whitewater and Wadena facilities, but an EBPR alternative was preferred for Whitewater because it had a much higher influent BOD/P ratio, 46 versus 26 for Wadena. The most cost effective alternative for Wadena was chemical treatment only.

More variable results were obtained from the alternative evaluations for the trickling filter/activated sludge (TF/AS) processes. For the four plants evaluated, the alternatives selected were either EBPR plus chemicals or chemical treatment. Two scenarios were evaluated for Glencoe. EBPR was not feasible for the Glencoe facility with the dairy operation, which had a very low influent BOD/P in the activated sludge system feed flow after the trickling filter treatment. The system also had a very high influent nitrogen concentration, which would result in no BOD available for the EBPR process. Without the dairy operation and bypassing the trickling filter, the EBPR process was the preferred alternative for Glencoe. EBPR and chemical treatment was the preferred alternative for the Marshall facility. For the Marshall facility, a cost-effective EBPR alternative involved bypassing the trickling filters, as the existing basins had sufficient capacity for a biological nutrient facility including anaerobic anoxic and aerobic treatment zones. Bypassing the trickling filter provided sufficient BOD for the EBPR process. If a TF/AS process was used to treat a typical domestic wastewater, there would not be sufficient BOD to support a downstream EBPR process. The high concentration of industrial wastewater to the influent of the Faribault facility provides sufficient BOD for EBPR in spite of the trickling filter roughing treatment for BOD removal. This was the case for the Faribault plant. Plant data indicated low BOD in the trickling filter effluent such that chemical treatment would be the preferred phosphorus removal alternative. For the Little Falls TF/AS facility, chemical treatment was favored even though there was a high influent BOD/P ratio (36). In this case there was not sufficient tank volume available to easily accommodate an EBPR process without a significant amount of tank construction.

GENERAL CONCLUSIONS

In summary, highlights of key general conclusions that can be drawn from this study are listed as follows:

- Chemical treatment is the recommended phosphorus removal alternative for plants using trickling filters, rotating biological contactors or lagoons for secondary treatment.

- For a given type of activated sludge system, the EBPR retrofit design and the choice of EBPR, EBPR with chemical treatment, or chemical treatment can vary depending on many site-specific factors.

- Wastewater characteristics must be determined to establish process requirements and effectiveness of EBPR.

- Wastewater characteristics have a major impact on the feasibility and economics of an EBPR retrofit for phosphorus removal. The influent BOD/P ratio has been used as a rough parameter to provide a general indication of the effect of the influent wastewater characteristics on EBPR performance. However, the influent soluble readily biodegradable COD, which is not commonly measured, is more directly related to EBPR performance. General guidelines for BOD/P ratio are as follows:

    - Wastewaters exhibiting BOD/P ratios of greater than 40 may be able to consistently achieve an effluent phosphorus of less than 1 mg/L;
    - Wastewaters with ratios between 25 and 35 will need chemical treatment for effluent polishing; and
    - If the BOD/P ratio is less than 25, chemical treatment is typically the most cost effective phosphorus removal alternative.

- Stand-by chemical treatment should always be provided with EBPR treatment systems.

- For treatment systems requiring chemical treatment only, two-point chemical addition at the primary and secondary clarifiers is the most cost effective system.

- For chemical treatment, the capacity of the sludge processing and handling operations should be evaluated during the design of the phosphorus removal treatment system.

- Sludge processing residuals and other plant returns must be characterized to assess their impact on phosphorus loads when evaluating phosphorus removal systems, especially EBPR.

- Phosphorus monitoring of the raw wastewater, defining influent phosphorus loads, and encouraging industrial pretreatment where appropriate are action items that could be considered for defining influent phosphorus loads and developing a management plan to control phosphorus.

SECTION 1

INTRODUCTION

Phosphorus is an important element in natural water systems because it is an essential nutrient (along with nitrogen) required for the growth of aquatic plants including algae. Its concentration is generally limited in rivers and lakes, whereas carbon and nitrogen are more readily available. Therefore, excessive growth of algae and aquatic plants in rivers and lakes can often be reduced or prevented by limiting the supply of phosphorus alone. Waters with high phosphorus concentrations are often described as eutrophic, in that they are nutrient rich and support excessive algae and aquatic plant growth. Eutrophication affects the dissolved oxygen (DO) concentration in lakes and rivers. Under sunlight photosynthesis by the algae and plants produces oxygen to elevate its concentration, but without light the biological activity associated with plant respiration and decay rapidly depletes the DO concentration to very low levels that are detrimental to aquatic life. Excess algae growth may also create unpleasant taste and odors in water supplies.

Algae can be either suspended (phytoplankton) or attached (periphyton or macrophytes). Attached algae are typically more important in shallow streams and suspended algae more important in deeper rivers, lakes and estuaries. Algal growth is dependent upon temperature, ambient light and nutrient levels coupled with residence time. That is, if sufficient light and nutrients are present in the water body but there is low residence time, algal growth can be minimal because there is not enough time for the algae to grow. Phosphorus can be present in both particulate and dissolved organic forms that subsequently can be converted to inorganic phosphorus (orthophosphate) through hydrolysis and mineralization. The orthophosphate form (PO_4) is the phosphorus component that is available for algal growth. The particulate fractions of phosphorus can settle to the sediments playing an important role in sediment cycling of phosphorus to and from the water column. Due to the role that phosphorus plays in algal growth and subsequent effects on dissolved oxygen (DO) levels, the ultimate impact can be on ambient DO levels or through more aesthetic impacts that can include algal blooms, nuisance algal growth or biological imbalances.

Phosphorus occurs in soils and rocks but in forms that are only slightly soluble. The principal sources of phosphorus are from point sources such as domestic and industrial wastewater treatment plant effluents and from natural runoff (non-point) sources from surrounding uses such as land application of fertilizers and farming operations. Many state regulatory agencies have implemented phosphorus reduction and removal programs to limit the discharge of phosphorus to waterbodies. These control programs have included establishing specific discharge permit limits for total phosphorus (TP).

Phosphorus enrichment in receiving waters associated with wastewater treatment plant (WWTP) discharge is a concern in many regions within the United States. These include the Great Lakes Drainage Basin, the Lower Susquehanna River Basin including the Chesapeake Bay, estuaries along the Florida coast, the Lake Tahoe area, and drainage basins for many states including Minnesota, New Jersey and Colorado. Historically, WWTP effluent TP discharge limits of 1.0 to 2.0 mg/L have been broadly applied. Currently a more systematic approach to protecting water quality is being used involving total maximum daily load (TMDL). This approach is based on model evaluations of receiving water and pollutant inputs to determine WWTP pollutant discharge levels and non-point source loads that can be present and not impair the water quality, including phosphorus concentrations. TMDLs can result in stricter limits for phosphorus control in WWTPs at more locations in the U.S. TMDL limits often apply only seasonally and may only apply during low flow conditions.

Based on TMDL studies, a greater number of WWTPs are required to implement phosphorus removal technologies. Effluent discharge permit levels vary widely, with many effluent phosphorus concentration values at 1.0 mg/L or less. In most cases the new limits are applied to existing wastewater treatment plants. The phosphorus removal technology and design that is most appropriate, based on economics, feasibility, and reliability considerations, varies as a function of the process, design and wastewater characteristics of the existing WWTP. These factors that affect the control of phosphorus discharges to surface waters have been a concern to the Minnesota Pollution Control Agency (MPCA) for many years. The MPCA has been actively involved in developing control measures to reduce phosphorus discharges from point and non-point sources to the surface waters of the State of Minnesota. In 1996, the MPCA initiated a phosphorus strategy for controlling point and non-point sources of phosphorus involving the following seven action items:

- Develop education/outreach information on environmental impacts of phosphorus;
- Cosponsor basin-wide phosphorus forums;
- Use basin management as the main policy context for implementing the phosphorus strategy;
- Broadly implement Minnesota's point source phosphorus controls;
- Broadly promote lake protection activities;
- Address phosphorus impacts on rivers; and
- Modify water quality standards if necessary.

One element of this ongoing program for phosphorus reduction and control is the development by the MPCA of a phosphorus control strategy involving the National Pollutant Discharge Elimination System (NPDES) permits for all dischargers to the waters of the State. The purpose of the NPDES phosphorus strategy is to provide a basic process for the MPCA to select and incorporate reduction and/or control measures that would be included in the NPDES permits. The MPCA has developed a decision tree which provides a procedure to allow the MPCA to decide on the approach and what measures for phosphorus control should be included in a permit. Control measures listed in the decision tree include establishing specific limits for phosphorus, implementing a 5 year monitoring program for effluent phosphorus, and recommending or requiring a phosphorus management plan as an essential section of the permit.

One of the critical steps in the MPCA phosphorus strategy is the development of a Phosphorus Management Plan (PMP) as part of a new or renewed permit. These plans are considered by the MPCA as guidance tools for dischargers to determine the phosphorus contributions from municipal and industrial treatment plants to the surface waters of the State and if required, to develop an implementation plan to reduce or remove phosphorus loadings through control measures. Control measures would include source control, pollution prevention or the implementation of improved wastewater treatment methods. As part of the PMP process, the MPCA has established guidelines for implementing a phosphorus control plan based on estimated influent and effluent total phosphorus concentrations. For a given concentration range, the MPCA has defined excessively high phosphorus levels and listed recommended phosphorus control goals. These guidelines are to assist treatment plants in establishing phosphorus control programs. The MPCA guidelines for influent phosphorus concentrations are presented in Tables 1.1 and 1.2 for influent municipal total phosphorus and industrial contributions to municipal plants, respectively. The tables present a range of influent total phosphorus from less than 4 mg/L to greater than 8 mg/L with an associated evaluation level and recommended goals for each influent phosphorus range. The MPCA phosphorus strategy, PMP program, and phosphorus management planning guidance are discussed in detail on the MPCA web site (www.pca.state.mn.us/).

Table 1.1 - MPCA Guideline for Municipal Wastewater Influent Total Phosphorus

Concentration	Evaluation	Recommended Goal
< 4 mg/L	Low	Maintain or improve performance.
4-8 mg/L	Medium	Determine if high-concentration industries exist. Take corrective action where needed.
> 8 mg/L	High	Identify high-concentration industries. Take correction action where needed.

Source: MPCA Phosphorus Strategy: NPDES Permits (March 2000)

Table 1.2 - MPCA Guideline for Industrial Total Phosphorus Contributions to Municipal WWTF or Lift Stations (Phosphorus Management Plan)

Concentration	Evaluation	Recommended Goal
< 4 mg/L	Low	Maintain or improve performance.
4-8 mg/L	Medium	Corrective action may be needed, depending on flow.
> 8 mg/L	High	Pretreatment needed.

Source: MPCA Phosphorus Strategy: NPDES Permits (March 2000)

The Minnesota Environmental Science and Economic Review Board (MESERB) has also been actively involved for a number of years in providing the resources needed to maintain the high quality of the surface waters of Minnesota. MESERB is a joint powers board organized in 1997 dedicated to the research, study and analysis of environmental issues important to Minnesota. MESERB members share a common goal of keeping Minnesota's waters clean, while working to ensure that environmental regulations are based on sound research. MESERB accomplishes this objective by supporting scientific research, providing technical expertise, working with the regulators to develop cost effective and scientifically valid regulations, and reviewing wastewater permit applications for individual members.

In the fall of 2001, MESERB members agreed to develop a Phosphorus Initiative to evaluate municipal wastewater treatment phosphorus reduction efforts and analyze the costs, level of reduction, and associated improvements to water quality. The location of the 22 MESERB wastewater treatment plant participants in the Phosphorus Initiative project is shown on Figure 1.1. The participants include the cities of Breckenridge, Detroit Lakes, Faribault, Fergus Falls, Glencoe, Grand Rapids, Little Falls, Luverne, Marshall, Moorhead, New Ulm, Red Wing, Redwood Falls, Rochester, St. Cloud, Thief River Falls, Wadena, Warroad, and Winona. Other participants include Alexandria Lake Area Sanitary District, Brainerd Public Utilities, and the Dover, Eyota, St. Charles Sanitary District (Whitewater River PCF).

MESERB submitted a work plan to the State of Minnesota for a grant to study effective phosphorus removal techniques at wastewater treatment plants. In 2003, MESERB received a $296,000 grant from the Legislative Commission on Minnesota Resources (LCMR) for the Wastewater Phosphorus Control and Reduction Initiative (Phosphorus Initiative). The project will run from July 1, 2003 to June 30, 2005 and has three phases:

- Site examination and data review of the participating facilities;
- Preparation of a best practices report detailing low-cost, high-efficiency phosphorus reduction methods; and
- Presentation and discussion of the report in two regional seminars.

Prepared by Flaherty & Hood, P.A. for the Minnesota Environmental Science and Economic Review Board *October 2003*
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Figure 1.1 Location Map of MESERB Phosphorus Initiative Participants

The technical approach used to address the stated requirements for the three phases involved the evaluation of phosphorus removal options for selected MESERB wastewater treatment plants that were cost effective, met an effluent phosphorus target concentration of 1 mg/L and would have wide application to treatment plants in Minnesota. To achieve these objectives, the engineering analysis involved the following major tasks:

- Identify and discuss a range of applicable phosphorus reduction and removal technologies;
- Characterize, group and select seventeen (17) wastewater treatment plants from MESERB's 22 participating plants;
- Develop a protocol to systematically evaluate the effectiveness of phosphorus removal alternatives for the 17 selected wastewater treatment plants; and
- Identify the most appropriate cost effective phosphorus reduction strategies for different types of biological treatment processes studied in this project to meet a monthly average phosphorus discharge target of 1 mg/L.

In this study, a protocol for evaluating phosphorus removal alternatives for representative wastewater treatment facilities was developed and applied in a consistent manner. The process involved defining the facility wastewater characteristics, design loads, and site conditions and preparing preliminary conceptual designs to retrofit existing plants leading to planning level cost evaluations. A result of this approach was the recognition that certain conditions could be identified that favored the selected phosphorus removal alternative and could meet the treatment goal of 1 mg/L at the lowest present worth cost.

The study was designed to develop a protocol to evaluate phosphorus removal alternatives for a wide range of biological treatment processes. Conceptual designs of phosphorus removal alternatives were developed for the 17 MESERB plants. These plants served as example treatment facilities to illustrate the use of the phosphorus removal protocol for a wide range of treatment plants in Minnesota. Wastewater characterization data, plant design flows and loads, process flow diagrams (PFD) and the type of biological treatment process served as the basic technical information and to develop the conceptual designs. The evaluation also included an analysis of relative cost at each plant to compare the cost for the different phosphorus removal alternatives at a specific site. Based on the plant evaluations presented in Section 5, pertinent process factors and process design guidelines were summarized in the report providing additional engineering and technical information needed for a detailed evaluation of phosphorus removal options.

This report includes the following sections:

- Section 1 presents an overview of the basis for the Phosphorus Initiative including a summary of the ongoing MPCA phosphorus strategy to control phosphorus levels in the discharge from wastewater treatment plants.
- Section 2 describes the basic principles of chemical treatment and biological treatment based on enhanced biological phosphorus removal (EBPR). The section presents a summary of the commonly used wastewater treatment plant configurations for phosphorus removal including full-scale plant examples. The potential impact of aluminum and iron based phosphorus compounds on allowable land application rates of biosolids are also discussed.
- Section 3 discusses the screening process used to develop preliminary treatment plant data and to select the 17 MESERB plants for the evaluation of phosphorus removal alternatives.
- Section 4 presents a description of the phosphorus removal alternatives applicable to the various types of biological treatment processes selected. The protocol developed to evaluate phosphorus removal alternatives is discussed. The advantages and disadvantages of each phosphorus removal alternative are presented along with the basis for the preliminary budgetary cost estimates.
- Section 5 presents a summary of the conceptual design analysis conducted to evaluate phosphorus removal alternatives for each plant. The analysis are based on the protocol developed in Section 4 and are presented to illustrate the usefulness of this procedure to effectively evaluate phosphorus removal alternatives. Included in this section are a description of each plant and a summary of plant performance, a discussion of the conceptual design modifications used for the analysis and an evaluation of phosphorus removal options based on technical and economic considerations.
- Section 6 presents a discussion on the results of the plant evaluations, reviews and compares the treatment alternatives selected, summarizes the process factors affecting the selection of a phosphorus removal alternative and discusses the process design guidelines for phosphorus removal processes.
- Section 7 presents the conclusions and recommendations.

SECTION 2.0

PHOSPHORUS REMOVAL TECHNOLOGIES

Phosphorus occurs in municipal wastewaters from domestic, commercial and industrial activities. The industrial and commercial sources of phosphorus are highly variable and can greatly affect the actual influent wastewater phosphorus concentration at a given municipal facility. The approximate contributions of phosphate from major sources to domestic wastewater are estimated in kilograms phosphorus/capita/year (kg P/capita/yr) as 0.60 from human wastes, 0.30 kg from laundry detergents with no restrictions on phosphorus content, and 0.10 kg from household detergents and other cleaners (Sedlak, 1991). Phosphorus occurs in wastewater as various forms of phosphate in dissolved or particulate materials. Most of the phosphorus in municipal wastewater treatment plants (WWTPs) is as dissolved phosphate. Without significant commercial or industrial loads, the influent concentration of total phosphorus may range from 6–8 mg/L P. About 50% is as orthophosphate, 35% is as condensed phosphates (e.g., pyrophosphate, tripolyphosphate, trimetaphosphate), and 15% is as organic phosphates (e.g. phospholipids, nucleotides). When restrictions on the use of phosphorus detergents are imposed, the influent concentrations to domestic wastewater treatment plants will be lower and in the range of 4-5 mg/L.

Phosphorus removal from wastewater treatment effluents requires the transfer of phosphate from the liquid to a solid form, followed by liquid-solids separation and ultimate removal of the phosphorus in the waste sludge. Two methods are used to transfer phosphorus into a solid form; chemical precipitation and enhanced biological phosphorus removal. Both require effective liquid-solids separation to minimize the total phosphorus concentration in the WWTP effluent discharge. For very stringent, low effluent discharge concentrations (less than 0.50 mg/L), filtration is used after secondary clarifiers (tertiary treatment) to remove the phosphorus laden suspended solids concentration to below 2-5 mg/L. Without filtration, effluent phosphorus concentrations in the range of 0.50 to 2.0 mg/L are feasible.

In this section the basic principles of chemical treatment and biological treatment with enhanced biological phosphorus removal (EBPR) are described, including commonly used treatment configurations and full-scale application examples.

2.1 CHEMICAL TREATMENT

Chemical treatment for phosphorus removal involves the addition of metal salts that react with soluble phosphate and form solid precipitates that are removed by solids separation processes such as clarification and filtration. Phosphate precipitation is achieved by the addition of metal salts that form sparingly soluble phosphate compounds. The common metals used are aluminum, iron and calcium. These salts are most commonly employed in the forms of lime ($Ca(OH)_2$), alum ($Al_2(SO_4)_3$), sodium aluminate ($NaAlO_2$), ferric chloride ($FeCl_3$), ferric sulfate ($Fe_2(SO_4)_3$), ferrous sulfate ($FeSO_4$), and ferrous chloride ($FeCl_2$). Simplified versions of chemical precipitation reactions are shown as follows for illustrative purposes (Tchobanoglous et al., 2003).

Phosphate precipitation with aluminum:

$$Al_2(SO_4)_3{\cdot}18H_2O + 2H_3(PO_4) \;=\; 2Al(PO_4) + 3H_2SO_4 + 18H_2O \qquad (1)$$

Phosphate precipitation with iron:

$$FeCl_3 + H_3(PO_4) \;=\; Fe(PO_4) + 3HCl_3 \qquad (2)$$

Phosphate precipitation with calcium:

$$10Ca(OH)_2 + 6H_3(PO_4) \;=\; Ca_{10}(PO_4)_6(OH)_2 + 18H_2O \qquad (3)$$

Equations 1 and 2 suggest that one mole of aluminum or iron will precipitate one mole of phosphate, but the reactions are much more complex than that. Along with these reactions, complex aluminum hydroxide and ferric hydroxide compounds are formed. Thus the precipitation reaction is not stoichiometric. Where the final phosphate concentration is high, the reaction is closer to the 1:1 stoichiometric ratio, but when low final effluent phosphorus concentrations are required (< 1.0 mg/L) there are more competitive reactions with the hydroxide formations and the molar ratio metal salt to phosphorus removal substantially increases. For the evaluation of phosphorus removal in this report, a relationship between the molar ratio of metal salts to phosphorus versus the effluent soluble phosphorus concentration is used to estimate the chemical dose, and was based on typically reported observations from studies with wastewater.

The pH value is also an important factor for efficient removal of phosphorus using alum or other salts, as the solubility of their precipitates various with pH. For alum, minimal solubilities occur in the pH range of 5.0 to 7.0 and for ferric in the range of 6.5 to 7.5. Iron and aluminum phosphate-containing sludges have been reported to be treated successfully in anaerobic digestion and sludge dewatering processes without phosphate release (Sedlak, 1991). The addition of alum and ferric salts consumes alkalinity. Therefore, for some wastewaters, depending on their initial alkalinity, alkalinity addition may be necessary to offset the alkalinity consumption by the metal salts to maintain the pH level required for the wastewater treatment processes. An alternative for alum is polyaluminum chloride, which does not consume alkalinity, but is more expensive than alum.

For lime addition, Equation 3 shows that the calcium reacts with phosphate to form calcium apatite ($Ca_{10}(PO_4)_6(OH)_2$). The formation and precipitation of apatite requires a high pH, and thus the reaction of lime with the wastewater first includes a water softening step in which calcium carbonate is formed, producing large amounts of sludge. Because of scaling problems associated with using lime, the large amount of sludge production, and the impact on pH, lime addition is seldom used for phosphorus removal in wastewater treatment. Thus the evaluations and alternatives in this report focus on using metal salt addition. Though the evaluations are based on alum addition, both metal salt will be equally effective and the choice depends mainly on local pricing.

Phosphorus precipitation using metal salts can be done at a number of different locations in WWTPs. Depending on the location for the chemical addition the phosphorus removal is classified as 1) pre-precipitation, 2) coprecipitation, and 3) postprecipitation (Tchobanoglous et al., 2003). The addition of chemicals to the raw influent wastewater in the primary sedimentation process is termed pre-precipitation. The precipitated phosphorus is removed with the settled primary sludge. In coprecipitation, chemicals can be added to 1) the effluent from the primary clarifier, 2) the mixed liquor in the activated sludge process, or 3) the effluent from a biological treatment process before the secondary clarifier. In all these cases, the precipitated phosphorus is removed along with the waste biological sludge. Postprecipitation involves the addition of chemicals to the effluent after the secondary clarification. Usually this is done in separate flocculation tanks and sedimentation facilities or in effluent polishing filters. In many cases the filter backwash is returned to the influent for settling and removal of the chemical sludge along with the settled primary sludge.

In many applications, a multiple-point addition procedure is followed for the most efficient use of chemicals for phosphorus precipitation. A common approach is the addition of chemicals before the primary clarifier and then again before the secondary clarifier. At the primary clarifier step, the amount of chemical addition is close to stoichiometric with a primary effluent phosphorus concentration at that point typically above 2 mg/L. The secondary clarifier chemical addition is normally well above the stoichiometric ratio in order to achieve low effluent phosphorus concentrations. It should also be noted that the efficiency of phosphorus removal by chemical addition to the primary clarifier is also limited by the fact that much of the polyphosphates have not yet been converted to orthophosphate, which occurs in the secondary treatment biological process. With two point chemical addition (primary and secondary clarifiers), a general practice for the primary metal salt dose is to achieve a primary effluent phosphorus concentration of about 2.0 mg/L, with the final phosphorus removal goal met with chemical addition in the secondary clarifiers (USEPA, 1987). Site-specific conditions will determine the most optimal two point chemical addition scheme. In Section 4, different chemical addition points are included in the various alternatives for phosphorus removal for different types of wastewater treatment systems.

The addition of chemicals to the primary clarifier also improves the suspended solids and biochemical oxygen demand (BOD) removal efficiencies. In addition to increasing the efficiency of primary clarification it reduces the organic load to the secondary biological process. The magnitude of the increased efficiency in primary treatment is proportional to the chemical dose. However, with the increased efficiency, a higher sludge production will occur in the primary clarifier step.

With chemical addition the amount of sludge production will increase in the wastewater treatment unit process where the chemical is applied. Results from a survey conducted on 185 WWTPs in Canada (USEPA, 1987) showed that to reach an effluent total phosphorus concentration of 1.0 mg/L, the sludge production increased by an average of 40% in primary treatment plants and 26% in activated sludge plants. However, it has been noted (USEPA, 1987) that generalizations about the sludge production are not possible, because it is related to site-specific wastewater characteristics and the treatment processes employed.

Certain guidelines can be used in assessing the amount of sludge production with chemical treatment. In primary treatment, increased sludge production is related to three factors: 1) the increased solids removal due to the effect of chemical treatment on suspended solids (TSS) removal efficiency, 2) the solids production due to the formation of the metal-phosphorus precipitate, and 3) the solids production from the metal hydroxide formation. The specific quantities can be calculated on a site by site basis based on the increased TSS removal efficiency in the primary clarifier, and the amount of metal-phosphorus formed and metal hydroxide formed. The latter two components are based on the amount of metal salt added and the amount of phosphorus removed. This fundamental approach is applied in the alternatives evaluation for phosphorus removal for the various types of WWTPs evaluated in this study.

Land application of biosolids to be used as fertilizer is a common means of biosolids disposal in Minnesota and is used by many treatment plants participating in this study. Multiple resources were researched to determine if these are maximum application rates for aluminum (Al) or iron (Fe) for land farming. So for combined biosolids and chemical solids, Specific application rates for Al or Fe could control land application rates of biosolids combined with chemical sludge. This review was undertaken in order to ensure that chemical treatment to remove phosphorus would not specifically restrict the amount of biosolids that can be applied to a certain land area. Federal and state regulations were researched including U.S. Environmental Protection Agency, Minnesota Pollution Control Agency, Wisconsin Department of Natural Resources, Michigan Department of Environmental Quality, New Jersey Department of Environmental Protection, and the New York State Department of Environmental Conservation. Although several metals are regulated, there are no federal or state mandated regulations governing the concentration of aluminum or iron in land applied biosolids at the time of this report. Information received from the Northwest Biosolids Management Association and Oregon State University indicated that it is unlikely that concentrations of aluminum and iron will be regulated in biosolids land application due to the fact that soils are largely composed of alumino-silicate minerals and iron oxides. Conversations with the Director of Regulatory Affairs at the Association of Metropolitan Sewerage Agencies (AMSA) confirmed that there are no regulations governing the land application of alum and ferric sludges. They did indicate, however, that the phosphorus is less available for nutrient uptake if it is bound in particulate form by either aluminum or iron. This was also supported by the information provided by Sedlak (1991) that no phosphorus was released.

Also, the potential release of phosphorus into the water column from chemically bound alum in pond systems does not appear to be a concern. Aluminum phosphate is highly stable over a wide pH range (4–9), which is typical of municipal wastewater. However, with decreasing pH below 4.0, phosphoric acid begins to form and at a pH above 9.0 aluminum hydroxide will form, with both of these reactions resulting in phosphorus release into the water column. A study prepared by the Technical Support Section of the USEPA Water Compliance Branch reviewed chemical phosphorus removal in several lagoon treatment systems in Canada, Minnesota and Michigan. All plants consistently achieved an effluent phosphorus concentration of less than 1.0 mg/L with influent concentrations being as high as 15.0 mg/L (Michigan). The Minnesota plants participating in this study had flows ranging from 0.017 – 0.672 MGD and influent total phosphorus levels between 1.5 mg/L and 6.0 mg/L. All of these treatment systems consistently met the effluent limit of 1.0 mg/L with the addition of liquid alum to the secondary lagoon cells. The research also showed that none of the lagoon systems (in the three study areas) had any problems related to sludge buildup causing a release of nutrients (phosphorus or nitrogen) which would increase the effluent concentration of phosphorus.

2.2 BIOLOGICAL TREATMENT

Phosphorus removal occurs to some degree as a natural step in biological wastewater treatment. In biological treatment processes for wastewater treatment, excess biomass is produced and wasted as a result of biological conversion of organic substances to new biological growth. The biological organisms require phosphorus for a number of cell components, including DNA, nucleotides such as adenosine triphosphate (ATP) used in energy transfer, and phospholipids storage products. An estimate of the bacteria phosphorus content on a dry weight basis is 1.5 to 2.0%. For domestic wastewater treatment with an average influent BOD concentration of about 200 mg/L, the average phosphorus removal efficiency based on biomass synthesis is about 20%. However, starting back in the mid 1970s, biological processes, now termed enhanced biological phosphorus removal (EBPR), have been developed and have demonstrated 80 to 90% phosphorus removal by biological means. EBPR processes are designed to culture bacteria which are able to take up and store phosphorus at levels greater than required for “normal” heterotrophic metabolic activity in the activated sludge process. The excess phosphorus removed in EBPR processes is directed to storage products in the cells, which have been shown to be able to accumulate phosphorus at levels of 20 to 30% of their dry weight. Removal of phosphorus from the wastewater EBPR processes occurs through two major steps: uptake by phosphorus accumulating organisms (PAOs) and removal, processing, and disposal or reuse of the phosphorus-enriched biosolids produced. The design of EBPR processes needs to address both of these components.

2.2.1 Enhanced Biological Phosphorus Removal (EBPR)

The following conditions have been defined as essential for excess biological phosphorus uptake and storage (Barnard, 1976; Stensel, 1991):

- Exposing the activated sludge bacteria to influent wastewater in an anaerobic contacting zone, followed by an aerobic (or anoxic) zone;
- Minimizing the amount of nitrate or oxygen fed to the anaerobic zone; and
- Availability of volatile fatty acids (VFAs), such as acetate and propionate or a source of readily biodegradable organic substrate in the anaerobic zone that can be fermented to VFA.

These conditions support the EBPR biochemical mechanisms described below, which have been defined by Wentzel, (1986), Comeau et al., (1989), Mino et al., (1994), and Smolders et al (1994): In the anaerobic zone, fermentation of complex and readily biodegradable Chemical Oxygen Demand (COD) to acetate and propionate occurs, the PAOs assimilate the acetate and propionate and convert them to intracellular polyalkanoates, such as polyhydroxybutyrate (PHB), and degradation of stored polyphosphate and glycogen provides energy for PHB formation. With the phosphorus release a milliequivalent release of associated cations, such as magnesium, potassium, and calcium also occurs. The amount of phosphorus released is directly related to the amount of VFA taken up in the anaerobic zone with 0.4 to 0.5 mg of phosphorus released per mg of acetate consumed.

In the aerobic zone, growth of PAOs occurs with subsequent uptake and storage of phosphorus. The excess biomass is wasted with the secondary sludge and thus removed phosphorus is carried out of the system. PAO growth results from the metabolism of the stored PHB with a portion of it being oxidized to provide energy and a larger portion used for catabolism for new cell production. Part of the PHB is also converted into glycogen. The energy is captured by the production of polyphosphate storage granules in the cell and results in phosphate and cation uptake from the liquid. Similar PHB oxidation and phosphorus uptake can occur in "anoxic" following the anaerobic zone. Anoxic is defined as biological respiration with nitrate or nitrite in lieu of oxygen.

Other bacteria can compete with the PAOs for the assimilation of organic substrates in the anaerobic zone. When these competing bacteria are present acetate and other soluble substrates are assimilated in the anaerobic phase without phosphorus release, and without polyphosphate storage and enhanced phosphorus removal in the aerobic phase. These non-phosphorus-accumulating organisms can deplete the VFA available for phosphorus accumulating organisms and impair phosphorus removal efficiency. This type of metabolism was first reported by Cech and Hartman (1990, 1993) as a result of laboratory studies on EBPR. Investigators termed the bacteria G bacteria due to their ability to convert the acetate consumed in the anaerobic zone to glycogen. They also identified them microscopically at 1000X as tetrad coccoid bacteria. Since then a number of other organisms have been found without the same morphological characteristics, and have been identified through molecular probes and termed GAO bacteria (Crocetti et al., 2000 and 2002). The conditions that appear to favor these bacteria are a pH in the anaerobic and aerobic zones below 7.2 (Felipe et al., 2001a and 2001b), warm temperatures, long solids retention time (SRTs), and excess acetate in the anaerobic zone (high VFA/P ratio). Of these, low pH and high VFA/P ratios have been the most significant parameters.

2.2.1.1 Recycle Streams with Phosphorus

The prediction of phosphorus removal by EBPR must consider the fate of the waste sludge. Since soluble phosphorus becomes bound in the intracellular polyphosphates through EBPR, phosphorus is actually removed from the system by the removal of excess biomass containing PAOs in sludge wasting from the secondary treatment step. The fate of the sludge waste stream in the solids-handling processes for thickening, stabilization, and dewatering can affect the overall phosphorus removal efficiency for the WWTP. For certain thickening processes, such as gravity figures, anaerobic conditions can be developed in the sludge and the PAOs will release some of the stored phosphorus. In anaerobic sludge digestion, phosphorus release also occurs, and about 30 to 40% of the phosphorus in anaerobic digestion can be released back into solution and returned with the liquid following sludge dewatering. In aerobic digestion, phosphorus is also released in direct proportion to the breakdown and mass destruction of the aerobic biomass, again at levels in the 40% range. When such solids handling processes are applied, the design must account for phosphorus return from the sludge processing. The effect of the recycle stream is to essentially increase the influent phosphorus concentration to the WWTP. Some solids handling processes have little impact on phosphorus release and return. Thickening by dissolved air flotation will prevent phosphorus release and for thickening by gravity belt filters, phosphorus release is minimal. When solids are reused by composting or by holding and direct hauling with dewatering the phosphorus return is minimized also.

2.2.1.2 Factors That Affect EBPR Phosphorus Removal Efficiency

The various conditions and parameters that impact EBPR efficiency can be grouped into three major categories: wastewater characteristics, environmental factors, and design/operating parameters.

The wastewater characteristics may be the most important parameter that affects phosphorus removal efficiency. Based on the mechanism described above for phosphorus removal, it is clear that as more VFA is supplied to an EBPR system, more PAOs can be grown and thus more phosphorus removal is possible. The VFA is supplied in two ways to the anaerobic contact zone. It is contained to some degree in the influent wastewater and is generated from fermentation in the anaerobic zone of soluble readily biodegradable COD that is in the influent wastewater. Soluble readily biodegradable COD (rbCOD) is truly soluble degradable organic compounds that are easily consumed by bacteria. In contrast, colloidal and particulate biodegradable substances require hydrolysis by extracellular enzymes before being available for biodegradation. In general, a greater phosphorus removal capacity has been correlated with higher influent wastewater BOD/P ratios, which indirectly assumes that more rbCOD is available as the influent BOD concentration increases. However the fraction of rbCOD in municipal wastewaters will vary, depending in large part on industrial wastewater contributions. General assumptions on EBPR performance, based only on influent BOD/P ratios, may be inaccurate. High phosphorus removal efficiency with effluent phosphorus concentrations of less than 1.0 mg/L has been associated with very high influent BOD/P ratios in excess of 40:1 for domestic wastewaters, but for many wastewaters the ratio is in the 20-30 range.

VFAs or rbCOD in the influent wastewater needed for EBPR and thus phosphorus removal efficiency may be decreased in direct proportion to the amount of oxygen and nitrate entering the anaerobic zone. Bacteria that can use oxygen or nitrate as electron acceptors will consume the influent rbCOD and VFA at a faster rate than that for fermentation and uptake of VFAs by PAOs. The wastewater plant process configuration must be addressed to minimize the amount of nitrate that may enter the anaerobic zone. EBPR process designs that address nitrate removal are presented below. Methods that result in aeration of the wastewater prior to feeding to the anaerobic contact zone, such as aerated grit chambers, screw pumps, and aerated feed channels must be minimized to prevent rbCOD uptake before the anaerobic contact zone or feeding oxygen into the anaerobic contact zone.

Certain treatment processes may remove rbCOD and VFAs ahead of EBPR process. Fixed film processes, such as trickling filters and rotating biological contactors, are in this category and it makes the application of EBPR more problematic as will be shown for alternatives presented in Section 4.

The VFA supply can be augmented. In many communities, especially those with combined sewer systems or short travel times in the sewer, the influent readily biodegradable COD concentrations can be relatively low. To increase the readily biodegradable COD, some treatment plants add VFAs chemically by the purchase of acetate or sugar or operate primary sludge fermenters to produce the VFAs needed for EBPR.

Environmental factors such as temperature and pH have been shown to have some impact on EBPR efficiency. Recent research (Filipe et al., 2001a; Filipe et al., 2001b) has documented an optimum pH range of 7.0 to 7.5 for PAOs, with decreasing activity at lower pH values. Temperature impacts the process as it relates to VFA generation in the anaerobic zone (Stensel, 1991). No impairment of PAO metabolism has been reported for low temperature operation other than decreasing the rate of VFA production and phosphorus uptake. However the minimal SRT for PAOs is less than that for nitrification showing that they are impacted by temperature at about the same level as many heterotrophic bacteria.

A number of process designs have been developed to apply EBPR and these are described in Section 2.2.1.3. In all of these an anaerobic contact basin is essential and this may be followed by anoxic or aerobic basins. Important process design and operating factors related to these designs are described as follows.

Anaerobic contact time can determine the amount of VFAs available to support EBPR. Longer anaerobic contact times can result in a greater conversion of colloidal and particulate biodegradable substances to VFAs to increase phosphorus removal efficiency. However, some research has shown that if PAOs are held under anaerobic conditions too long without a steady VFA, phosphorus can be released without any PHB formation (Barnard, 1984). This phenomenon, termed "secondary release", is detrimental to EBPR because the released phosphorus is not taken up under aerobic conditions as it was not associated with VFA uptake and PHB storage.

Diurnal fluctuations in hydraulic and organic loading rates can lead to wide fluctuations in anaerobic and aerobic contact times and the amount of VFA available for the PAOs. A more uniform and steady supply of VFA improves EBPR performance. In bench-scale reactor research using synthetic wastewater, Stephens and Stensel (1995) showed that EBPR performance could be negatively affected by periods of low food or VFA availability.

Nitrification can have an impact on EBPR by increasing the nitrate concentration in the return activated sludge (RAS) stream. This results in more VFA consumption in the anaerobic contact zone for nitrate reduction, leaving less VFA for the PAOs that causes a reduction in EBPR efficiency.

Sidestream processes may help or hinder EBPR efficiency. Sludge thickening processes that produce VFAs can produce intermittent loads that may benefit phosphorus removal performance, while other sludge processing operations, such as digestion, may return phosphorus to the liquid treatment system to essentially increase the influent phosphorus loading. This may result in increased effluent phosphorus concentrations if sufficient readily degradable COD is not available for the PAOs.

Solids retention time (SRT) is a fundamental design parameter for activated sludge systems and the SRT used is usually dictated by requirements of BOD removal, ammonia removal, or denitrification. However, the design SRT could impact phosphorus removal performance. At longer SRTs, a greater proportion of the PAOs that are produced are lost to endogenous decay, resulting in less PAOs in the waste sludge, and thus a lower phosphorus removal efficiency (Stensel, 1991; Whang and Park, 2001 and 2002).

2.2.1.3 EBPR Process Descriptions

The advent of a new generation of activated sludge treatment technology occurred in the mid 1970s when Barnard (1974) recognized key process requirements that promoted enhanced biological phosphorus removal (EBPR) in activated sludge processes. The key process configuration proposed was termed the Phoredox process and involved the use of an anaerobic contact basin with a relatively short hydraulic retention time (45-60 minutes) prior to the aerobic treatment reactor (Figure 2-1). This process is commonly referred to today as the A/O process.

Influent wastewater and return activated sludge are mixed in the anaerobic reactor prior to an aeration tank. Nitrate and oxygen input to the anaerobic reactor must be minimal, so that one of the main metabolic conditions for substrate utilization is anaerobic fermentation. Barnard (1974) noted that nitrate or oxygen into the anaerobic contact zone would consume substrate that would otherwise be used for EBPR. The process configuration promotes the selection of bacteria that are capable of removing and storing phosphorus at high levels in the aeration zone, and are referred to as phosphorus accumulating organisms (PAOs). Phosphorus is removed from the system via excess sludge production rich in stored phosphorus. Other process configurations have been developed to maximize phosphorus removal efficiency using the concept of anaerobic contacting preceding aerobic treatment.

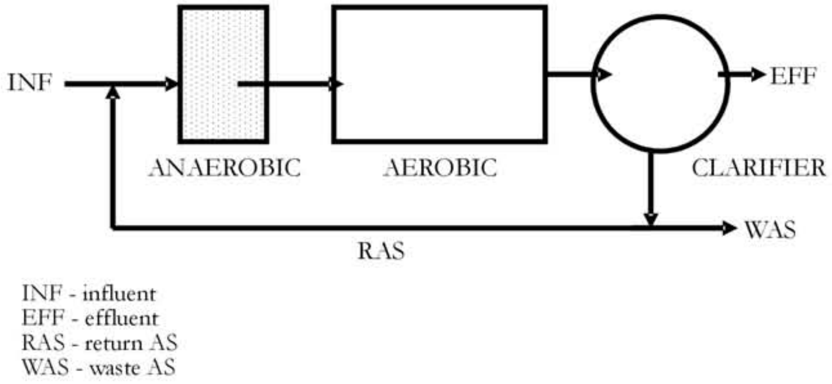


Figure 2.1 - Anaerobic/Aerobic Process (A/O) for Enhanced Biological Phosphorus Removal (EBPR)

Other process configurations that incorporate the A/O process are presented in Figures 2-2 through 2-5. They show different designs that were developed to minimize the amount of nitrate that may enter the anaerobic contact zone in the return activated sludge. For systems in which nitrification occurs, the simple A/O treatment scheme shown in Figure 2-1 is not appropriate because the nitrate in the return activated sludge flow will result in decreased EBPR efficiency. For the anaerobic/anoxic/aerobic (A^2O) process in Figure 2-2, 75–85% of the nitrate produced by nitrification in the aerobic zone is removed by an internal recycle of nitrate to a preanoxic zone, where nitrate provides an electron acceptor for BOD removal in lieu of aerobic respiration.

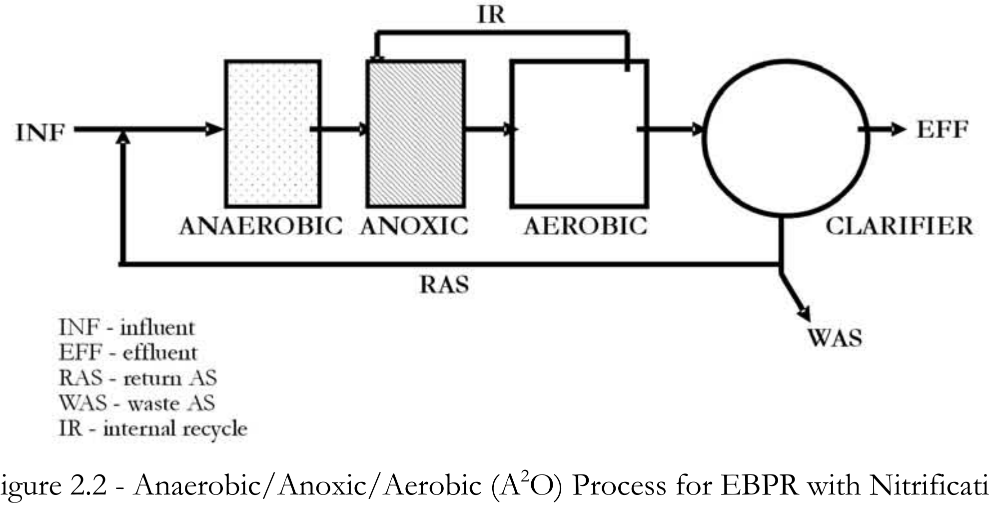


Figure 2.2 - Anaerobic/Anoxic/Aerobic (A^2O) Process for EBPR with Nitrification

Thus, a lower concentration of nitrate is directed to the anaerobic reactor in the return activated sludge (RAS) stream. In the modified Bardenpho Process (Figure 2-3) the RAS nitrate concentration is minimized further by the addition of an anoxic zone after the aeration zone.

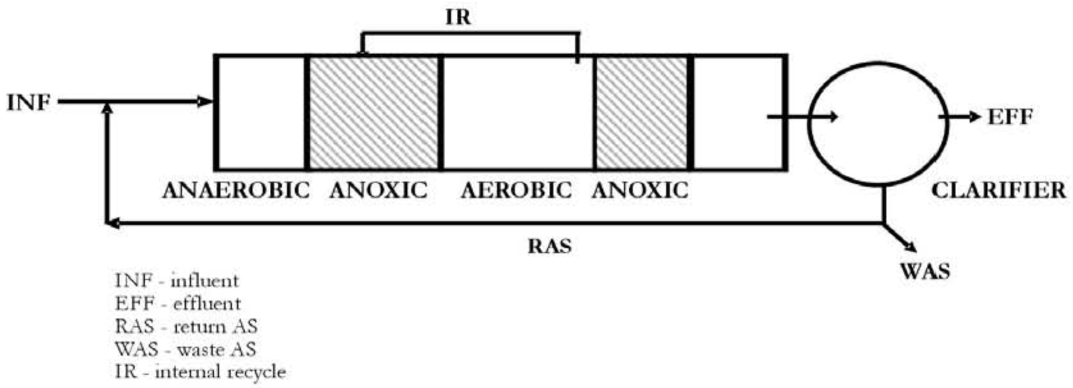


Figure 2.3 - Modified Bardenpho Process for EBPR and to Minimize Nitrate

Processes that result in none or very little nitrate feed to the anaerobic zone are described by Figures 2-4 and 2-5; the University of Capetown (UCT) and Johannesburg (JHB) processes, respectively. In the UCT process the RAS is directed to an anoxic zone first for nitrate removal. The anoxic zone mixed liquor, with a minimal nitrate concentration, is recycled to the anaerobic zone to provide mixed liquor to the reactor. Another version of the UCT process is the modified UCT (MUCT) process in which the anoxic zone is staged with return of mixed liquor from the last stage to the anaerobic contact zone to assure minimal nitrate to the anaerobic zone.

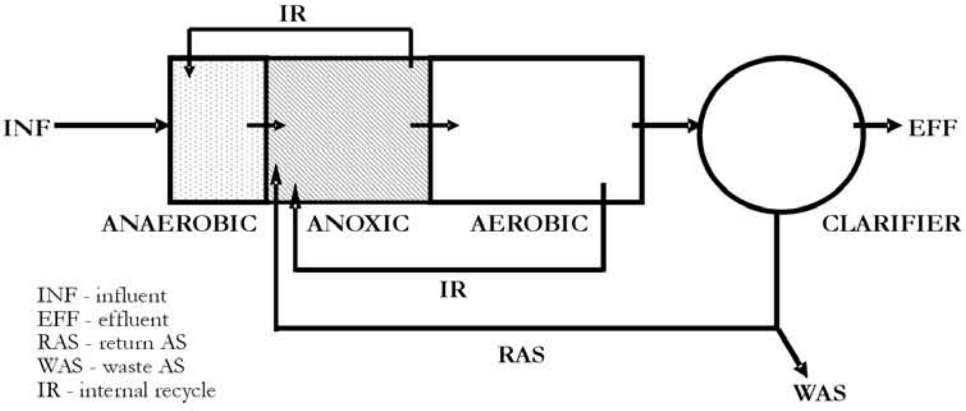


Figure 2.4 - University of Capetown (UCT) Process for EBPR with Minimal Nitrate Feed to the Anaerobic Zone

The JHB process (Figure 2-5) has a simpler operation and less recycle systems than the UCT or MUCT, but also assures minimal nitrate feed to the anaerobic contact zone by holding the RAS in a mixed anoxic tank prior to the anaerobic zone. All of these processes have the necessary anaerobic contact zone to provide EBPR.

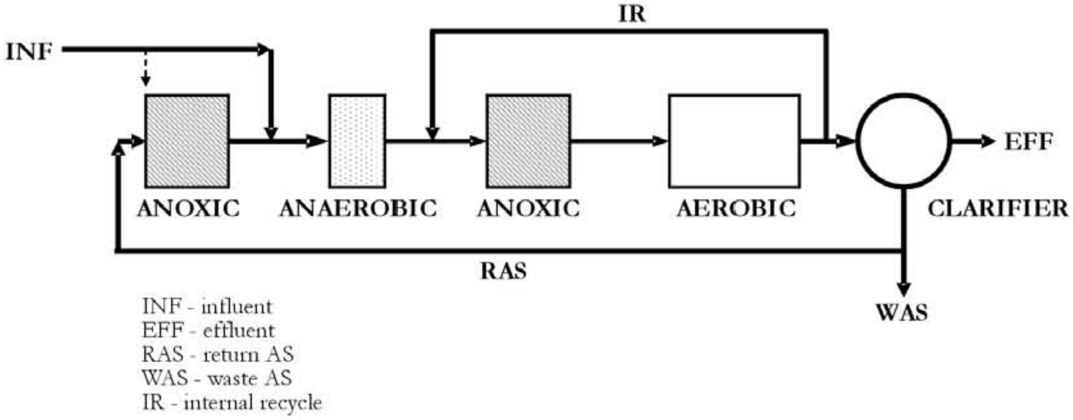


Figure 2.5 - Johannesburg (JHB) Process for EBPR to Minimize Nitrate in Influent to the Anaerobic Contact Zone by Denitrification of RAS

For the evaluation of alternatives incorporating EBPR at existing facilities in Section 5, the commonly used A^2O process shown in Figure 2.2 will be used as a representative EBPR process as it is one that is commonly used. A detailed engineering design analysis for a specific site application would be needed to select between the available processes to find the optimal phosphorus removing process for a particular WWTP.

2.3 EXAMPLES OF FULL-SCALE APPLICATION AND PERFORMANCE

In this section performance data is summarized for the various types of phosphorus removal treatment systems to demonstrate their application and effectiveness. Chemical treatment facilities are presented first followed by EBPR systems.

2.3.1 Chemical Treatment Systems

Chemical treatment is the most common method used for phosphorus removal and numerous plants employ chemical addition, as alum or iron salts, with primary and/or secondary treatment to meet effluent phosphorus concentrations below 1.0 mg/L. Some examples are shown here in a series of tables for chemical addition to primary, secondary, and to both primary and secondary treatment steps of activated sludge plants. An example is also provided for a lagoon and trickling filter system. Phosphorus removal performance for a large number of plants achieving effluent P concentrations less than 1.0 mg/L are summarized in the EPA technology transfer manual on retrofitting POTWs for phosphorus removal in the Chesapeake Bay Drainage Basin (USEPA, 1987).

2.3.1.1 Chemical Treatment to Primary Treatment

Phosphorus removal at the South Shore WWTP (Table 2.1) was accomplished by the addition of waste pickle liquor (ferrous sulfate) to the primary clarifier influent. Chlorine addition was also necessary to oxidize the ferrous to ferric iron, which is needed for effective phosphorus precipitation. The operating results for one year showed that with a dose of about 1.7 mole Fe/mole P, the final effluent phosphorus concentration following primary treatment and activated sludge treatment was in the range of 0.8 to 0.9 mg/L on a monthly average basis. The use of chemicals in the primary treatment step improved the primary treatment efficiency and reduced the BOD and suspended solids loading to the secondary treatment process.

Table 2.1 - Chemical Addition with Primary Treatment at Milwaukee, WI South Shore WWTP (1986)

Parameter	Units	Value
Influent Flow	MGD	100
Influent Total BOD	mg/L	138
Influent TSS	mg/L	169
Influent Total P	mg/L	5.0
Chemical Type		Ferrous sulfate
Chemical Dose	lb as Fe/lb P	1.0
Monthly Average Effluent P	mg/L	0.80 to 0.90

2.3.1.2 Chemical Treatment to Activated Sludge System

Phosphorus removal by alum addition to the activated sludge influent is practiced at the Port Huron, MI WWTP. An example of performance under cold temperature operating conditions is shown in Table 2.2. The alum dose averaged about 4.0 mole Al/mole P and the effluent P concentration averaged about 0.70 mg/L. Polymer addition was used in the secondary clarifier to improved solids capture with alum treatment.

2.3.1.3 Chemical Treatment with Two-Point Dosing

Ferric chloride is added to the influent of the primary and secondary treatment systems at the lower Potomac Fairfax County WWTP to meet very low effluent phosphorus concentrations. The data are summarized in Table 2.3. After secondary treatment polishing filters were used to improve the effluent solids removal, which reduces the effluent phosphorus concentration. For 1987, the effluent phosphorus concentration averaged 0.12 mg/L. About half of the iron dose was added to the primary treatment step, and for the long-term operation, the iron dose averaged around 4.0 mole Fe per mole P removed. The dose was higher than that which could have been used to meet an effluent, phosphorus concentration of 1.0 mg/L.

Table 2.2 - Chemical Addition with Secondary Treatment at Port Huron, MI WWTP (Winter 1986)

Parameter	Units	Value
Influent Flow	MGD	11.8
Influent Total BOD	mg/L	89.2
Influent TSS	mg/L	75.6
Influent Total P	mg/L	2.7
Chemical Type		Alum + polymer
Chemical Dose	lb as Al/lb P	3.6
Monthly Average Effluent P	mg/L	0.70

Table 2.3 - Chemical Addition to Primary and Secondary Treatment Steps at the Lower Potomac WWTP (1987)

Parameter	Units	Value
Influent Flow	MGD	33.0
Influent Total BOD	mg/L	177
Influent TSS	mg/L	215
Influent Total P	mg/L	7.0
Chemical Type		Ferric
Chemical Dose	lb as Fe/lb P	2.5
Monthly Average Effluent P	mg/L	0.12

2.3.1.4 Chemical Treatment with Trickling Filters

An example of chemical addition for a trickling filter secondary treatment system at Elizabethtown, PA is shown in Table 2.4. The effluent limit was 2.0 mg/L P concentration and the plant averaged 1.2 mg/L, with an average alum dose to the secondary clarifier of 2.2 mole Al/mole P. Polymer was added at 0.80 mg/L and the secondary clarifier effluent TSS concentration averaged 15 mg/l.

Table 2.4 - Chemical Addition to Trickling Filter WWTP at Elizabethtown, PA (1987)

Parameter	Units	Value
Influent Flow	MGD	1.7
Influent Total BOD	mg/L	133
Influent TSS	mg/L	223
Influent Total P	mg/L	7.3
Chemical Type		Ferric
Chemical Dose	lb Al/lb P	2.5
Monthly Average Effluent P	mg/L	1.2

2.3.1.5 Chemical Treatment with Lagoons

Alum treatment by batch addition to lagoons using a boat for to provide the alum feeding and mixing has been reported for Isle and Belle Plaine, Minnesota. An effluent P concentration of less than 1.0 mg/L P was achieved with alum applications of 2.0 and 3.0 lb Al/lb P removed (1.7 and 2.6 mole Al/mole P, respectively). With this batch feeding operation monitoring methods are needed to determine when the lagoon phosphorus concentration is reduced to acceptable levels before the chemical dosing is temporarily stopped.

2.3.2 Enhanced Biological Phosphorus Removal (EBPR) Systems

Compared to chemical treatment, a wider range of design and operating conditions are possible for EBPR systems and these affect the effluent P concentration that can be produced. The variables in system design and operation include the aerobic SRT, the method to remove nitrate (e.g. A^2O, JHB, Bardenpho), the influent BOD/P ratio, and the addition of metal salts for phosphorus precipitation in conjunction with EBPR. Some examples of wastewater designs and performance are shown in this section to illustrate EBPR applications for a variety of situations.

Many facilities that employ EBPR processes also use some form of chemical addition to assure that the effluent phosphorus concentration required can be met. Based on the results of a recent survey on existing EBPR facilities, it was found that most plants used some form of chemical addition, either metal salts for phosphorus precipitation or VFA addition, to achieve effluent phosphorus concentrations below 1.0 mg/L. The results of this survey are illustrated in Figure 2.6. For the EBPR plants without VFA or chemical addition, only 40% of them could achieve an annual average effluent phosphorus concentration of 1.0 mg/L or less. The need for VFA or chemical addition, is related more to the influent wastewater characteristics than to the EBPR process design. Thus, the EBPR performance experiences presented in the following sections are very site-specific, and are presented to demonstrate the phosphorus removal abilities of EBPR processes with and without chemical addition.

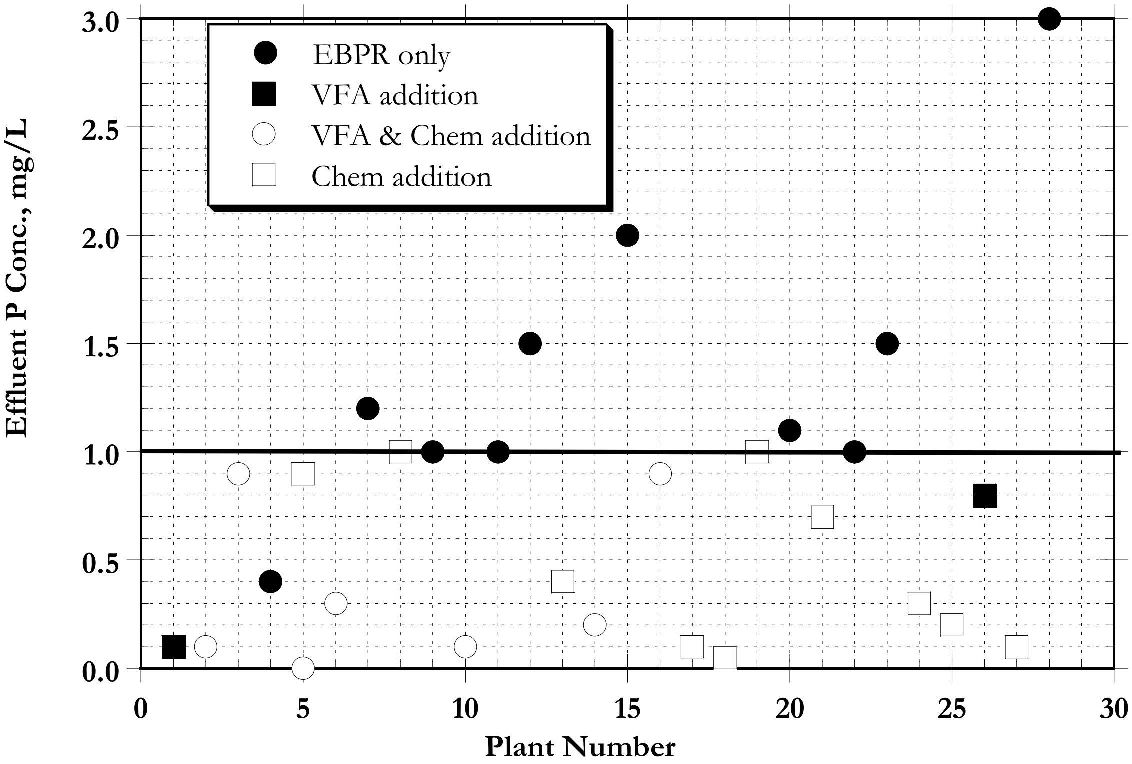


Figure 2.6 - Plant Survey Results for EBPR Wastewater Treatment Plants Showing Ability to Achieve P Concentration < 1.0 mg/L (Annual Average Data)

2.3.2.1 Conventional Activated Sludge Process with Anaerobic Contact Zone for EBPR

An example of converting a conventional activated sludge process to an EBPR system by the addition of an anaerobic contact zone is provided by results reported for the East Boulevard plant at Pontiac, Michigan. The system consisted of primary treatment followed by a secondary treatment activated sludge process. The HRTs of the anaerobic contact zone and activated sludge aeration basins were 1.7 and 6.4 hours, respectively. The results in Table 2.5 show that the EBPR system could achieve a very low effluent phosphorus concentration in the range of 0.30 – 0.90 mg/L, even though the anaerobic zone received a significant nitrate in the return sludge recycle. The system was operating at high enough SRTs to support nitrification and no anoxic treatment zone was provided to remove nitrate. However, a key factor related to the high phosphorus removal performance was the influent BOD/P ratio, which had an average value of 70. A value of 40 is considered a good level to promote EBPR. At the high BOD/P ratio available excess rbCOD was available for biological phosphorus removal.

Table 2.5 - EBPR Process with Conventional Activated Sludge – Anaerobic/Aerobic Process at Pontiac, MI WWTP (Results for 1987)

Parameter	Units	Value
Influent Flow	MGD	3.5
Influent Total BOD	mg/L	228
Influent TSS	mg/L	213
Influent TKN	mg/L	22
Influent Total P	mg/L	3.2
Aeration MLSS	mg/L	2500-3000
SRT	days	11 – 20 days
Influent BOD/P	g/g	71
Monthly Average Effluent P	mg/L	0.30 – 0.90

2.3.2.2 A^2O Process for EBPR

Treatment performance results for the operation of the A^2O process at the York River WWTP are shown in Table 2.6 and illustrates the effect of a relatively low BOD/P ratio on EBPR performance. With the A^2O process the effluent NO_3-N concentration ranged from 4–6 mg/L, but the effluent total P concentration averaged 4.2 mg/L for a 3 month sampling period from August through October. The relatively low influent BOD/P ratio suggest that there not a sufficient amount of rbCOD in the feed to the anaerobic zone to support enough PAO growth to remove P to effluent concentrations below 1.0 mg/L.

Table 2.6 - Summary of EBPR Performance for the York River WWTP Operated with A^2O Process (Results for 1986)

Parameter	Units	Value
Influent Flow	MGD	5.9
Influent Total BOD	mg/L	206
Influent TSS	mg/L	93
Influent TKN	mg/L	25
Influent Total P	mg/L	12.8
SRT	Days	10-12 days
Influent BOD/P	g/g	16
Monthly Average Effluent P	mg/L	4.2

2.3.2.3 A^2O Plant with Primary Sludge Fermentation for EBPR

The Durham Oregon WWTP uses an A^2O process for biological nitrogen and phosphorus removal. The design has included other provisions to further enhance its phosphorus removal efficiency. A primary sludge fermenter is operated to provide additional volatile fatty acids (rbCOD) to the influent to the anaerobic contact zone, and alum is added before the secondary clarifier to control the effluent phosphorus concentration to a target of 0.50 mg/L. On the negative side concerning factors that can affect the performance for EBPR, anaerobic digested sludge is dewatered by centrifugation and a phosphorus rich centrate stream is recycled back to the influent of the secondary treatment system. The plant has demonstrated consistently low effluent phosphorus concentrations with this operation, which is only required in the summer months. The results for the year 2002 are shown in Table 2.7.

Table 2.7 - Summary of EBPR Performance for the Durham, Oregon WWTP Operated with A^2O Process and Primary Sludge Fermentation (Results for 2002)

Parameter	Units	Value
Influent Flow	MGD	20.0
Influent Total BOD	mg/L	221
Influent TSS	mg/L	210
Influent TKN	mg/L	35
Influent Total P	mg/L	7.8
SRT	Days	10 days
Influent BOD/P	g/g	28
Monthly Average Effluent P	mg/L	0.50

2.3.2.4 EBPR with a Trickling filter/Activated Sludge System

A unique design and operation was required to accomplish EBPR for the trickling filter/activated sludge system at the Chapel Hill Mason Farm WWTP. Initial attempt at achieving biological phosphorus removal was made by placing an anaerobic contact zone between the trickling filter effluent and activated sludge aeration basins. This was unsuccessful because a substantial amount of the influent BOD was removed by the trickling filter, which was operated at an organic loading normally used to achieve a secondary treatment effluent. Thus, another source for rbCOD was sought to allow EBPR treatment. This was obtained by using primary sludge fermentation with decanting of fermenter liquor rich in volatile fatty acids, which provided rbCOD in a feed stream to an anaerobic contact zone installed in the activated sludge recycle line. After contacting the return sludge with the rbCOD the anaerobic contact zone effluent was mixed with the trickling filter effluent before the activated sludge aeration basin. The necessary anaerobic-aerobic activated sludge contacting for EBPR was provided by this unique flow schemes. The results for testing in January 1990 as shown in Table 2.8 indicate that effective EBPR treatment was possible.

Table 2.8 - Summary of EBPR Performance for the Chapel Hill Mason Farm Trickling Filter/Activated Sludge WWTP with Primary Sludge Fermentation (Results for January, 1990)

Parameter	Units	Value
Influent Flow	MGD	6.0
Influent Total BOD	mg/L	185
Influent TSS	mg/L	200
Influent Total P	mg/L	7.1
Trickling Filter Loading	lb/d-1000 ft^3	35
Aeration SRT	Days	5 days
Monthly Average Effluent P	mg/L	0.70

2.3.2.5 EBPR with Oxidation Ditch Treatment

The Elburg, Netherlands WWTP has an EBPR process with an oxidation ditch and with alum addition. The plant flow scheme consists of primary treatment, an anaerobic contact zone with a 2.4 hour HRT, an oxidation ditch with about a 24 hour HRT, and secondary clarifiers. Only 20% of the return sludge flow is directed to the anaerobic contact tank which consists of 4 stages. Alum is added to the last stage of the anaerobic contact tank to control the effluent phosphorus concentration. The results are presented in Table 2.9. The average alum dosing rate has been about 0.40 mole Al/mole P. This appears to have overcome a relatively low influent BOD/P ratio and provides a reported average effluent P concentration of 0.60 mg/L.

Table 2.9 - Summary of EBPR Performance for Elburg, Netherlands WWTP Operated with an Oxidation Ditch and Anaerobic Contact Zone Process (Average results for 1995-1998)

Parameter	Units	Value
Influent Flow	MGD	4.76
Influent Total BOD	mg/L	226
Influent TKN	mg/L	49
Influent Total P	mg/L	12.9
SRT	Days	25 days
Influent BOD/P	g/g	18
Monthly Average Effluent P	mg/L	0.60

SECTION 3.0

FACILITIES SELECTED FOR EVALUATION

A screening process was developed to select 17 representative wastewater treatment plants from the 22 MESERB Phosphorus Initiative participants. The selected plants would be examined to evaluate phosphorus removal practices to control the discharge of phosphorus in the final effluent. The objective of the screening process was to select plants with different biological treatment processes, located throughout the State of Minnesota and representative of a broad spectrum of the types of treatment plants in Minnesota. This section presents a summary of the screening process conducted. Included in Section 3 are a discussion of the screening process, a general description of the wastewater treatment plants selected and a summary of the site visits.

3.1 TREATMENT PLANT SCREENING PROCESS

The type of plant data considered for the screening process included plant size, type of plant, permit requirements, existing wastewater characteristics, industrial contributions, and sludge handling operations. A four page wastewater facility screening form was developed to obtain preliminary wastewater treatment plant data. The screening form was reviewed and approved by MESERB and submitted to the 22 participating wastewater treatment plants. An example screening form is included as Appendix 1.1. The form was divided into the following six categories: 1. General Plant Information such as plant name, contact, and plant size; 2. Discharge Permit Information including permit limits, actual discharge concentrations and sample type and frequency; 3. Liquid Process Description Section requesting information on the type and size of pretreatment units, primary treatment, secondary treatment, secondary clarifiers, tertiary treatment and disinfection; 4. Sludge Processing/Ultimate Reuse or Disposal information on primary and secondary thickening, sludge digestion, dewatering and sludge storage, and disposal; 5. Additional Information on industrial contributions and collection system; and 6. Plant Sampling and Analysis of influent and effluent type and frequency of sampling and in-plant laboratory capabilities.

3.2 SELECTED WASTEWATER TREATMENT PLANTS

The completed screening forms were reviewed and the data summarized into two categories, general plant information and treatment processes. Three plants did not submit a screening form and were not considered for the evaluation. The 19 plants were grouped into the following eight biological treatment processes: activated sludge, biological nutrient removal (BNR), oxidation ditch, high purity oxygen biological treatment, trickling filter, combined trickling filter and activated sludge, lagoons, and rotating biological contactors (RBC). These biological processes are discussed in detail in Section 4, Application of Phosphorus Removal Technology for Upgrading Plants. Two plants, Warroad and Winona, had treatment characteristics similar to other plants in the study and were not selected. Warroad is a 0.37 million gallon per day (MGD) lagoon treatment system and is one of three pond wastewater treatment systems participating. Winona is a 6.5 MGD activated sludge treatment system similar to the other biological treatment systems. The completed forms are included in Appendix 1.2. The following treatment plants were selected:

- Alexandria Lake Area Sanitary District Wastewater Treatment Facility (WWTF) is a 3.25 MGD activated sludge plant with tertiary treatment and chemical addition. The plant has a phosphorus limit of 1.0 mg/L and discharges to Lake Winona.
- Brainerd and Baxter Wastewater Treatment Plant (WWTP) is a 3.13 MGD Rotating Biological Contactor (RBC) treatment plant with primary and secondary clarifiers and discharges to the Mississippi River. The plant has no limits for phosphorus or ammonia nitrogen.
- Detroit Lakes WWTF is a 1.64 MGD trickling filter plant with primary and final clarifiers. The plant has a phosphorus discharge limit of 1.0 mg/L and the final effluent discharges into Lake St. Clair.
- Faribault WWTF is a 7.0 MGD combined trickling filter and activated sludge system with primary and secondary clarifiers. There are several food industries discharging wastewaters into the plant. The plant is required to monitor for phosphorus and ammonia nitrogen. The plant discharges to the Cannon River.
- Fergus Falls WWTP is a 2.81 MGD Biological Nutrient Removal (BNR) treatment system with primary and final clarifiers. The plant has a phosphorus discharge limit of 1 mg/L and an ammonia nitrogen (NH_4-N) discharge limit of 4.3 mg/L. The effluent is discharged to the Otter Tail River.
- Glencoe WWTF is a 1.60 MGD combined trickling filter and activated sludge with primary and secondary clarification and filters for tertiary treatment. The plant has total nitrogen discharge limits and the final effluent discharges to Buffalo Creek. The plant has no permit requirements for phosphorus.
- Grand Rapids WWTF is a 14.3 MGD activated sludge plant with primary and secondary clarifiers and polishing ponds for tertiary treatment. The major industrial contributor is a paper mill which discharges nutrient deficient wastewater to the treatment plant. This requires the addition of ammonia and phosphorus at the treatment plant. The plant discharges to the Mississippi River. The plant is required to monitor for phosphorus. There are no permit requirements for nitrogen.
- Little Falls WWTF is a 2.4 MGD combined trickling filter/activated sludge plant with primary and secondary clarification. The plant monitors for phosphorus and ammonia nitrogen and discharges to the Mississippi River.

- Marshall WWTF is a 3.3 MGD trickling filter/activated sludge plant with industrial contributions from several food processing plants. The plant has no permit requirements for phosphorus or ammonia nitrogen and discharges to the Redwood River.
- Moorhead WWTF is a 6 MGD high purity oxygen wastewater treatment plant with an ammonia limit from June to September. The plant samples for phosphorus and ammonia. The plant discharges to the Red River of the North.
- New Ulm WWTF is a 6.77 MGD activated sludge system with primary and final clarification. There are at least two industries that discharge into the New Ulm system. The plant discharges between 4 and 5 mg/L phosphorus into the Minnesota River. Monthly monitoring for phosphorus in the effluent is required. There are no permit discharge limits for phosphorus or nitrogen.
- Redwood Falls WWTP is a 0.824 MGD lagoon system with no industrial contributions and discharges to the Minnesota River. The plant monitors for phosphorus and ammonia in the effluent and has a discharge limit for ammonia nitrogen.
- Rochester Water Reclamation Plant (WRP) is a 19.1 MGD high purity oxygen treatment system with phosphorus discharge level of 1.0 mg/L and ammonia nitrogen limit of 1.6 mg/L. The plant discharges to the Zumbro River.
- St. Cloud WWTF is a 13 MGD BNR plant with primary and secondary clarification. There are no permit requirements for nitrogen or phosphorus. The plant discharges less than 1 mg/L phosphorus into the Mississippi River.
- Thief River Falls WWTP is a 2.57 MGD wastewater treatment lagoon system treating several industries. The treatment system has no permit limits for phosphorus or nitrogen. Total nitrogen and phosphorus is monitored in the effluent prior to discharging to the Red Lake River.
- Wadena WWTF is a 0.50 MGD oxidation ditch treatment system with primary and secondary clarification and filtration is a tertiary treatment step. The plant is required to monitor for phosphorus and data indicated effluent levels at 2 mg/L. There are three different seasonal ammonia nitrogen (NH_4-N) discharge limits for December through September. The plant discharges to Union Creek.
- Whitewater River Pollution Control Facility (PCF) serving the Dover, Eyota and St. Charles Sanitary District is a 0.80 MGD oxidation ditch treatment system with no primary clarification. The plant has a filter following the secondary clarifiers. The plant has no permit limits, monitors for phosphorus and ammonia nitrogen and discharges into the South Fork of the Whitewater River.

A summary of the general plant information and preliminary treatment process data collected from the screening forms is presented in Tables 3.1 and 3.2, respectively, for the selected plants. These data were used specifically for the selection and grouping of the treatment plants.

Table 3.1 - General Plant Information

(Screening Form Data and Permit Information)

	Flow (MGD)		Phosphorus (mg/L)		Ammonia-Nitrogen (mg/L)			
Treatment Plants by Process Category	*Design	Existing	*Permit Limit	*Effluent	*NH_4-N Permit Limit	NH_4-N Effluent	Receiving Water Body	Industrial Contributions
Activated Sludge								
Alexandria Lake WWTF	3.25	2.60	1.0	0.33	MO	NA	Lake Winona	Northern Food and Dairy, Nordic Asceptic, 3M (Abrasives)
Grand Rapids WWTF	14.3	9.00	MO	NA	(July-Sept) 8	NA	Mississippi River	Paper Mill (provides nutrient deficit which requires the addition of N/P)
New Ulm WWTF	6.77	2.60	MO	4-5		NA	Minnesota River	Kraft Foods, Schell Brewing Co.
Biological Nutrient Removal (BNR)								
St. Cloud WWTF	13.0	9.74	MO	0.97	NR	NA	Mississippi River	Metal finishers, commercial laundry
Fergus Falls WWTP	2.81	1.90	1.0	0.66	(July-Sept) 4.3	1.0	Otter Tail River	None
Oxidation Ditch								
Wadena WWTF	0.50 (dry) 0.75 (wet)	0.35	MO	2	*Seasonal Limit, see Table 3.3*		Union Creek	Metal finishing, car washes, laundromat, dry cleaner, hospital, nursing home
Whitewater River PCF	0.80	0.68	MO	6.9	*Seasonal Limit, see Table 3.3*	0.24	South Fork, Whitewater River	North Star Foods, Inc
High Purity Oxygen (HPO)								
Moorhead WWTF	6.0	4.2	MO	3.9	MO	2.2	Red River of the North	Malt House, paper packaging, railway yard
Rochester WRP	19.1	13.7	1.0	0.8	1.6	0.1	Zambro River	Dairy, cannery, cheese processing
Trickling Filter								
Detroit Lakes WWTF	1.64	1.30	1.0	5	MO	NA	Lake St. Clair	None
Trickling Filter/Activated Sludge								
Faribault WWTF	7.0	4.5	MO	4	MO	6	Cannon River	Faribault Foods (cannery), Turkey Store (turkey processing), Protient (soy protein)
Marshall WWTF	3.3	2.4	NR	7.5	*Seasonal Limit, see Table 3.3*	NA	Redwood River	Corn processing, ice cream & convenience food plants
Glencoe WWTP	1.6	0.85	MO	NA	*Seasonal Limit, see Table 3.3*		Buffalo Creek	Dairy
Little Falls WWTF	2.4	1.3	MO	2.5	MO	10	Mississippi River	Ethanol Plant (does not pre-treat)
Lagoons								
Redwood Falls WWTP	1.3	0.79	NR	0.65-5.85	*Seasonal Limit, see Table 3.3*	0.08-33.0	Minnesota River	None
Thief River Falls WWTP	2.6	1.53	MO	5	MO	NA	Red Lake River	Food processing, recreational vehicles
Rotating Biological Contactors								
Brainerd Area WWTP	3.13	2.70	MO	17.5	MO	2.4	Mississippi River	Acrometal, North Star Plating (metal anodizing)

NR = No Requirement

NA = Not Available/Not Known

MO = Monitor Only

*All treatment plant drainage areas are separate sewers with the exception of Little Falls which has a few blocks of combined sewer systems

Table 3.2 - Preliminary Treatment Process Information

(Screening Form Data Only)

						Sludge Handling Operations			
Treatment Plants by Process Category	Pre-Treatment	Primary/ Final	Secondary	Tertiary	Disinfection	Primary/ Secondary Thickening	Digestion	Dewatering	Disposal
Activated Sludge									
Alexandria Lake WWTF	Self-cleaning bar screens, comminutor, aerated grit removal, other grit removal	Clarifiers	AS	Sand/Anthracite filters	Chlorinination/ Dechlorination	Primary Tanks	Aerobic	Centrifuge	Land Application
Grand Rapids WWTF	Self-cleaning bar screen	Clarifiers	AS	Polishing Ponds	Chlorine	Primary Tanks/Gravity	None	Belt Filter Press	Landfill
New Ulm WWTF	Bar screen, comminutor, aerated grit removal	Clarifiers	AS	None	Chlorinination/ Dechlorination	Gravity	ATAD		Land Application
Biological Nutrient Removal (BNR)									
St. Cloud WWTF	Self-cleaning bar screen, other grit removal	Clarifiers	AS BNR	None	Chlorinination/ Dechlorination	Gravity, Belt Thickener, DAF	Anaerobic		Land Application
Fergus Falls WWTP	Self-cleaning screens, aerated grit removal	Clarifiers	AS BNR	None	Chlorinination/ Dechlorination	Primary Tanks, Gravity	Anaerobic	Belt Filter Press	Land Application
Oxidation Ditch									
Wadena WWTF	Comminutor, Aerated Grit Removal, Hydro gritter	Clarifiers	OD	Traveling carriage filter	Chlorinination/ Dechlorination	None	Anaerobic		Land Application
Whitewater River PCF	Self-cleaning screens, Vortex grit removal system	Final Only	OD	Sand/Coal Filter	Chlorinination/ Dechlorination	None	None	None	Land Application
High Purity Oxygen (HPO)									
Moorhead WWTF	Self-cleaning bar screen, aerated grit removal	Clarifiers	O_2	None	Chlorinination/ Dechlorination	DAF	Anaerobic		Land Application
Rochester WRP	Self-cleaning screens, aerated grit removal	Clarifiers	O_2	None	Chlorinination/ Dechlorination	Belt Thickeners	Anaerobic	6% thickened on gravity belt thickeners	Land Application
Trickling Filter									
Detroit Lakes WWTF	Bar screen, Aerated Grit Removal	Clarifiers	TF	None	Chlorine	Gravity	Anaerobic	None	Land Application
Trickling Filter/Activated Sludge									
Faribault WWTF	Self-cleaning bar screens, aerated grit removal	Clarifiers	TF+AS	None	Chlorinination/ Dechlorination	Gravity	Anaerobic	None	Land Application
Marshall WWTF	Comminutor, Vortex	Clarifiers	TF+AS	Traveling Bridge Filter	Ultraviolet	None	Anaerobic	None	Land Application
Glencoe WWTP	Bar screen/washer packer, Cyclone grit removal	Clarifiers	TF+AS	Sand/Coal Filter	Chlorinination/ Dechlorination	Primary Tanks/DAF	Anaerobic	Drying Beds	Land Application
Little Falls WWTF	Self-cleaning bar screens, aerated grit removal, other grit removal	Clarifiers	TF+AS	None	Chlorinination/ Dechlorination	Gravity	Anaerobic	None	Land Application
Lagoons									
Redwood Falls WWTP	None	None	L	None	None	No Sludge	No Sludge	No Sludge	No Sludge
Thief River Falls WWTP	Bar screen	None	L	None	None	No Sludge	No Sludge	No sludge	No Sludge
Rotating Biological Contactors (RBC)									
Brainerd Area WWTP	Self-cleaning screens, aerated grit removal w/ auger, grit pump	Clarifiers	RBC	None	Chlorinination/ Dechlorination	Gravity	Anaerobic	None	Land Application

AS = Activated Sludge
BNR = Biological Nutrient Removal
RBC = Rotating Biological Contactor
TF = Trickling Filter
L = Lagoon
OD = Oxidation Ditch
F = Effluent Filter

Data in these tables were reviewed with plant personnel during the site visits and updated where appropriate. Completed updated plant data sets are presented in Appendix 2, and pertinent plant information from the Appendix was used for the plant evaluations in Section 5.

Table 3.1 presents a summary of the general plant information for each plant including design and existing flows, permit limits and effluent concentration for phosphorus, ammonia nitrogen (NH_4-N) and total nitrogen, the receiving water body, and industrial contributions. The data on Table 3.1 show that the wastewater design flows range between 0.5 MGD to 19.1 MGD. Of the 17 plants evaluated, 15 sample for phosphorus, 8 sample for ammonia nitrogen and 14 plants receive wastewater from industrial operations. Four plants, Alexandria, Fergus Falls, Rochester, and Detroit Lakes have a phosphorus discharge limit of 1.0 mg/L. Eight plants, Grand Rapids, Fergus Falls, Wadena, Whitewater River, Rochester, Marshall, Glencoe, and Redwood Falls have permit limits for ammonia nitrogen.

The preliminary treatment process information is presented in Table 3.2. The table includes a list of the treatment units for each plant including pretreatment steps, primary and final clarification, secondary biological treatment, tertiary treatment (e.g., filtration), disinfection, and sludge handling operations. The plants are grouped by biological process category. There are three activated sludge plants, two biological nutrient removal plants (BNR), two oxidation ditch facilities, two high purity oxygen plants, one trickling filter plant, four combined trickling filter and activated sludge systems, two lagoon systems, and one rotating biological contactor (RBC) plant. Also, there are five plants that have a filtration step after final clarification (tertiary treatment), five plants dewater the waste sludge, and all plants except Grand Rapids and the two lagoon treatment systems, Redwood Falls and Thief River Falls, land apply the stabilized biosolids.

3.3 SITE VISITS

The site visits were scheduled during September and October, 2003, as follows:

- week of September 15 – St. Cloud, Whitewater, Rochester, Faribault, and Glencoe
- week of October 6 – Grand Rapids, Brainerd, Wadena, and Little Falls
- week of October 20 – Alexandria, Fergus Falls, Detroit Lakes, Thief River Falls, Moorhead, Marshall, New Ulm, and Redwood Falls

The purpose of the site visits was to obtain plant information to become familiar with the operations and capabilities relative to assessing the treatment requirements for effective phosphorus removals. At each site, there was a presentation of the project goals and approach to evaluate phosphorus removal options, a plant tour, and a review of plant operations and the need for additional plant information.

The visits began with a brief presentation on the Phosphorus Initiative project. The presentation focused on the different types of plants selected for the evaluation, a review of the approach and factors affecting different phosphorus removal technologies, and the need for additional plant data and a review of different biological phosphorus removal and chemical treatment systems. A copy of the presentation is included in Appendix 1.3. Copies of the presentation were provided to plant personnel. Details on the approach and procedure used to evaluate different phosphorus removal options is discussed in Section 4.

All unit operations were reviewed during the plant tour including discussions with plant personnel on individual treatment units (e.g., secondary treatment, sludge handling and disposal, process return lines), plant operations including plant performance and capabilities, design conditions, removal rates, chemical addition, and existing and future permit discharge limits. Plant personnel at all facilities were very cooperative and helpful in reviewing plant operations and capabilities and in providing requested information promptly. The information requested included the following:

- Permit information such as discharge limits, seasonal requirements and sample type and frequency;
- Plant design data such as design flow, carbonaceous biochemical oxygen demand ($CBOD_5$) and total suspended solids (TSS) loadings, and size of treatment units;
- Latest facility plan report including process flow diagrams;
- Plant performance reporting data including discharge monitoring reports;
- Plant monitoring data on individual treatment units (e.g., pH, temperature, mixed liquor suspended solids (MLSS), dissolved oxygen (DO));
- Influent wastewater characterization data for $CBOD_5$, TSS, ammonia, phosphorus;
- Sludge handling and disposal activities such as thickening, dewatering, digestion, disposal, return lines; and
- Sample collection methods and laboratory capabilities.

The influent and effluent wastewater characteristics and pertinent permit information are summarized on Table 3.3. For each plant, design and actual flows are presented along with the monthly averages of the influent and effluent parameters; BOD ($CBOD_5$), TSS, total phosphorus (TP) and ammonia-nitrogen (NH_4-N). Permit limits for BOD, TSS, TP and NH_4-N are also presented for each plant. These data along the preliminary plant data summarized on Tables 3.1 and 3.2 were used with additional treatment plant information collected during the site visits to develop conceptual designs for the evaluation of phosphorus removal. A detailed description of each plant and the analyses conducted on the evaluation of phosphorus removal options are discussed in Section 5.

Table 3.3 - Summary of Influent and Effluent Wastewater Characteristics and Permit Information

Plant Name	Flow (MGD)		Influent (mg/L)				Effluent (mg/L)				Permit Limit (mg/L)			
	Design	Actual	CBOD$_5$	TSS	TP	NH$_4$-N	CBOD$_5$	TSS	TP	NH$_4$-N	CBOD$_5$	TSS	TP	NH$_4$-N
Activated Sludge														
Alexandria Lake WWTF	3.25	2.6	240	191.6	6.6	NA	3.1	2.1	0.4	NA	25	30	1.0	MO
Grand Rapids WWTF	14.3	8.8	307	268	NA	NA	2.7	11.4	0.6	NA	25	30	MO	8$^{(1)}$
New Ulm WWTF	6.77	2.5	387	273	8.9	NA	3.5	4.2	4.8	<0.13	25	30	MO	NR
Biological Nutrient Removal (BNR)														
St. Cloud WWTF	13	10.8	144	153	5.2	21.1	5.7	7.8	1.1	12.0	25	30	MO	NR
Fergus Falls WWTP	2.81	1.76	184	217	5.9	19.8	3.0	6.7	0.6	7.2	25	30	1.0	4.3$^{(1)}$
Oxidation Ditch														
Wadena WWTF	0.50	0.32	153	204	6.9	22.9	2.3	1.5	6.2	2.1	10	30	MO	(2)
Whitewater River PCF	0.80	0.66	463	344	10.4	NA	2.7	5.0	7.0	0.3	5	30	MO	(3)
High Purity Oxygen (HPO)														
Moorhead WWTF	6	3.9	267	187	6.3	20.4	8.7	7.0	3.9	19.4	12	30	MO	MO
Rochester WRP	19.1	13.2	376	212	9.4	18.8	3.2	6.0	0.8	0.1	14	20	1.0	1.6
Trickling Filter														
Detroit Lakes WWTF	1.64	1.06	191	168	5.5	NA	24.1	22.5	4.3	NA	20	20	1.0	MO
Trickling Filter/Activated Sludge														
Faribault WWTF	7	4.1	345	241	7.6	14.6	8.8	16.0	4.7	7.3	25	30	MO	MO
Marshall WWTF	3.3	2.1	387	455	13.7	14.9	2.5	4.7	5.8	0.6	5	30	NR	(4)
Glencoe WWTP	1.6	0.8	317	349	15.1	NA	2.9	4.6	9.2	0.7	25	30	MO	(5)
Little Falls WWTF	2.4	1.5	133	170	3.5	26.4	10.5	15.7	2.2	11.4	25	30	MO	MO
Lagoons														
Redwood Falls WWTP	0.824	0.76	200	297	NA	NA	8.3	32.7	2.9	7.2	25	45	MO	(6)
Thief River Falls WWTP	2.6	1.4	260	207	11.1	NA	5.7	24.3	2.7	4.1	15	45	MO	MO
Rotating Biological Contactors (RBC)														
Brainerd Area WWTP	3.13	2.61	167	152	5.6	NA	11.4	8.2	2.9	17.7	25	30	MO	MO

Appendix 2 contains the detailed data summaries for each plant.
NA - No Available Data

Permit Summary

* MO = Monitor Only
* NR = No Requirement
(1) - Limit is July - September

(2) - Dec - March = 15 mg/L
- April - May = 8.0 mg/L
- June - Sept = 2.0 mg/L
- October-November = 8.0 mg/L

(3) - June - Sept = 1.3 mg/L
- Oct - Nov = 4.3 mg/L
- Dec - March = 10.8 mg/L
- April - May = 3.2 mg/L

(4) - June - Sept = 1.1 mg/L
- Oct - Nov = 2.3 mg/L
- Dec - March = 9.4 mg/L
- April - May = 2.4 mg/L

(5) - Dec - March = 7.7 mg/L
- April - May = 4.0 mg/L
- June - Sept = 1.0 mg/L
- Oct - Nov = 4.3 mg/L

(6) - June - Sept = 7.5 mg/L
- Oct - Nov = 9.7 mg/L
- Dec - March = 94 mg/L
- April - May = 64 mg/L
- Un-ionized Ammonia - Jan - Dec = 1.0 mg/L

SECTION 4

APPLICATION OF PHOSPHORUS REMOVAL TECHNOLOGY FOR UPGRADING WASTEWATER TREATMENT FACILITIES

One of the main goals of this project was to determine the most applicable technologies for upgrading secondary treatment processes in the state of Minnesota to achieve phosphorus removal to reach a target monthly average effluent concentration of 1.0 mg/L. Since the discovery of activated sludge treatment in the late 1890s, a wide range of biological secondary treatment processes have been developed and applied. All of these processes in different forms are represented at various locations in the state of Minnesota, and include activated sludge, activated sludge with biological nutrient removal, oxidation ditch, high purity oxygen activated sludge, trickling filters, rotating biological contactors, trickling filter/activated sludge, and lagoons. A number of alternatives exist for converting existing facilities to phosphorus removal and these depend to a large part on the type of secondary process used and the influent wastewater characteristics.

In this section for each type of secondary treatment process the basic mechanisms of the process are described and the feasible alternatives that can be used to convert the process to achieve phosphorus removal to a monthly average target concentration of 1.0 mg/L or less are presented along with advantages and disadvantages. This section also includes a discussion of the process evaluation and design protocol used to evaluate phosphorus removal at the treatment facilities. The basis for the cost estimates used to select the phosphorus removal alternative is also summarized in this section.

4.1 PHOSPHORUS REMOVAL ALTERNATIVES

As described in Chapter 2, the two basic approaches for phosphorus removal are chemical precipitation and enhanced biological phosphorus removal (EBPR). These two approaches can be applied singularly or in combination to upgrade existing treatment facilities. For existing facilities in which the wastewater treatment process consumes all or most of the influent BOD before it can be made available to an EBPR process, chemical precipitation will clearly be the phosphorus removal alternative selected. For cases where the influent wastewater is at sufficient strength relative to the influent phosphorus loading and where the anaerobic contact zone for the EBPR process can be easily incorporated into the existing system, the use of EBPR will be favored. With these considerations the phosphorus removal alternatives possible for the various types of existing wastewater treatment facilities evaluated in this study are described below.

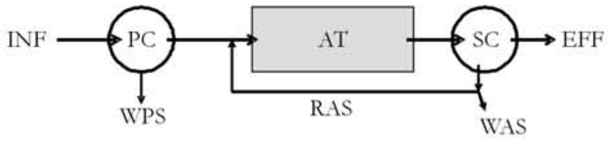
4.1.1 Conventional Activated Sludge Process and Activated Sludge with Biological Nutrient Removal (BNR)

The conventional activated sludge process along with schematics of various alternatives for phosphorus removal are shown in Figure 4.1a through Figure 4.1f. The basic process shown in Figure 4.1a consists of an aeration tank (AT) in which microorganisms that remove organic substances from the influent wastewater are kept in suspension and aerated. A secondary clarifier (SC) is used for liquid-solids separation prior to discharge of a clarified effluent, and the settled thickened solids from the clarifier are returned to the activated sludge aeration basin. A portion of the settled sludge recycle flow is wasted to remove excess suspended solids from any residual influent nonbiodegradable particulates from the primary clarifiers and from the biomass produced in the aeration system. Typical values for the AT hydraulic retention time (HRT), mixed liquor suspended solids (MLSS) and solids retention time (SRT) are 4-6 hours, 2000 – 3000 mg/L, and 5-8 days, respectively. For most applications primary clarification precedes the activated sludge process.

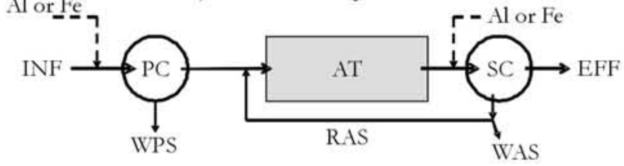
Table 4.1 provides a brief description of the phosphorus removal alternatives shown in Figures 4.1b through 4.1f and summarizes the factors that favor each of the alternatives. The conventional activated sludge process is suitable for both chemical and enhanced biological phosphorus removal processes. Site-specific conditions will determine which of these or a combination of these is most appropriate for cost-effective phosphorus removal. The major factors that favor the selection of EBPR alone are a high influent BOD/P ratio and excess capacity in the aeration tank which may be used for the EBPR anaerobic contact zone. A BOD/P ratio of 40 or greater would be needed to support EBPR alone. On the other hand, a weak organic wastewater strength ($BOD/P < 25$) relative to the influent phosphorus concentration would favor chemical treatment. In between these BOD/P ratios, a combination of EBPR and chemical addition is more likely to be appropriate.

Activated sludge BNR systems are conventional activated sludge systems that already have process designs similar to those shown in Figure 4.1c through Figure 4.1f. In such cases, the alternative evaluation involves evaluating the existing process performance and determining process design or operating changes that can improve the level of phosphorus removal, if necessary. It could involve modifying the tank sizes or internal recycle rates for Alternative (c) as shown in Figure 4.1. Or it could involve adding chemicals to convert the existing activated sludge BNR process to Alternative (e) shown in Figure 4.1. Depending on the cost of an exogenous carbon source the activated sludge BNR process could be converted to that shown in alternative (d) in Figure 4.1. Thus, alternatives for activated sludge BNR processes will be very site-specific and will depend on the operation and performance of the existing system.

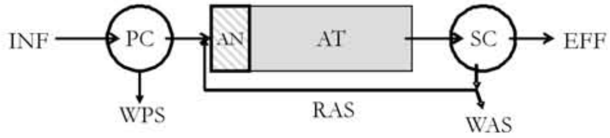
a) Conventional Activated Sludge Process



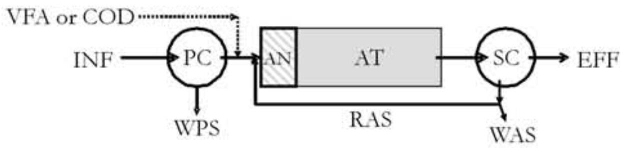
b) Chemical Precipitation



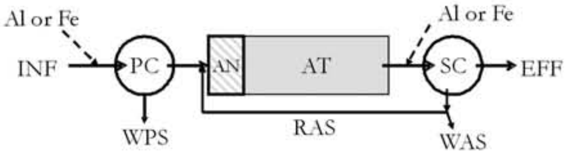
c) Enhanced Biological Phosphorus Removal



d) Enhanced Biological Phosphorus Removal with COD Addition



e) Enhanced Biological Phosphorus Removal with Chemical Precipitation



f) Enhanced Biological Phosphorus Removal with Nitrification

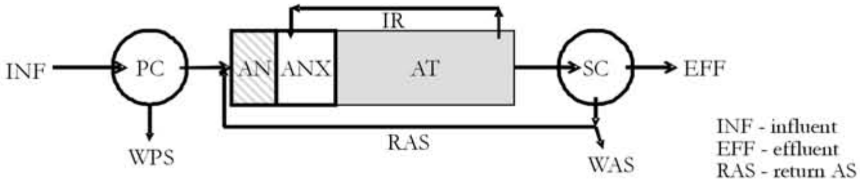


Figure 4.1- Conventional Activated Sludge Phosphorus Removal Alternatives
(PC-primary clarifier, SC-secondary clarifier, AT- aeration tank, WPS-waste primary sludge, WAS-waste activated sludge, AN-anaerobic tank, ANX-anoxic tank, IR-internal recycle flow)

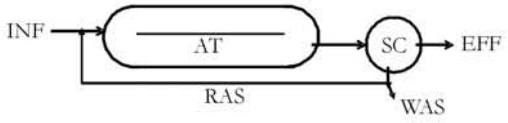
Table 4.1 - Summary of Phosphorus Removal Alternatives for the Conventional Activated Sludge Process and Factors that Favor each Alternative

Alternative	Brief Description	Favorable factors for alternative
4.1b - Chemical Treatment only	Al or Fe salts are added to the PC and SC for phosphorus precipitation	-low influent BOD/P ratio -variable influent BOD with low influent rbCOD at times -secondary process has limited excess volume to enable adding EBPR anaerobic tank - can be easily and rapidly implemented
4.1c –EBPR	A portion of the aeration tank can be converted to a mixed anaerobic tank with a detention time of about 1.0 hour (hr)	-the wastewater has a high influent BOD/P ratio - volume is available in existing aeration tank for conversion to an anaerobic contact zone.
4.1d –EBPR with COD addition	A portion of the aeration tank can be converted to a mixed anaerobic tank with a detention time of about 1.0 hour and an exogenous organic source such as sugar or acetic acid (i.e. COD) is purchased and added to the anaerobic process	-the cost of the exogenous carbon must be less than the cost of adding metal salts for phosphorus precipitation.
4.1e -EBPR with chemical precipitation	A portion of the aeration tank can be converted to a mixed anaerobic tank with a detention time of about 1.0 hour and chemicals are added to the PC and SC	-the wastewater has a moderate influent BOD/P ratio and some variability - volume is available in existing aeration tank for conversion to an anaerobic contact zone.
4.1f – EBPR with nitrification	Nitrification is required in the activated sludge process so an anoxic contact zone is used to remove nitrate (A^2O process is one option) -option can be used also with chemical addition	-Sufficient influent BOD/P to promote effective EBPR treatment.

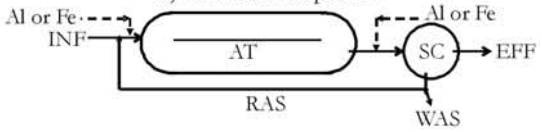
4.1.2 Oxidation Ditch Activated Sludge Process

The oxidation ditch activated sludge process (Figure 4.2 with phosphorus removal alternatives) was developed in Europe in the 1950s and was intended to be a simple, cost-effective process for small treatment facilities. In contrast to the conventional activated sludge process, the oxidation ditch normally does not have primary treatment and has a relatively long aeration tank HRT and SRT, typically 24 hours and 30 days, respectively. Mixed liquor suspended solids concentrations are typically in the range of 3000-4000 mg/L and conservative hydraulic application rates have been used for the secondary clarifiers. The long liquid and solids retention times used provide a system that can handle wide variations in flow and loadings. The process is designed to produce an aerobic well-stabilize sludge for land application. However, based on today's 503 biosolids regulations, the typical SRT used in oxidation ditches is not sufficient to meet a Class B biosolids classification.

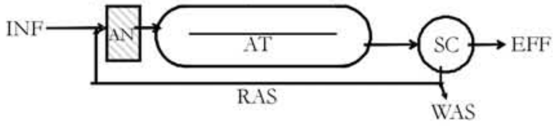
a) Oxidation Ditch System



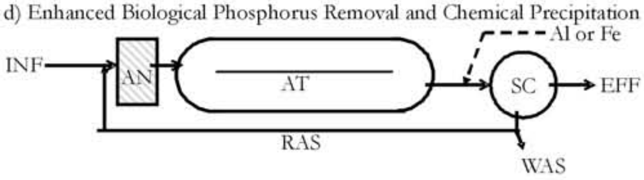
b) Chemical Precipitation



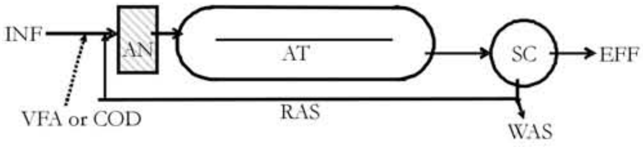
c) Enhanced Biological Phosphorus Removal



d) Enhanced Biological Phosphorus Removal and Chemical Precipitation



e) Enhanced Biological Phosphorus Removal with COD Addition



f) Oxidation Ditch System Converted to EBPR Process

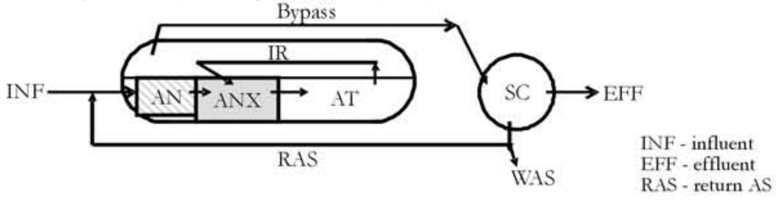


Figure 4.2 - Oxidation Ditch System and Phosphorus Removal Alternatives
(SC-secondary clarifier, AT- aeration tank, WAS-waste activated sludge, AN-anaerobic tank, ANX-anoxic tank, IR-internal recycle flow)

As in the conventional activated sludge process, the phosphorus removal alternatives include chemical precipitation alone, EBPR alone, EBPR with chemical precipitation, and EBPR with additional BOD added via the purchase of sugar or acetic acid or a waste source for BOD. Primary sludge fermentation is not a viable option for an additional volatile fatty acid (VFA) source, as the process does not normally have primary treatment. Table 4.2 provides a brief description of the phosphorus removal alternatives shown in Figures 4.2b through 4.2f and summarizes the factors that favor each of the alternatives.

Two major considerations for the use of EBPR with the oxidation ditch are that an external anaerobic contact tank must be installed and the ditch must be operated to accomplish a high level of nitrate removal, so that minimal nitrate is added with the activated sludge recycle to the anaerobic zone located ahead of the ditch. To accomplish nitrate removal, the oxidation ditch system must be operated with some type of dissolved oxygen (DO) control strategy. A typical approach is to use DO control methods that can vary the aeration output with influent loading changes, so that the DO concentration in the channel downstream from the aeration zone reaches zero within 50 to 75% of the ditch volume. This is done by locating a DO concentration probe at an appropriate location upstream of the zero DO concentration zone. The remaining downstream volume is anoxic and the mixed liquor consumes nitrate in lieu of oxygen. Another control method uses oxidation-reduction potential (ORP) control technology with an on/off aeration operation.

Because of the longer SRT employed in oxidation systems the EBPR phosphorus removal efficiency for the oxidation ditch process is less than that for a conventional activated sludge process. At the longer SRT more endogenous respiration occurs and less biological phosphorus removal is possible due to the lower net biomass production. Another factor that reduces the EBPR phosphorus removal efficiency for oxidation ditch processes is the effect of the variable loading normally experienced for smaller size wastewater treatment systems. In the late evening and early morning hours the influent BOD concentration is much lower than during the day and the lack of steady food decreases the efficiency of the PAOs. This problem has been observed but is difficult to quantify in process models or design approaches.

For Alternative (f) on Figure 4.2 the oxidation ditch system is converted to a conventional EBPR process with separate reactors for aeration, anaerobic contact (AN) and nitrate removal (ANX). This approach requires considerable modifications to the existing tankage and piping. For the A^2O system treatment scheme shown, the system SRT is lower than for the oxidation ditch operation. Because of the lower SRT the system treatment capacity for the oxidation ditch conversion can be increased considerably, by 25 to 75%. This alternative is favored for design modifications that are intended to also increase the treatment system capacity in addition to meeting phosphorus removal requirements. To meet the increased capacity other modification would be needed within the plant, and may include additional secondary clarification, headworks, and sludge processing tankage and equipment.

Table 4.2 - Summary of Phosphorus Removal Alternatives for the Oxidation Ditch System and Factors that Favor each Alternative

Alternative	Brief Description	Favorable factors for alternative
4.2b - Chemical Treatment only	Al or Fe salts are added to the ditch influent and SC for phosphorus precipitation	-low influent BOD/P ratio -variable influent BOD with low influent rbCOD at time -space and layout make it difficult to anaerobic tank for EBPR - can be easily and rapidly implemented
4.2c -EBPR	An external anaerobic tank with a detention time of about 1.0 hour (hr) is added before the ditch.	-the wastewater has a high influent BOD/P ratio - site layout and space make the anaerobic tank addition feasible -the variability in wastewater load is minimal
4.2d -EBPR with chemical precipitation	An external anaerobic tank with a detention time of about 1.0 hr is added before the ditch. Chemicals are added to the ditch and SC	-the wastewater has a moderate to high influent BOD/P ratio and some variability - site layout and space make the anaerobic tank addition feasible.
4.1e - EBPR with COD addition	An external anaerobic tank is added as in 4.2c and an exogenous organic source such as sugar or acetic acid is purchased and added to the anaerobic process	-the cost of the exogenous carbon must be less than the cost of adding metal salts for phosphorus precipitation.
4.1f - EBPR with nitrification	The system design is changed to an A^2O process -option can be used also with chemical addition	-Sufficient influent BOD/P to promote effective EBPR treatment. -there is need to increase the treatment plant capacity as well

4.1.3 High Purity Oxygen Activated Sludge Process

The high purity oxygen (HPO) sludge process (Figure 4.3 with phosphorus removal alternatives) is a staged activated sludge process with its aeration tank consisting of 3 to 4 stages in series. High purity oxygen is added to the first stage and the headspace gas and mixed liquor flow concurrently from stage to stage. The high oxygen partial pressure in the headspace provides for a much higher oxygen transfer rate to the mixed liquor, and thus allows a higher treatment capacity per unit volume of aeration tank compared to that for the conventional activated sludge process. In view of this the aeration tank HRT and SRT are much lower than conventional activated sludge, and are in the range of 1-2 hours and 2-3 days, respectively. Because of the staged tank configuration the application of an EBPR process requires the addition of an external anaerobic contact tank as shown by alternative (c) in Figure 4.3.

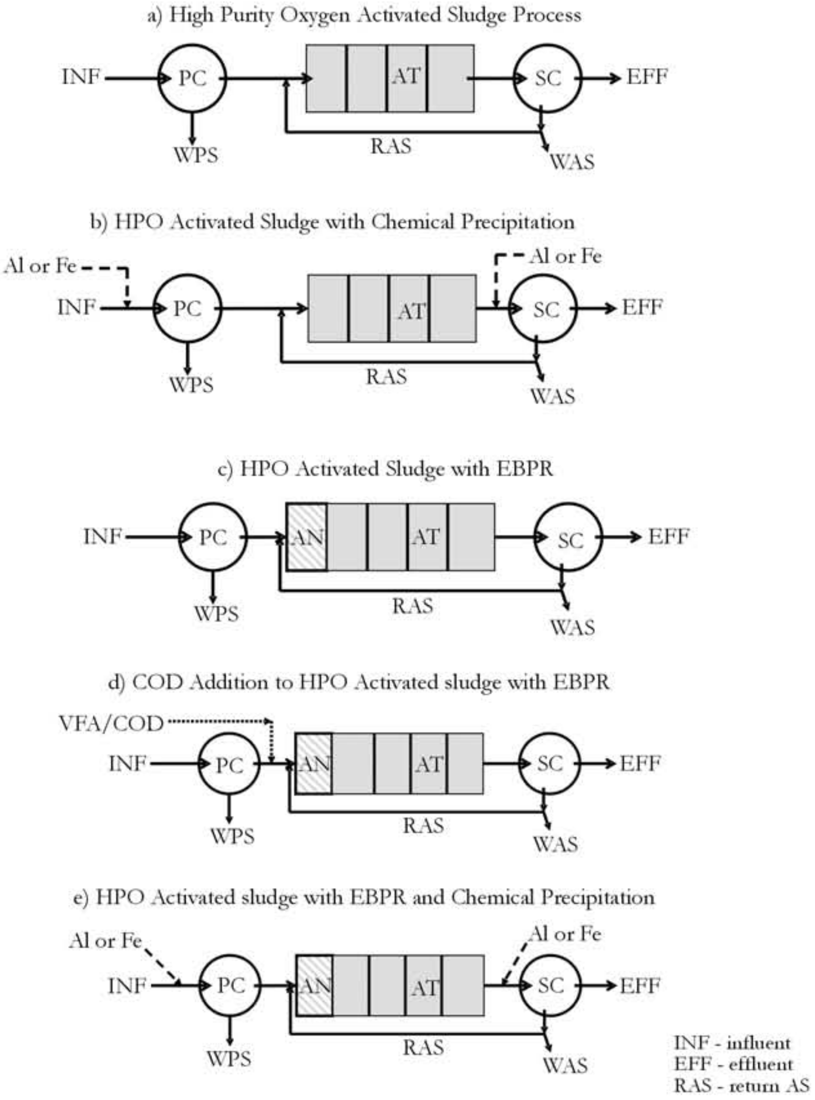


Figure 4.3 - High Purity Oxygen Activated Sludge Phosphorus Removal Alternatives (PC-primary clarifier, SC-secondary clarifier, AT- aeration tank, WPS-waste primary sludge, WAS-waste activated sludge, AN-anaerobic tank, ANX-anoxic tank, IR-internal recycle flow)

The phosphorus removal alternatives for the HPO activated sludge process (Alternatives (d) and (e) on Figure 4.3) are similar to that shown in Figure 4.1 for the conventional activated sludge process with the exception of Alternative (f). Because the HPO activated sludge process is operated at a low SRT nitrification does not occur and thus there is no requirement for an anoxic reactor for nitrate removal. The alternative descriptions and factors that favor each alternative are summarized in Table 4.3. The lower operating SRT for the HPO activated sludge process provides for a slightly higher efficiency for EBPR.

Table 4-3 - Summary of Phosphorus Removal Alternatives for the HPO Activated Sludge Process and Factors that Favor each Alternative

Alternative	Brief Description	Favorable factors for alternative
4-3b - Chemical Treatment only	Al or Fe salts are added to the PC and SC for phosphorus precipitation	-low influent BOD/P ratio -variable influent BOD with low influent rbCOD at times - can be easily and rapidly implemented
4-3c – EBPR	An external anaerobic tank with a detention time of about 1.0 hour (hr) is added before the aeration tank.	-the wastewater has a moderate to high influent BOD/P ratio - site layout and space make the anaerobic tank addition feasible
4-3d - EBPR with COD addition	An external anaerobic tank with a detention time of about 1.0 hour is added before the aeration tank and an exogenous organic source such as sugar or acetic acid is purchased and added to the anaerobic process	-the cost of the exogenous carbon must be less than the cost of adding metal salts for phosphorus precipitation
4-3e - EBPR with chemical precipitation	An external anaerobic tank with a detention time of about 1.0 hour is added before the aeration tank and chemicals are added to the PC and SC	-the wastewater has a moderate influent BOD/P ratio and some variability - site layout and space make the anaerobic tank addition feasible

4.1.4 Fixed Film Biological Treatment Processes

Two types of commonly used fixed film biological treatment processes are used in the state of Minnesota. These are the trickling filter process and the rotating biological contactor process (Figure 4.4). These are both unsubmerged fixed film biological reactors that use rock (trickling filter only) or plastic packing material over which wastewater is distributed continuously. Treatment occurs as the liquid flows over the attached biofilm and oxygen is supplied by aeration that occurs by natural convection or forced air with blowers. Primary clarification is normally used before either of these fixed film processes to prevent clogging of the media by influent debris and high solids concentrations. Secondary clarification is used for liquid-solids separation of the biomass and solids that continuously slough off of the fixed film packing material.

The only alternatives shown for phosphorus removal (Figure 4-4b) with these fixed film processes is chemical precipitation with chemical addition to the primary and secondary clarifiers. An EBPR process is not feasible with the processes because the EBPR process requires that readily biodegradable COD (rbCOD) be in the influent wastewater added to the EBPR anaerobic contact tank. For the fixed film systems the logical location for the anaerobic contact tank is directly downstream of the trickling filter or rotating biological contactors, which will have already removed the rbCOD. Thus there would not be sufficient carbon available for a successful EBPR operation. Therefore the alternative of choice is the use of chemical precipitation for phosphorus removal.

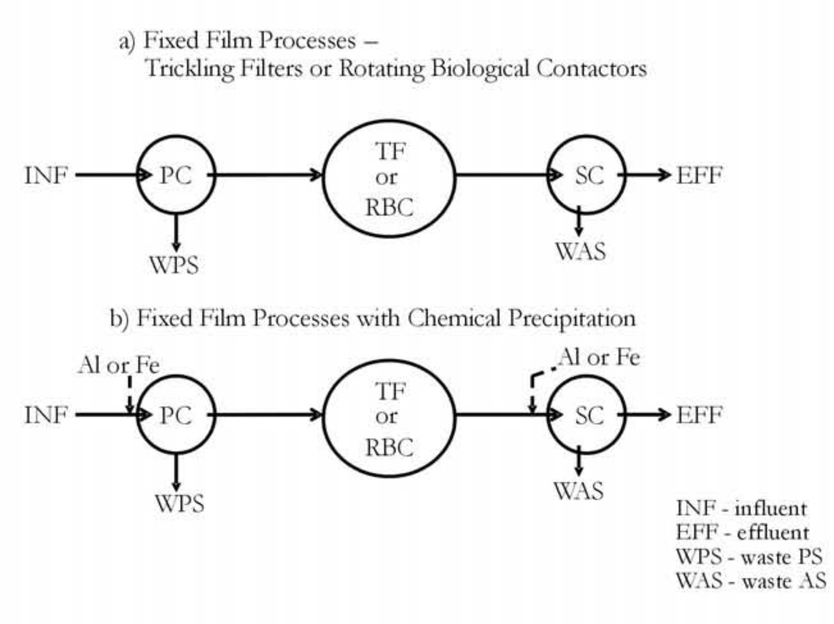


Figure 4.4 - Chemical Precipitation for Trickling Filter (TF) and Rotating Biological Contactor (RBC) Processes

4.1.5 Lagoon Treatment Process

Lagoons are long-retention time (20-40 days) holding ponds that use natural processes for wastewater treatment. Processes involved are biological oxidation, sedimentation, photosynthesis, and anaerobic degradation in the lagoon sediment layers. They may be non-aerated or facultative lagoons with an upper aerobic zone and bottom anaerobic zone, partially aerated, or fully aerated basins. They normally consists of at least two cells in series with the secondary cell(s) utilized for storage and final settling. The secondary cell is designed at a minimum of about 1/3 the volume of the entire lagoon system. For primary cells, the state requirement is one acre of water surface for each 100-120 design population with a BOD loading of less than or equal to 22 lbs/acre-day. Typically, the cells should have sufficient capacity to store wastewater for a minimum detention period of 180 days to handle the winter season and transitory spring period.

Chemical precipitation is the only feasible process for phosphorus removal for lagoon systems (Figure 4.5). Alum is the chemical of choice as it will assure a more stable alum phosphate precipitate in the lower pH zones in the lagoon sediment. Because of the relatively long detention time in the lagoon, alum can be added on a batch basis using motor boats which can also provide mixing with the alum addition. This approach can be managed to assure that the effluent discharge meets the phosphorus concentration requirement. In addition to this chemical feed equipment can be use to add alum on a flow-paced basis with the influent wastewater.

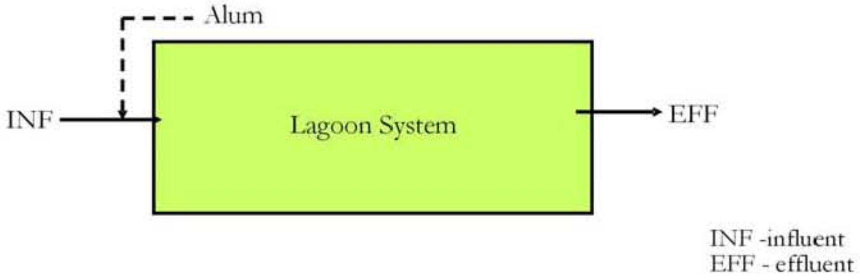


Figure 4.5 - Chemical Precipitation is the Phosphorus Removal Alternative for Lagoons

4.1.6 Trickling Filter/Activated Sludge Treatment Process

A trickling filter/activated sludge (TF/AS) process is a combined biological treatment process that employs a fixed film trickling filter reactor ahead of the activated sludge (Figure 4.6). Normally the trickling filters are preceded by primary clarification to protect the media from debris and plugging due to high solids concentrations. In most cases the trickling filter effluent is fed directly to the activated sludge process without intermediate clarification and the return activated sludge from the secondary clarifier is directed to the activated sludge aeration basin. The most common application for the TF/AS process is for the trickling filter designed as a roughing filter for 40 to 70% BOD removal. This process is attractive for treating higher strength municipal wastewater with constant or seasonal industrial wastewater addition. The trickling filter is an efficient, low-energy method for removal of BOD and also improves the sludge settling characteristics for the activated sludge process. The activated sludge process provides a better quality effluent and efficient nitrification in contrast to operating a trickling filter system only. A number of alternatives are shown in Figure 4.6 for upgrading the TF/AS process to phosphorus removal. Table 4.4 describes the various alternatives and summarizes factors that favor the particular alternative. Alternative 4.6b is easy to implement and does not involve any changes in the TF/AS design or operation.

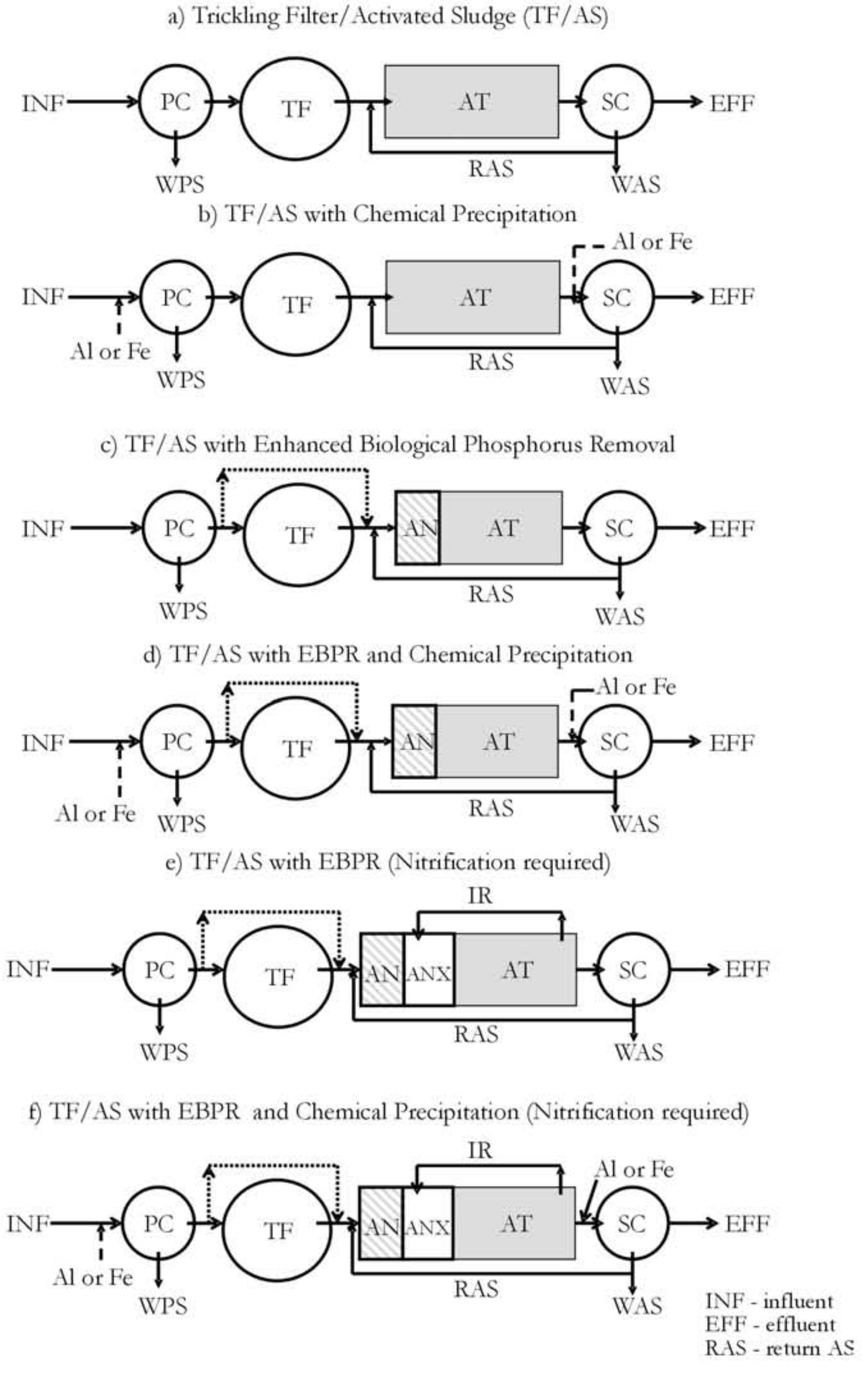


Figure 4.6 - Trickling Filter/Activated Sludge Process and Phosphorus Removal Alternatives (PC-primary clarifier, WPS-waste primary sludge, SC-secondary clarifier, TF-trickling filter, AT-aeration tank, WAS-waste activated sludge, AN-anaerobic tank, ANX-anoxic tank, IR-internal recycle flow)

Table 4.4 - Summary of Phosphorus Removal Alternatives for the TF/AS Process and Factors that Favor each Alternative

Alternative	Brief Description	Favorable factors for alternative
4.6b - Chemical Treatment only	Al or Fe salts are added to the primary and secondary clarifiers.	-little BOD remaining after trickling filter to support EBPR -variable influent BOD with low influent rbCOD at time -space and layout make it difficult for an anaerobic tank for EBPR - can be easily and rapidly implemented
4.6c – EBPR	An anaerobic tank with a detention time of about 1.0 hour (hr) is added before the aeration basin. Ability to bypass the PC effluent to the anaerobic tank is provided	-the wastewater has a high influent BOD/P ratio - site layout and space make the anaerobic tank addition feasible -excess capacity in aeration basin allows using a portion of it for the anaerobic contact zone -the variability in wastewater load is minimal
4.6d - EBPR with chemical precipitation	An anaerobic tank with a detention time of about 1.0 hour is added before the aeration basin. Ability to bypass the PC effluent to the anaerobic tank is provided. Chemicals are added to the primary and secondary clarifiers	-the wastewater has a moderate to high influent BOD/P ratio and some variability - excess capacity in the aeration basin allows using a portion of the basin for the anaerobic contact zone
4.6e - Nitification is required. EBPR only	The activated sludge system is converted to an A^2O process by dividing the existing basin or additional external tanks are added. Bypass of PC effluent to anaerobic contact zone is possible.	-Excess tankage capacity is available in the existing aeration basin to use for anoxic and anaerobic tanks.
4.6f - Nitification is required. EBPR with chemical precipitation	The same conversion as in 4.6e but with chemical addition to primary and secondary clarifiers	- Excess tankage capacity is available in the existing aeration basin to use for anoxic and anaerobic tanks. -Influent BOD/P is moderate to weak and variability is significant.

For Alternative 4.6c an EBPR process is incorporated into the TF/AS system. This approach could be attractive provided that there is excess capacity in the aeration tank so that a portion can be used for an anaerobic contact tank. A consideration with regard to the simplicity and costs for such a conversion is the configuration or layout of the aeration tank. If it is a plug flow basin, for example, the conversion can be simple and may only require the addition of a baffle wall and a mixer for the anaerobic contact zone.

The potential for using an EBPR process in a TF/AS system depends on how much soluble BOD remains in the liquid after the trickling filter treatment. For high strength wastewaters, possibly due to industrial inputs, and for higher volumetric organic loadings to the trickling filter (lb BOD/1000ft^3-d) more soluble BOD will be available for an EBPR process. Where the TF BOD removal efficiency is too high, consideration should be given for bypassing a portion or all of the TF influent to the EBPR process.

Alternative 4.6d is the same as Alternative 4.6c with the addition of chemical precipitation in the primary and secondary clarifiers. Compared to Alternative 4.6c, this alternative is attractive if the influent wastewater is weaker or more variable requiring the need for chemicals to offset a lower phosphorus removal efficiency from the EBPR process at times of lower wastewater strength.

The last two alternatives in Figure 4.6, Alternatives (e) and (f), are for applications where nitrification is required and EBPR is to be used for phosphorus removal. In this case an anoxic reaction zone is necessary for nitrate removal to minimize the amount of nitrate fed to the anaerobic contact zone. Thus these two alternatives are only feasible if there is sufficient excess tank capacity in the aeration basin to incorporate an anoxic zone. If not, Alternative 4.6b is more favorable. Anoxic zone detention times for this A^2O process application are in the range of 1.5 to 2.0 hours. The difference between alternatives 4.6e and 4.6f is the use of chemical additions in Alternative 4.6f, which would be favored for applications with a weaker and more variable influent wastewater strength. Both systems have bypass capability around the trickling filter to provide rbCOD to the anaerobic contact tank.

4.2 PROCESS EVAUATION AND DESIGN PROTOCOL USED TO EVALUATE EXISTING FACILITIES

The phosphorus removal alternatives presented in the previous section for each type of wastewater facility were investigated to determine which alternatives were feasible and which were preferred for each of the wastewater treatment facilities identified in this study. All the alternatives involved either chemical addition alone, an EBPR process alone, or a combination of chemical addition and an EBPR process. Chemical addition could be applied in some way to any of the different type of wastewater treatment facilities, but the feasibility of an EBPR process had to be investigated for each facility. Key issues for the phosphorus removal alternatives evaluations were as follows:

- Is there sufficient volume available in the existing facility to accommodate an anaerobic contact tank needed for EBPR?
- Is the plant layout and aeration tank configuration favorable for the installation of an anaerobic contact tank?
- Can a sufficient amount of phosphorus removal be accomplished to justify the cost associated with installing an EBPR process in the facility?
- For nitrification facilities, can the existing facility be modified to accommodate an anoxic tank for nitrate removal to enable the performance of an EBPR process?

To determine which of the possible phosphorus removal alternatives was most applicable for a given facility, it was necessary to develop conceptual designs so that a relative cost comparison could be done. All the conceptual designs were done with the goal of meeting current discharge permit effluent concentrations plus phosphorus removal to a monthly average target concentration of 1.0 mg/L or less. The conceptual designs determined required tank volumes, additional reactor mixing requirements, primary, secondary, and chemical sludge production rates, internal recycle rates where necessary, the acceptability of other unit process loadings such as secondary clarifiers, chemical dose requirements, the amount of biological phosphorus removal, and changes in alkalinity concentrations. The designs did not evaluate the existing aeration equipment and capacities.

A conceptual design protocol was developed to evaluate the phosphorus removal alternatives, and it was applied to the different types of wastewater treatment facilities selected in this study. The protocol and site specific conceptual designs were useful for identifying and incorporating key design information and assumptions, and the integration of primary treatment, secondary treatment, polishing filters where necessary, and recycle loads. Commercial computer software packages based on International Water Association Activated Sludge Models are available but were not used due to their lack of flexibility for addressing the entire plant treatment system, and more importantly because of their inability to accurately model biological phosphorus removal without specific site calibration procedures.

The protocol developed was based on providing broad based procedures to evaluate phosphorus removal at wastewater treatment plants for use throughout the State of Minnesota. This section presents a detailed description of the phosphorus removal alternatives protocol developed for this project.

4.2.1 Alternative Evaluation Protocol

The general protocol for the alternative evaluations is illustrated on Figure 4.7. The three basic types of phosphorus removal alternatives (EBPR plus chemicals, EBPR only, and chemicals only) are indicated and each has its own design pathway. For many existing facilities, it was necessary to develop preliminary designs for all three basic approaches. However, for plants with only trickling filters, rotating biological contactors or lagoons for secondary treatment, the chemical only alternative is the only applicable alternative as explained in Section 4.1. The first step in the evaluation protocol for any of the phosphorus removal alternatives type was to obtain and organize the information shown under the key design inputs on Figure 4.7. Each of these is described, along with their relative importance on the design and performance of the phosphorus removal alternatives.

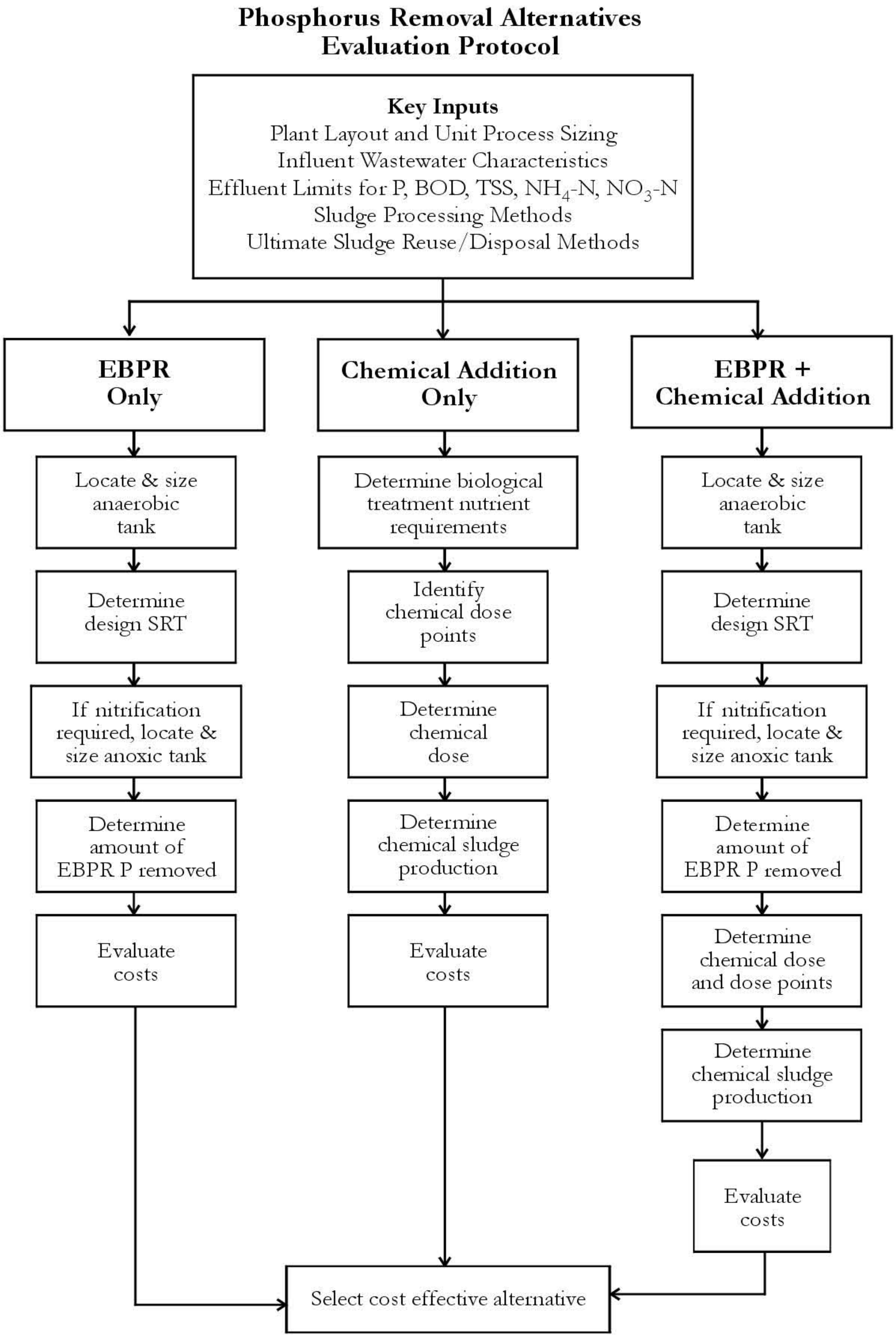


Figure 4.7 – Phosphorus Removal Alternatives Evaluation Protocol

4.2.1.1 Design Inputs

Plant layout and unit process sizing information was obtained on the treatment system layouts and unit process sizing and loadings from site visits and design summary documents. These data were critical for eventually determining what reasonable facility modifications could be made, where chemical addition could be applied, and how the existing facility loadings and operation might affect the performance of EBPR and chemical treatment processes.

Influent wastewater characteristics are critical for the design and evaluation of any nutrient removal process. Table 4.5 lists the key influent wastewater parameters and their impacts on the phosphorus removal alternatives designs. The plant ultimate design flow rates were used for all the analyses. The actual plant influent wastewater sampling and analyses results for the one-year period (e.g. October 2002-October 2003) were used to establish the design concentrations of the influent wastewater parameters. Where data were lacking for critical influent wastewater constituents, assumptions were made based on the concentrations measured for other related parameters and the information provided on industrial wastewater sources. In addition to influent flow rate, the main influent wastewater parameter affecting the chemical treatment design was the influent phosphorus concentration. As the chemical dose is directly related to the amount of phosphorus removed, higher influent phosphorus concentrations required a greater chemical consumption. Subsequently with more chemical consumption and chemical precipitation, a greater amount of chemical sludge is produced.

For the EBPR process alternatives many other influent wastewater parameters in addition to the influent phosphorus concentration are important in affecting the process design and expected performance. The most critical of these is the influent readily biodegradable COD (rbCOD), which is the dissolved biodegradable organic material that is quickly consumed by the phosphorus accumulating organisms (PAOs) in the anaerobic contact zone. For EBPR processes the rbCOD will be preferentially consumed by the PAOs, because the anaerobic contact zone is the first activated sludge reactor in which the influent wastewater is applied to the mixed liquor. The amount of phosphorus removal is directly proportional to the amount of rbCOD available for the PAOs. Information on the influent wastewater rbCOD concentration was not available for any of the facilities, as this is not a conventional parameter normally monitored at wastewater plants. For final engineering designs for EBPR systems a sampling program is necessary to characterize the influent rbCOD concentration among other important wastewater characteristics.

In this project an alternative approach was needed to approximate the influent rbCOD concentration for the different facilities in this study. The rbCOD concentration was based on an estimate of the influent soluble BOD concentration. The soluble BOD test measures the biodegradability of a filtered sample that contains both truly dissolved and colloidal organic material. A value of 0.70 was used for the ratio of truly dissolved rbCOD to the soluble BOD concentrations,

Table 4.5 - Influent Wastewater Characteristics and Their Effect on Phosphorus Removal Alternatives

Wastewater Parameter	Impact On Ebpr Design	Impact On Chemical Treatment Design
Design influent flow rate	All facility tank and equipment sizes	Chemical dose
Total $CBOD_5$	Secondary process tank sizes and equipment and sludge processing	-
TSS	Increase secondary aeration tank size and more sludge production	Increases sludge production for chemical treatment in primary clarifiers
Total phosphorus	Effluent phosphorus concentration possible	Chemical dose and sludge production
BOD/P ratio	Lower phosphorus concentration generally found with higher BOD/P ratios	-
Readily biodegradable COD (rbCOD)	More P removal as rbCOD increases	-
TKN/NH_3	Where nitrification is required, increased concentration can decrease EBPR efficiency	-
Loading variations	High diurnal and daily variations can decrease EBPR efficiency	-
BOD/TKN	For BOD/TKN ratios < ~ 4.0 insufficient nitrate removal occurs for systems with nitrification and the EBPR efficiency is lower	-
Temperature	Increased tank volumes needed at lower temperature	-

which is a conservative assumption. Though the influent soluble BOD concentration also was not measured for these facilities in this study, it could more easily be estimated based on knowledge of the industrial wastewater sources and characteristics. A soluble BOD to influent total BOD ratio of 0.25 to 0.40 is common for municipal wastewater plants receiving mostly domestic wastewater. Information on industrial wastewater inputs was available for most of the facilities in this study, and based on the type of industrial wastewater contained in the facility influent wastewater a soluble BOD concentration was estimated. Thus, using this information, the soluble BOD concentration of the influent wastewater was estimated as some fraction of the total BOD concentration that was measured for each facility. From this, a design rbCOD concentration was determined and used to evaluate the EBPR phosphorus removal efficiency. This approach was useful to account for different wastewater characteristics, but for an actual design appropriate wastewater characterization would be necessary.

Data was available for most of the facilities to enable a calculation of the influent wastewater BOD/P ratio. For many full-scale EBPR systems the phosphorus removal efficiency has been generally correlated with the influent BOD/P ratio. The influent BOD/P ratio was determined for each facility and was used as an indicator for the expected EBPR phosphorus removal efficiency. Reports on full-scale EBPR facilities have clearly indicated good phosphorus removal efficiency (effluent P < 1.0 mg/L) when the influent BOD/P ratio is greater than 40.

Table 4.5 also indicates that the influent flow and loading variability can affect the EBPR phosphorus removal efficiency. In Section 2, the negative effects of periods of low influent rbCOD concentrations on EBPR process performance was discussed. It is necessary to note this is an important factor that affects phosphorus removal and EBPR processes, but the intensive influent wastewater characterization program needed to address this issue was beyond the scope of this study. This factor was not addressed for the conceptual designs developed in this study and would have to be investigated further with more wastewater information when preparing final EBPR designs.

The influent TKN concentration is an important parameter related to EBPR process efficiency for systems in which nitrification is needed to meet an effluent ammonia concentration in the discharge permit. In these systems an anoxic zone is used in the process to remove 85% or more of the nitrate produced. For wastewaters with higher TKN concentrations larger anoxic tank volumes are needed for nitrate removal. To keep the EBPR process alternatives evaluation at a manageable level, only the A^2O process was designed for systems with nitrification, but other nitrogen removal alternatives, such as the UCT processes and JHB process, would be considered for design optimization in any final engineering study. The influent BOD/TKN ratio is also an important wastewater characteristic parameter that can be related to the EBPR process efficiency. At BOD/TKN ratios below about 4.0, there is insufficient organic material for removal of most of the nitrate produced in a nitrification system. When that happens more nitrate remains in the system and is recycled to the anaerobic contact zone, where it has a negative effect on the EBPR process efficiency. The nitrate removes rbCOD in the anaerobic contact zone that could otherwise be consumed by the PAOs.

The discharge permit effluent concentrations for each facility for regulated parameters were used in the analysis with the addition of producing an effluent phosphorus concentration of 1.0 mg/L or less. For a few plants an effluent phosphorus concentration of less than 1.0 mg/L was already being met by chemical addition. In these cases, the potential of an EBPR process modification was compared to the existing chemical treatment system. A nitrification design was required for facilities with low ammonia effluent concentration permit values, which then required that the EBPR preliminary design include the A^2O process. Discharge permits at a few facilities required low effluent TSS concentrations and in such cases polishing filters had been installed. The effect of filtration was accounted for in the design alternatives as it improved phosphorus removal efficiencies by removing phosphorus associated with effluent suspended solids.

Information on the sludge processing methods was obtained and included in the evaluation of the EBPR removal alternatives. The main impact concerned the release of phosphorus during processing waste activated sludge containing PAOs. About 20 to 40% of the phosphorus removed by EBPR can be released in anaerobic or aerobic digestion processes. If the digested sludge is dewatered on-site, the filtrate or centrate from the dewatering operation could result in a recycle stream that, in essence, adds an additional phosphorus load to the influent wastewater. Sludge thickening processes that create anaerobic conditions can also result in phosphorus release and recycle for facilities with phosphorus rich waste activated sludge from EBPR processes.

The ultimate sludge reuse or disposal method was obtained for all the study facilities. This also was an important factor in evaluating the potential phosphorus removal efficiency of an EBPR process application. Many of the facilities in this study were unique in that digested or process sludge was not further dewatered, but was instead held in holding tanks or lagoons prior to land application. With this practice, the release and return of phosphorus removed by an EBPR process was generally avoided.

4.2.1.2 EBPR Design Components

Important key steps in the development of preliminary designs for the EBPR process alternatives are shown on Figure 4.7, but a comprehensive design approach for the primary and secondary liquid treatment processes was necessary in all cases. The key steps for the EBPR process designs are the location and sizing of the anaerobic contact tank, selecting the design SRT, incorporating and sizing the anoxic tank for nitrate removal if nitrification is used, determining the amount of phosphorus removed by the EBPR process, and determining the final effluent phosphorus concentration. For cases where the design procedure shows that the EBPR process alone can not meet effluent requirements, chemical treatment design steps are incorporated. These involve determining the chemical dose for different chemical addition points and the amount of chemical sludge production. Key aspects of these design steps are described here, and then the key assumptions and relationships used are described in more detail in Section 4.2.2 below.

The anaerobic contact zone tank size was based on a typical HRT of 1.0 hour. The plant layout, aeration tank configurations, and the potential for excess existing aeration tank capacity was considered to determine if the contact tank could be incorporated into an existing tank or if the construction of an external anaerobic contact tank was required.

The design SRT was in important parameter for determining the required aeration volume needed. This was the first step towards determining the aeration volume requirements. It was controlled by one of two factors; the SRT needed for the PAOs or the SRT needed for nitrification. Both of these are a function of the wastewater temperature as shown in Section 4.2.2.

Once the SRT was selected, the required aeration tank volume was determined based on a solids yield which was a function of the wastewater characteristics and SRT and an assumed MLSS concentration. EBPR processes produce very good settling sludge, so for the EBPR process design a MLSS concentration of 3,500 mg/L was used. For the chemical only treatment systems, a lower MLSS concentration was used, typically within 2,500 to 3,000 mg/L. In both cases an adequate secondary clarifier design is assumed present.

An *anoxic zone design* was required for EBPR processes in which nitrification occurred. The A^2O process was the default system used for nitrate removal. For retrofit designs some portion of the existing aeration tank volume had to be used for an anoxic zone or additional external tank volume was required. The required anoxic zone volume was based on the amount of nitrate produced in the activated sludge system, the assumed nitrate concentration in the effluent (5-8 mg/L), and a denitrification rates in the anoxic zone. The amount of nitrate produced was the difference between the influent TKN and the nitrogen used for biomass growth (function of BOD removed) and the effluent ammonia nitrogen concentration. The denitrification rate was determined using a common empirical relationship that correlates the specific denitrification rate (g NO_3-N reduced/g MLSS-d) to the anoxic zone BOD food to mass ratio loading. For oxidation ditch designs the anoxic zone occurs in a section of the ditch channel that is downstream of the aeration zone after the oxygen is depleted and the denitrification rate is driven by the endogenous respiration of the biomass. A relationship was used to account for the denitrification rate for this type of nitrate reduction also (Tchobanoglous et al., 2003).

The *amount of biological phosphorus removal* by the EBPR process was a major process design issue for assessing the feasibility and performance of the EBPR process design. The removal was related to the amount of rbCOD that was available in the anaerobic contact zone for given facility design and the system SRT. The amount of rbCOD available in anaerobic contact zone was a function of the assumed value for the influent sBOD concentration and its fraction as rbCOD, the amount of rbCOD used to biologically reduce nitrate entering the anaerobic contact zone, the amount of rbCOD removed in processes prior to the anaerobic contact zone, and the amount of rbCOD produced from the biodegradation of particulate BOD material entering the anaerobic contact zone in the influent wastewater. Typical biomass growth yield and cellular phosphorus content values for PAOs were used for this calculation. The calculated results agreed well with biological phosphorus removal efficiencies observed for full-scale facilities at similar influent BOD/P ratios.

For most of the facilities, the secondary treatment process was preceded by primary treatment, which would not affect the rbCOD content of the influent wastewater as only particulate material was removed in the primary treatment step. However, for one type of facility, the trickling filter/activated sludge system (TF/AS), rbCOD is removed before the EBPR process. For the TF/AS plants trickling filter BOD removal design models were used to determine the rbCOD remaining in the trickling filter effluent before the EBPR process. The amount remaining was a function of the trickling filter volumetric organic loading; higher loaded trickling filters had less BOD removed and had less of an impact on the EBPR process.

4.2.1.3 Chemical Treatment Design Components

The chemical treatment design approach was more straightforward than that required for the EBPR processes, and consisted of a mass balance between the chemical addition, the stoichiometry between the chemical added and phosphorus removed, and the phosphorus concentration after the chemical addition. For the preliminary design analyses alum was used as the metal salts for chemical precipitation. Similar types of treatment responses would also occur with iron addition, which is a viable precipitation alternative, and the cost comparisons would be similar.

The *chemical dose* in mg/L was based on the amount of phosphorus to remove with chemical precipitation, the equilibrium phosphorus concentration after the chemical reaction, and a relationship shown in Section 4.2.3 between the stoichiometric alum dose and equilibrium phosphorus concentration. Chemical addition was evaluated in general for two scenarios; for effluent polishing in the secondary process and for two-point addition, with chemical applied in both the primary clarifier feed and secondary treatment steps. For chemical addition in the secondary treatment process, the chemical addition point to the mixed liquor stream was assumed to be just before the secondary clarifier. When alum or ferric is added to the primary treatment step, the BOD and TSS removal efficiencies are increased at some proportion related to the chemical dose. This effect was accounted for in the spreadsheet design approach. Without chemical addition, typical primary treatment BOD and suspended solids removal efficiencies of 33 and 65%, respectively, were used. A relationship was used in the spreadsheet designs that increased these efficiencies as a function of the chemical dose.

The *chemical sludge production* was based on the stoichiometry between alum addition and the formation of aluminum phosphate and the formation of aluminum hydroxide. Where alum was added at the stoichiometric amounts for phosphorus precipitation, little hydroxide sludge would be formed. Where it was added in excess of the stoichiometry amount needed for phosphorus precipitation, the amount of alum as aluminum hydroxide sludge was calculated.

Alum or iron addition also results in *alkalinity destruction*. The amount of alkalinity consumed due to alum addition was accounted for by the stoichiometric reactions of aluminum sulfate in water and the amount of alum added.

4.2.2 Design Assumptions and Relationships Used in the EBPR Preliminary Process Designs

Key design assumptions and equations used in the spreadsheet design procedures are summarized in this section. The spreadsheet design followed the fate of BOD, rbCOD, suspended solids, nitrogen, phosphorus and biomass by mass balances to account for their consumption, production and concentrations.

4.2.2.1 Design Solids Retention Time (SRT)

The minimal design SRTs applied for the activated sludge design was based on that needed for EBPR, but if nitrification was required at the facility, it was based on that needed for nitrification. The SRT required for nitrification is much greater than that needed for EBPR. The required SRT for both processes is a function of temperature. For systems with just chemical treatment for phosphorus removal, and without the need for nitrification, a conventional SRT of at least 5 to 7 days was used for BOD removal.

Based on reported SRTs for EBPR process operations, the following relationship (Equation 1) was used in the spreadsheet designs to relate the required SRT to the operating temperature for the EBPR designs. At a temperature of 10°C the required SRT is 5.14 days, for example.

$$\text{EBPR SRT} = (19.5)T^{-0.5793} \qquad (1)$$

where: T = temperature, $^{\circ}$C

The required SRT for nitrification designs was based on nitrification kinetics and accounted for the expected aeration tank dissolved oxygen (DO) concentration and the required effluent NH_4-N concentration as well as temperature and nitrification kinetics. The equations used to calculate the design SRT in the spreadsheet designs are shown below as Equations 3 and 4, for the specific growth rate as a function of the maximum specific growth rate for nitrifying bacteria, the half-velocity coefficient, Kn, and decay coefficient, bn, as a function of temperature, the aeration tank DO concentration, the effluent NH_4-N concentration, and safety factor (typically 1.5) for a completely-mixed single staged aeration tank. For some facilities staged aerobic reactors may be present and the nitrification efficiency for these is greater. However a single stage system was assume in this preliminary design analysis. A more detailed nitrification design would be determined for a more detailed engineering analysis for a final design. The temperature dependence equation

(Equation 2) is given as follows. Table 4.6 gives the temperature coefficient and 20^0C values for the key nitrification kinetic parameters.

$$R_T = \left(R_{20^o C}\right)\theta^{(T-20)} \qquad (2)$$

where: T = temperature, °C
θ = temperature correction coefficient
R_T = reaction rate at temperature T
$R_{20^o C}$ = reaction rate at 20°C

Table 4.6 - Nitrification Kinetic Coefficients and Temperature Dependence

Coefficient	Definition	20^0C Value	Temperature Coefficient, θ
μ_m	maximum specific growth rate, g/g-d	0.80	1.072
Kn	Half-velocity coefficient, mg/L	0.50	1.053
bn	Nitrifying bacteria decay coefficient, g/g-d	0.17	1.029

The specific growth rate at a given condition is given as follows:

$$\mu = \left[\frac{\mu_m N}{Kn + N}\ \frac{DO}{Ko + DO}\right] \text{-bn} \qquad (3)$$

where:
μ = nitrifying bacteria specific growth rate, g/g-d
μ_m = nitrifying bacteria maximum specific growth rate, g/g-d
N = NH4-N concentration, mg/L
DO = aeration tank dissolved oxygen concentration, mg/L
Ko = DO half-velocity coefficient, mg/L
bn = nitrifying bacteria endogenous decay coefficient, g/g-d

The design SRT is a function of the specific growth rate and a design safety factor. A safety factor value of 1.5 was used for the analysis to account for variations in loading and operations variability.

$$SRT = SF\frac{1}{\mu} \qquad (4)$$

where:
SF = safety factor

4.2.2.2 Aeration Tank Volume

The required aeration tank volume is a function of the sludge production, SRT and MLSS concentration (Tchobanoglous et al, 2003), and was determined using the following two equations. The first equation determines the amount of daily sludge production in the aeration tank and the second determine the aeration volume as a function of the SRT and MLSS concentration. Typical design values were used for Y and b, of 0.60 g TSS/g BOD and 0.08 g/g-d. The value of Xi varies with the level of pretreatment. For primary treatment a value of 0.20 g inert TSS/g BOD (g/g) was typically used, and for no primary treatment a value of 0.50 g/g was used. With chemical addition to primary treatment a greater capture of inert solids occurs, so the Xi value in that case was 0.10 to 0.15 g/g. A key design assumption in Equation 6 is the MLSS concentration.

$$\mathrm{Px} = \frac{\mathrm{Y}}{(1+\mathrm{bSRT})}\mathrm{Q(So)}8.34 + \mathrm{XiQ(So)}8.34 \qquad (5)$$

where:

Px = sludge production, lb/d

Y = synthesis yield, g TSS/g BODremoved

b = endogenous decay coefficient, g/g-d

Q = flow rate, MGD

So = BOD removed, mg/L

Xi = inert solids yield fraction, g nbTSS/g BODremoved

nbTSS is non biodegradable influent TSS,mg/L

$$\mathrm{V} = \frac{\mathrm{Px(SRT)}}{\mathrm{MLSS}(8.34)} \qquad (6)$$

where:

V = aeration tank volume, Mgal

SRT = solids retention time, days

MLSS = mixed liquor suspended solids concentration, mg/L

4.2.2.3 Specific Denitrification Rate in Anoxic Zone

The specific denitrification rate (SDNR) used to determine the nitrate reduction rate on the anoxic zones, and thus the size of the anoxic zones, based on the amount of nitrate fed to the anoxic zone and the MLSS concentration was based on a commonly used empirical equation (Tchobanoglous et al. 2003) shown as follows. This equation provides a more conservative rate but is adequate for this conceptual design approach.

$$\mathrm{SDNR} = 0.03(\mathrm{F/M}) + 0.029 \qquad (7)$$

where:

F/M = BOD food to mass ratio to anoxic zone based on activated sludge influent loading, lbBOD/lb MLSS-day

SDNR = specific nitrate utilization rate, g NO3-N/g MLSS-d

4.2.2.4 Phosphorus Removal Stoichiometry

The amount of phosphorus removed by the EBPR process in mg/L was based on the rbCOD consumption, the biomass growth of the PAOs, and the phosphorus content of the PAOs, which was related to the activated sludge SRT, as shown by Equations 8 and 9. The effect of SRT on the phosphorus content of the PAOs was done empirically to account for the fact that EBPR processes are less efficient at longer SRT. At short SRTs the phosphorus content of the PAOs was 25% based on dry weight.

$$R_{\mathrm{PAOs}} = \frac{Y(\mathrm{rbCOD\ removed,\ mg/L})Q(8.34)}{(1 + b_{\mathrm{PAO}}\mathrm{SRT})} \qquad (8)$$

where:

R_{PAOs} = rate of PAO biomass production, lb/d

b_{PAO} = endogenous decay rate of PAOs, g/g-d

$$\text{Bio P removal, mg/L} = \frac{R_{\mathrm{PAOs}}[0.25 - 0.002(\mathrm{SRT})]}{Q} \qquad (9)$$

The amount of phosphorus removal due to heterotrophic biomass synthesis was also calculated based on the influent BOD removal, other than the rbCOD taken up by the PAOs. The same synthesis yield and endogenous decay coefficients, as shown in Equation 5, were used to determine the biomass production rates. The phosphorus content of the heterotrophic biomass was assumed to be 1.5%, based on dry weight. This synthesis phosphorus removal pathway was also applied in the chemical treatment only systems to account for phosphorus removal by biomass production.

For some designs with high influent BOD/P ratios, the amount of phosphorus removed by the EBPR process was greater than the amount of soluble phosphorus in the influent to the EBPR process. For these cases, a soluble phosphorus concentration of 0.30 mg/L was assumed.

Biological phosphorus removal does slightly increase sludge production above that normally observed for BOD removal. Besides the amount of phosphorus removed certain cations (K, Mg, and Ca) are also contained in the biomass such that the total amount of these cations is equal to the equivalence of phosphorus removal. The resulting sludge production due to phosphorus and cation removal is 1.93 g biomass/g P removed. This does not show up as a sludge handling problem or additional cost, because the overall sludge resulting from EBPR processes is denser and thickens more readily.

4.2.2.5 Trickling Filter Removal of rbCOD

Tricking filter design procedures described in Tchobanoglous et al. (2003) were used to calculate the amount of total and soluble BOD removed by the existing trickling filters in the facilities with TF/AS processes. In this approach the settled BOD for the trickling filter effluent is calculated using Equation 10. The effluent soluble BOD is based on the assumption that 50% of the settled BOD is soluble. Where intermediate clarifiers are not used the solids degradation and biomass production is accounted for to estimate the solids load to the activated sludge process. The degradation coefficient was corrected for temperature, media depth, and influent wastewater BOD concentration according to the procedures in Tchobanoglous et al. (2003) and these correction relationships are included here in Equations 11 and 12, respectively.

$$Se = Soe^{(-kD/q^n)} \tag{10}$$

where:

Se = settled effluent BOD, mg/L

So = influent BOD, mg/L

k = treatability coefficient, $gpm^{0.5}/ft^2$

D = media depth, ft

q = hydraulic application rate, gpm/ft^2

n = hydraulic coefficient, 0.50

$$k = k_{20}(\Theta^{T-20}) \tag{11}$$

where:

k_{20} = treatability coefficient at 20^0C, 0.071 $gpm^{0.5}/ft^2$

Θ = temperature coefficient, 1.035

$$k_2 = k_1\left(\frac{20}{D_2}\right)^{0.5}\left(\frac{150}{S_2}\right)^{0.5} \qquad (12)$$

where:

k_2 = treatability coefficient corrected for depth and influent BOD, $gpm^{0.5}/ft^2$
k_1 = treatability coefficient, k, $gpm^{0.5}/ft^2$
D_2 = site media depth, ft
S_2 = site trickling filter influent BOD concentration, mg/L

4.2.3 Design Assumptions and Relationships Used in the Chemical Treatment Preliminary Process Designs

The relationship used in the spreadsheet design approach to determine the chemical doses for phosphorus removal and effect on the primary clarifier BOD and suspended solids removal efficiency are described.

4.2.3.1 Alum Dose

It is well established that the molar ratio of alum to phosphorus increases at lower soluble phosphorus concentrations due to reactions forming aluminum hydroxide. Based on literature values, a relationship between the molar alum to P ratio versus soluble P concentration was developed and is shown on Figure 4.8. The figure shows that at above a soluble phosphorus concentration of 1.0 mg/L the molar Al/P ratio approaches the stoichiometric value of 1.0 for the formation of $AlPO_4$. The relationship in Figure 4.8 was fitted with an equation that was used in the design spreadsheets to calculate the alum dose as a function of the soluble P concentration after the alum addition points. For alum addition in the primary clarifier step, for example, the procedure was as follows: 1) the amount of phosphorus removed by chemical precipitation in mg/L is selected, 2) this was subtracted from the influent phosphorus concentration to obtain the final soluble phosphorus concentration, and 3) the relationship in Figure 4.8 was used to calculate the alum dose by using the Al/P ratio at the given soluble P concentration and multiplying it by the phosphorus removed. The dose as alum was determined from the molar Al amount by multiplying it by the molecular weight of alum (666) and dividing it by the molecular weight of aluminum (27). The equation in the spreadsheet model used to represent the relationship in Figure 4.8 was as follows:

$$\text{Molar Al/P ratio} = 1.75(P^{-0.4437}) \qquad (13)$$

where:

P = soluble phosphorus concentration, mg/L

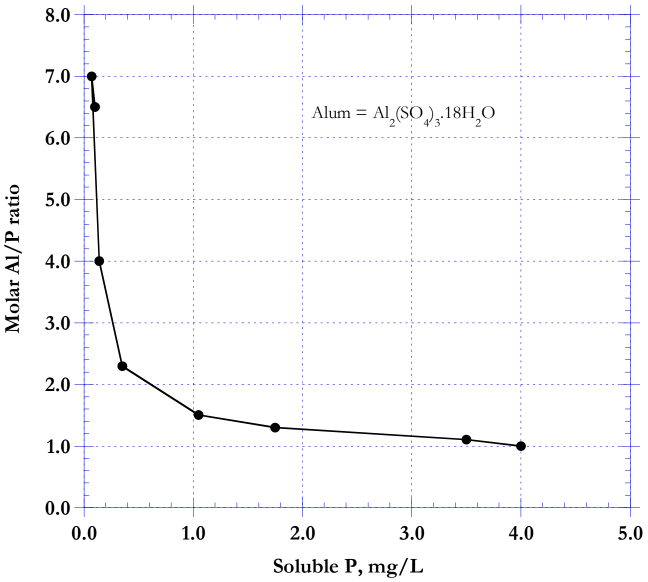


Figure 4.8 - Alum Dose as Molar Al/P Ratio versus Soluble P Concentration

4.2.3.2 Alum Sludge Production and Alkalinity Consumption

Based on a stoichiometric balance for the formation of aluminum phosphate precipitate with alum or aluminum hydroxide the chemical sludge production was calculated based on a ratio of 3.93 g sludge/g P removed by alum and 0.23 g aluminum hydroxide sludge/g of alum used. The alkalinity consumption was 0.45 g alkalinity as $CaCO_3$ used per g of alum applied.

4.2.3.3 Effect of Alum Dose on Primary Treatment Efficiency

Alum addition improves flocculation in primary clarifiers which increases the BOD and TSS removal efficiencies. Based on reported removal efficiencies a relationship between the alum dose and BOD and TSS removal efficiencies was developed and used in the spreadsheet designs to determine the primary effluent BOD and TSS concentrations as a function of the influent wastewater characteristics and chemical dose. The equations used are as follows:

$$EBOD = EBODo(0.0065Al + 1.0) \quad (14)$$

where:

Al = alum dose, mg/L

EBOD = BOD removal efficiency with alum added, %

EBODo = BOD removal efficiency with no alum added, 33%

$$ETSS = ETSSo(0.0021Al + 1.0) \qquad (15)$$

where:

Al = alum dose, mg/L

ETSS = TSS removal efficiency with alum added, %

ETSSo = TSS removal efficiency with no alum added, 65%

At an alum dose of 150 mg/L, for example, the BOD and TSS removal efficiencies are estimated to be 65 and 85%, respectively. At high alum dose the upper limit for the BOD and TSS removal efficiencies was set at 70 and 90%, and the primary effluent and influent soluble BOD concentration remained equal.

4.3 BASIS FOR PRELIMINARY COST ESTIMATES

Based on the variation in treatment processes, plant size and plant loadings, a select number of phosphorus removal techniques were considered for retrofitting the MESERB plants. As discussed previously in this section, phosphorus removal at treatment plants is typically achieved by two technologies, EBPR and chemical treatment. Capital and operations and maintenance (O&M) costs are factors along with the technical feasibility of a specific treatment scenario that was used in the evaluation of phosphorus removal alternatives.

The preliminary costs presented in Section 5 are based on the conceptual designs of biological and chemical precipitation (treatment) systems to meet an effluent phosphorus target of 1 mg/L. The costs are planning level estimates developed to evaluate the different alternatives, to provide a framework to allow comparison of relative costs, and to assist individual plants to further investigate viable phosphorus removal options. The cost estimates are based on a compilation of cost information from USEPA reports, trade journals, vendor's quotes and internal project data.

Included in this section are a description of the capital cost elements for the EBPR and chemical precipitation systems, a summary of the annual cost factors associated with the budgetary O&M costs, and a discussion of the preliminary cost estimate methodology used to develop capital and annual costs for the phosphorus removal alternative for each wastewater treatment plant.

4.3.1 Capital Costs

The preliminary capital costs included component costs (installed equipment cost and miscellaneous structures), non-component costs (piping, electrical, instrumentation and site preparation) and non-construction costs (engineering and construction supervision, contractor profit and contingencies). The capital costs assumed that land needed for siting any new tankage was already owned by the municipality and the cost to acquire land was not included. Potential costs items that were not taken into account in this evaluation included the following factors: specific site conditions such as land acquisition, layout constraints for tanks, equipment or piping; treatment system upgrades due to normal tank or equipment wear or age; chemical requirements for alkalinity consumption; additional sludge handling and disposal equipment for chemical phosphorus removal; and potential hydraulic constraints such as limited capacity of existing pumps and/or piping or the potential impact of additional tanks or equipment on the existing hydraulic profile or piping routes. All dated cost information was scaled up to present day costs using Engineering News Record (ENR) Construction Cost Index (CCI - 20 city average) for October 2004 (ENR CCI = 7314). RS Means and recent vendor information were considered current and not scaled up.

The potential impact of the chemical sludge generated from chemical treatment for phosphorus removal on sludge handling and disposal operations was reviewed for several plants. The preliminary analysis considered both the combined EBPR and chemical addition process and chemical addition only. The analysis indicated that the increase in waste sludge from chemical treatment would range between 5 and 25 percent for the plants based on design flows and loadings. Sludge handling design parameters such as anaerobic digester residence time of 15-20 days, sludge thickening to 4 to 5 percent and the periodic return of supernatant from the digester or sludge storage tank were used to assess the need for additional sludge handling tanks or equipment. The screening analysis concluded that the estimated chemical waste sludge would have a minor impact on sludge handling and disposal operations. Based on this assessment, the cost for additional sludge handling and/or disposal operations was not included in the preliminary cost analysis presented in Section 5. Similar to the wastewater analysis wastewater, future consideration of phosphorus removal for any treatment plant must include a detailed review of the existing sludge handling operations and the potential impact of increased waste sludge from chemical treatment on sludge disposal.

While additional alkalinity may be required, the cost for feed equipment was not included in this conceptual design analysis for the phosphorus removal options. This cost would be included during any detailed engineering analysis of chemical feed systems for a specific plant.

The capital cost components associated with EBPR include tankage (new tankage or baffling of existing tankage if excess capacity is available), mechanical mixing in the form of surface or submersible mixers and recycle pumping. Tankage requirements assumed the need for both anaerobic and anoxic zones, however, the anoxic zone was only required for plants that nitrify. A detention time of 1 hour was used for the anaerobic and anoxic tank sizing. For plants with sufficient excess capacity, a retrofit of the existing tankage is the most cost effective means to convert a plant to EBPR. This would include tank baffling, installation of mixing equipment in the unaerated portions of the biological system for an anaerobic zone and effluent recycle pumping. Plants with limited air distribution control would require air system modifications to regulate air flow to individual treatment zones. For plants without sufficient excess tank capacity, new tanks would be required. Unit costs for tankage retrofit costs ranged from $10 to $20 per square foot of baffle wall/curtain installed. New tankage costs had a wide range from $0.31 per gallon for concrete tanks greater than 5 MG to $1 to $2 per gallon for steel tanks less than 0.05 MG.

Mixing and recycle horsepower requirements were assumed at 50 hp per million gallon of tank volume and 200 percent (of influent flow) recycle at 10 feet of head, respectively. Mixing could be accomplished using either top entering, bridge mounted mixers or submersible style mixers with submersible mixers commonly used for EBPR. Pumped-flow mixing systems would also be available but were more expensive than mechanical mixers (and were not considered in this cost analysis) but may be more cost competitive as the required recycle flow increases. Mechanical mixing equipment costs were on the order of $1,000 to $2,000 per horsepower. Recycle pumping equipment costs ranged from $6,500 to $5,000 per MGD of pump capacity.

Chemical treatment capital costs included the feed equipment, storage tank and chemical treatment building. The largest portion of the equipment (bare) cost was the building (60-65%) used to house the chemical storage tanks and the feed equipment. A building cost of $92 per square foot was used for the chemical feed building. Storage tank costs varied from $6,500 to $40,000 while feed equipment costs based on a vendor quote ranged $19,000 to $25,000 for 1 and 10 MGD plants, respectively.

4.3.2 Operation and Maintenance (O&M) Costs

The operation and maintenance costs included the cost for chemicals, power, labor, and chemical sludge disposal. Chemical costs included chemicals required for chemical precipitation as well as EBPR. Liquid alum costs (delivered) ranged from $0.06 to $0.20 per pound of liquid while local ferric chloride costs ranged from $0.14 to $0.21 per pound of liquid plus the cost of transportation. Screening of chemical costs for alum and ferric chloride indicated similar costs for either coagulant. Alum is safer to handle and less corrosive than ferric chloride and alum was selected as the appropriate chemical for the chemical precipitation alternative. The use of ferric chloride may be more favorable than alum in some cases e.g., when waste pickle liquor is available locally or complex sludge handling is practiced. Both coagulants should be investigated during the detailed design of chemical phosphorus removal facilities. The alum cost selected for plant design O&M costs was assigned at $0.10 per pound. Based on wastewater characteristics and process kinetics, EBPR may require the addition of alkalinity. Alkalinity costs were based on the use of soda ash at a cost of $0.303 per pound of alkalinity.

Energy requirements were based on the mixing/pumping horsepower required for EBPR only. Mixing requirements were based on 50 hp per million gallons of tank volume while recycle pumping requirements were based on 200 percent of influent flow at a head of 10 feet. Power requirements for chemical feed equipment were found to be minor and, therefore, not included. Electrical rates for commercial customers and how they are applied vary greatly from place to place (i.e., straight use vs. base use plus demand charge). In lieu of a detailed electrical cost review, the electrical rate used for economic review was taken as $0.08 per kilowatt-hour. An additional energy requirement that was not considered in the O&M costs but should be included in a detailed engineering analysis, is chemical storage building heating.

Labor rates for MESERB plants based on conversations with plant operators ranged from $16 to $25 per hour. A labor rate of $20 per hour was assumed for O&M analysis. Local MESERB plant labor rates that may be higher should be scaled up accordingly.

The cost of biosolids disposal was also an important factor in the selection of a phosphorus removal alternative. Nearly all of the MESERB study plants use land application for biosolids disposal. Grand Rapids was the only plant that practiced landfilling of biosolids. Since Grand Rapids owns and operates the landfill their biosolids disposal costs were the lowest ($36 per dry ton) of any of the plants that provided disposal cost information. A review of the plants land applying biosolids indicated a range in costs from $120 to $200 per dry ton with an average cost of $180 per dry ton.

4.3.3 Methodology for Preliminary Cost Estimates

This section presents a discussion of the methodology used to estimate the preliminary budgetary capital and O&M costs for retrofitting the existing wastewater treatment plants for EBPR and/or chemical treatment processes. The three cost curves presented are for the preliminary capital and O&M costs for the EBPR process, and for the preliminary capital costs for chemical treatment. The cost curves are presented as a function of plant design flow rate and are based on September 2004 US dollars.

Figure 4.9 presents the preliminary capital costs for retrofitting the A^2O and AO biological processes into existing plants to convert these treatment plants to an EBPR process. These processes were discussed in detail in Sections 4.1 and 4.2. The cost curves presented on Figure 4.9 represent the addition of external tankage and equipment for plant conversion to the A^2O process and two scenarios for AO process conversion, new external tankage and retrofit of existing tankage with internal baffling. The A^2O process is for those plants that are currently nitrifying or will be required to nitrify. The cost curve for this option assumes conversion will require external tankage for both anoxic and anaerobic treatment. The A^2O process option assumed a 1.0 hour anaerobic and 1.0 hour anoxic zone detention times, 200% activated sludge process effluent recycle and new external tankage.

The cost curve for the second biological scenario, the AO process, was developed for those plants that do not have to nitrify. Two cost curves are presented for the AO process. The cost curves were based on conceptual designs of the AO process using a 1.0 hour anaerobic zone detention time. The upper curve labeled “AO Retrofit w/External Tanks” is for those wastewater treatment plants whose existing tank capacity is limited and new external tankage would be required for process conversion to EBPR. The lower curve labeled "AO Retrofit w/ Existing Tanks Baffled" is for those treatment plants whose aerobic biological process has enough excess capacity to convert a portion their existing tankage to an anaerobic zone with a 1.0 hour detention time. In this case, a portion of the tank would be isolated with a baffle wall, air supply to this zone would be turned off and mechanical mixing would be added to keep the mixed liquor in suspension. In all three scenarios presented, a mixing requirement of 50 hp per million gallons of unaerated tankage was assigned in the conceptual designs.

As shown on Figure 4.9, the A^2O process would have the highest capital cost based on the larger tank volumes and mixing required and the extra recycle pumping that is required of the A^2O process. Based on the fact that tank baffling is a fraction of the cost of new external tankage, the lowest capital costs would be for the AO process utilizing available tankage at the plants.

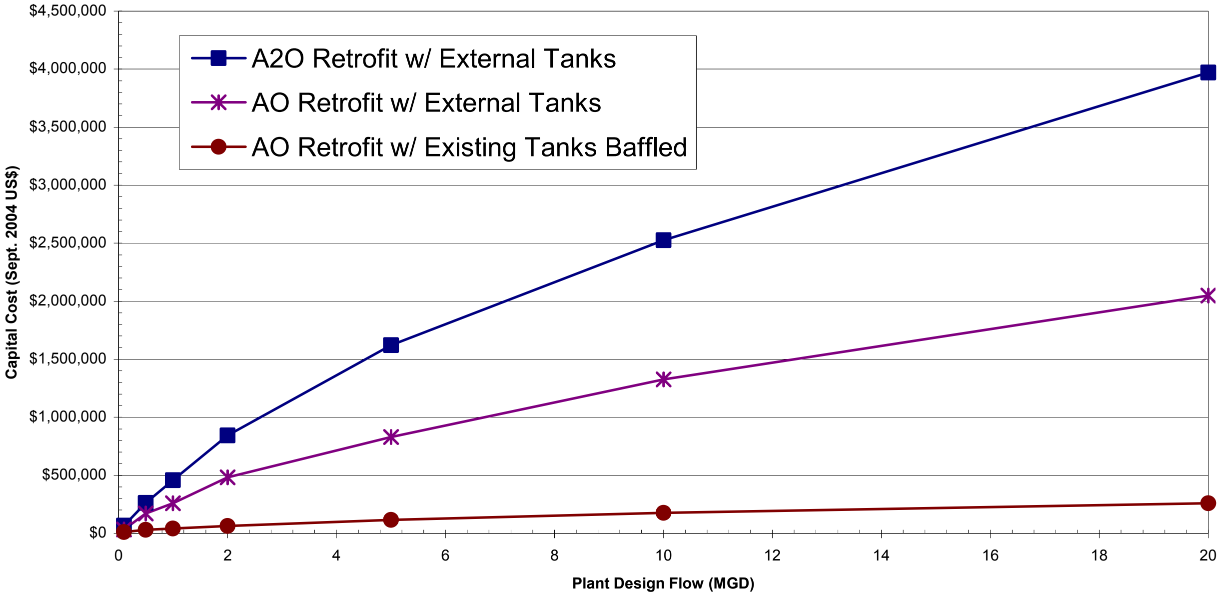


Figure 4.9 – Preliminary Budgetary Retrofit Capital Costs – Enhanced Biological Phosphorus Removal

The EBPR process O&M costs are summarized on Figure 4.10 as a function of plant design flow. The cost curves are presented in a similar manner as the preliminary capital costs. The costs include electric costs for the installed equipment to provide the horsepower for mixing and recycle, as applicable, and the labor cost estimated at two percent of the retrofit capital cost. The A^2O process would have the highest estimated O&M cost based on the larger equipment required. The

AO design scenarios would have identical electric costs since they would have the same installed equipment requirements but the labor would be lower for a baffled system.

Preliminary capital cost for chemical treatment is presented on Figure 4.11 as a function of design flow. It represents the line of best fit for either one or two stage chemical addition. The cost curve was developed from the sources of chemical costs previously discussed. The cost includes feed equipment and chemical storage facilities with allowances for piping, instrumentation, electrical and site work as well engineering, profit and contingencies.

The annual O&M costs for chemical treatment were based on three cost factors, chemical requirements, labor and sludge disposal costs. Power requirements for feed equipment were estimated to be minor. Chemical costs include alum addition and alkalinity replacement. Calculated alum requirements to meet effluent phosphorus goals were used assuming alum costs at $0.10 per pound. When alum addition resulted in alkalinity consumption in excess of 100 mg/L, the need for

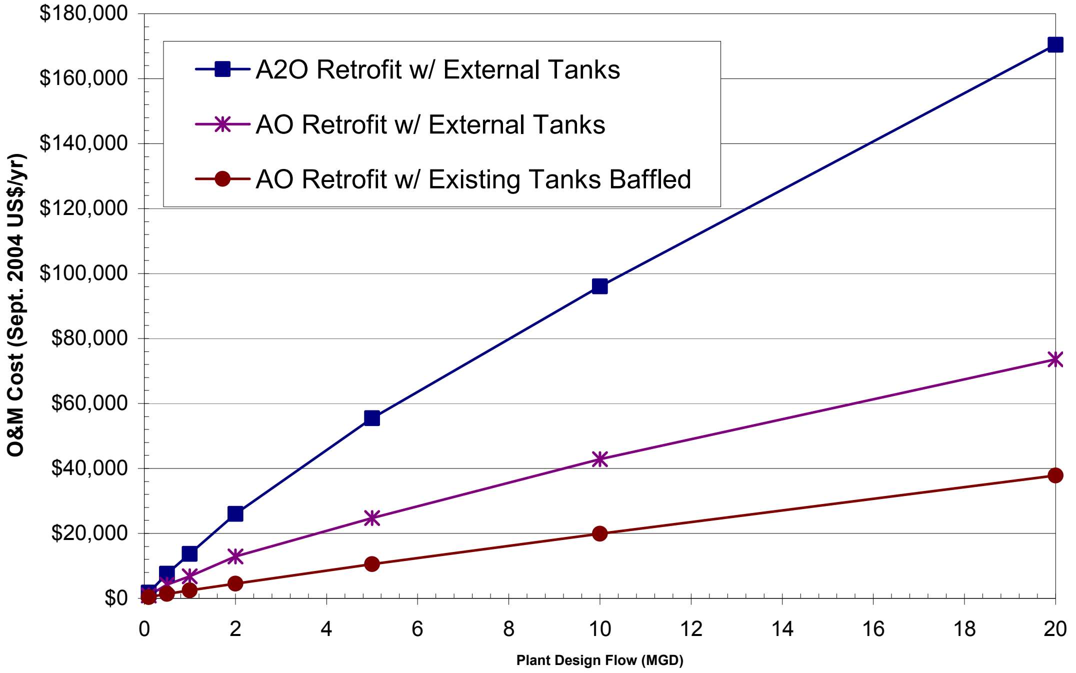


Figure 4.10 – Preliminary Budgetary O&M Costs – Enhanced Biological Phosphorus Removal

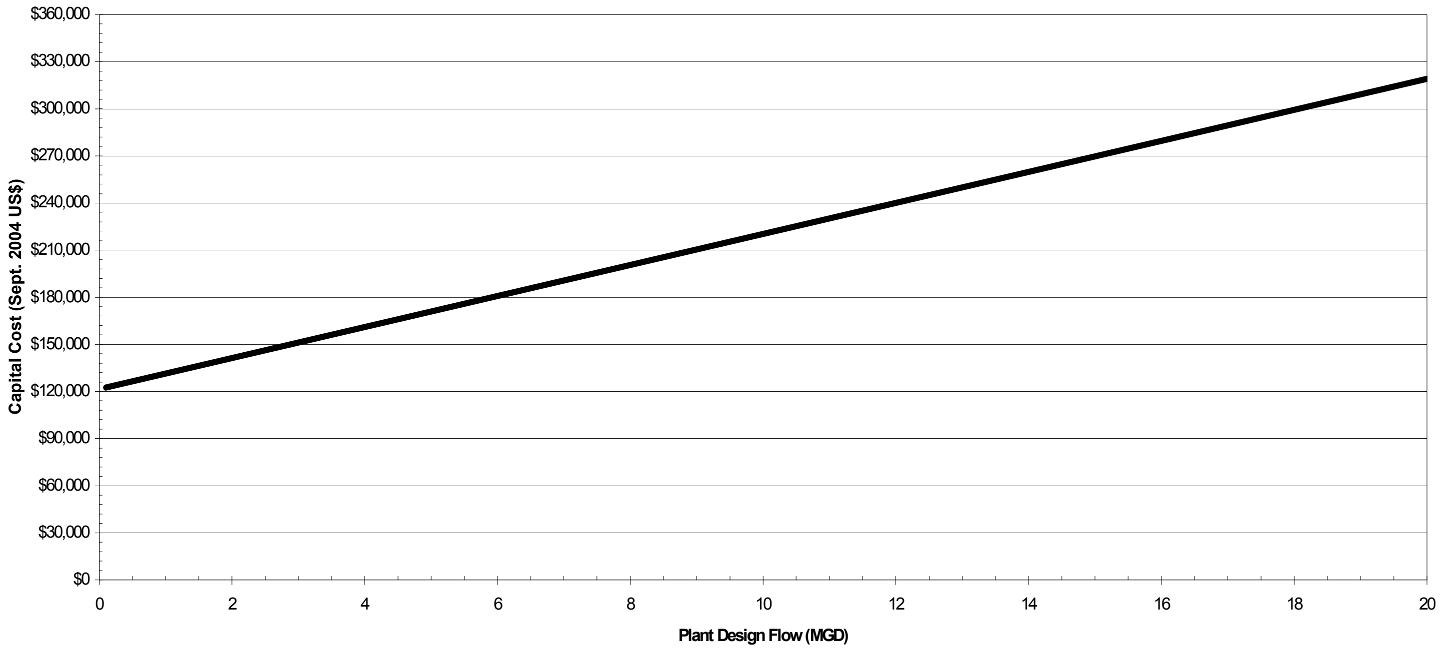


Figure 4.11 – Preliminary Budgetary Retrofit Capital Costs – Chemical Precipitation

supplemental alkalinity addition was recognized. Soda ash was used for supplemental alkalinity at a cost of $0.303 per pound of alkalinity as $CaCO_3$. Costs for soda ash were based on replacing the portion of alkalinity above 100 mg/L. Increased sludge disposal costs for chemical precipitation were based on calculated alum sludge production and a sludge disposal cost of $180 per ton. Labor costs were based on operational hours estimated for chemical treatment and a labor rate of $20 per hour.

A present worth cost analysis was used to compare the retrofit cost for the phosphorus removal alternatives for each plant to illustrate the most cost effective alternative for each site. The present worth represents the equivalence of any future amount to any present amount. In this case, the present worth cost was used for the O&M cost for each alternative. The analysis considered a 20-year time period and an average interest rate of 5 percent which was based on December 2004 Minnesota municipal bond information. Total present worth cost was the sum of the capital cost and the O&M present worth cost. The analysis is discussed in Section 5 for each treatment plant.

4.4 COMPARISON OF USING FERMENTATION TO ALUM ADDITION TO INCREASE PHOSPHORUS REMOVAL

As was discussed in Section 2.3, many facilities using EBPR processes can provide a significant amount of phosphorus removal, but may not have enough influent rbCOD to remove phosphorus to a concentration below 1.0 mg/L without some type of chemical addition. There are three options available for providing additional chemicals for phosphorus removal. The options are:

- Providing VFA from an on-site fermenter using primary clarifier sludge;
- Purchasing rbCOD via sugar or acetic acid; and
- Purchasing alum to remove additional phosphorus by chemical precipitation.

The chemical addition alternatives were evaluated using the current cost of $0.18/lb of sugar addition and $0.10/lb of alum addition. For sludge fermentation, the main cost is the capital cost of the fermenter in contrast to operating costs for chemical addition. The capital cost was estimated for fermenters for different plant sizes and then was converted to an equivalent annual operating costs based on a present worth calculation using 5% interest for a 20 year period. The fermentation unit was designed based on the following conditions, which are representative of fermenter applications in EBPR systems:

1. Influent TSS concentration of 200 mg/L to primary clarifier and 65% TSS removal efficiency;
2. Solids thickening to 3% concentration in the primary clarifier;
3. A 3-day SRT for sludge fermentation in a gravity thickener;
4. A VFA production of 0.15 g VFA/g TSS applied;
5. An elutriation efficiency of 70% for return of VFA to the influent of the EBPR anaerobic contact zone; and
6. A ratio of 12 pounds (lb) of P removed per pound of additional VFA to the EBPR process.

The required fermenter volumes would range from 9,000 gallons for a 1 MGD plant to 90,000 gallons for a 10 MGD plant. The cost analysis and design did not include odor control facilities.

Using the cost estimates and the estimate for the additional P removal per mg of VFA produced, the cost of P removal in $/lb was determined as a function of plant size. This is compared to the cost of adding alum for P removal at a $0.10/lb of alum. The alum dose was assumed at 1.0 mole Al/mole of P.

Sugar or acetic acid can be purchased to provide rbCOD for EBPR. Sugar is less expensive than acetic acid and was used as the preferred exogenous carbon source to improve biological phosphorus removal. Its cost was estimated at $0.18/lb and the necessary dose was at 12 lb phosphorus removed per lb sugar added, similar to VFA addition.

The cost comparison between alum addition, sugar addition, and the investment for a fermenter installation is shown in Figure 4.12. For a plant size below 5.0 MGD, alum addition is clearly much less expensive than the cost of phosphorus removal by obtaining COD from a sludge fermenter. However, the cost of phosphorus removal using COD from a fermenter becomes more competitive compared to purchasing alum to improve phosphorus removal as the plant size increases. At a 10 MGD plant size, the cost of using fermentation is about 72% of that for alum purchase, and, at a 20 MGD plant size, the cost is about 55% of purchasing alum. However, these costs do not include the cost for odor control and maintenance costs related to the fermenter operations. The cost comparison also shows that the addition of sugar or acetic acid is more expensive than using alum for phosphorus precipitation.

Based on this preliminary cost analysis, fermenters were not considered in the conceptual design evaluations for retrofitting the selected wastewater treatment facilities as many of the plants were below the 10 to 20 MGD plant sizes. Also, if there were a cost savings by using fermentation, the magnitude in the savings was not sufficient to offset other cost uncertainties related to odor control and plant operations. It should also be noted that less than 10% of EBPR systems throughout the country use fermenters.

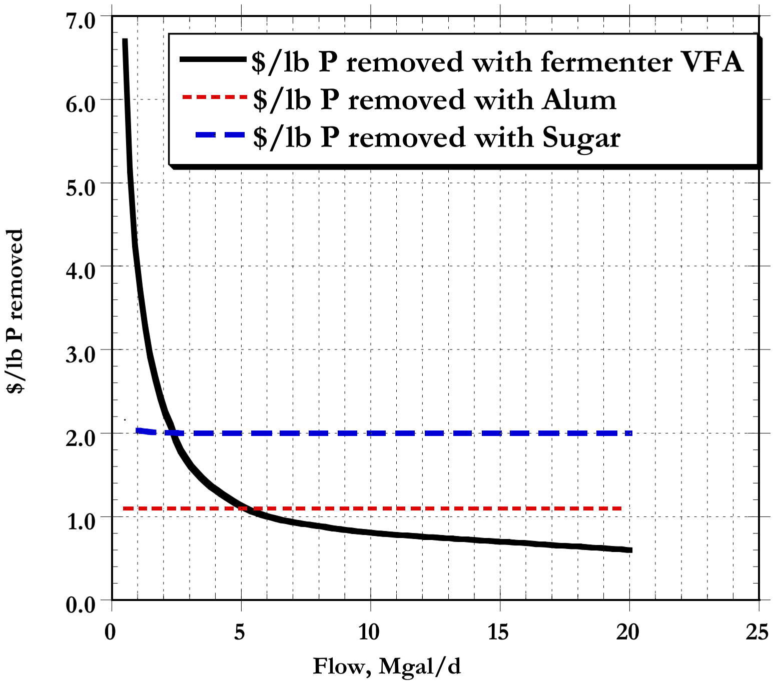


Figure 4.12 - Comparison of Phosphorus Removal by Alum or Sugar Addition or Using VFA from an On-site Fermenter at Equivalent Costs

SECTION 5

PLANT EVALUATIONS

This section presents a summary of the treatment analysis conducted on phosphorus removal alternatives for each treatment plant. The section is divided into eight subsections based on the different biological treatment processes. Within each category, a summary of the phosphorus removal analysis is presented for each treatment plant. The summary includes plant operations and performance analysis, design modifications used for phosphorus removal analysis and an evaluation of the different phosphorus removal options based on technical and economic considerations.

The purpose of the analysis was to evaluate appropriate phosphorus removal systems that were cost effective, met a monthly average phosphorus discharge target of 1 mg/L (the most stringent effluent concentration specified in current MPCA regulations) and would have application to a wide range of treatment plants in the State. Conceptual designs were developed for each facility so that the performance of possible phosphorus removal alternative could be evaluated and relative cost determined. The conceptual designs determined required tank volumes, additional reactor mixing requirements, primary, secondary, and chemical sludge production rates, internal recycle rates where necessary, the acceptability of other unit process loadings such as secondary clarifiers, chemical dose requirements, the amount of biological phosphorus removal, and changes in alkalinity concentrations.

The basis for the evaluation was the plant data collected from the screening forms and site visits in September and October 2003. The plant data reviewed included the completed screening forms which summarized plant operating data and treatment sizes discharge monitoring reports for one year (October 2002-September 2003) NPDES permit; plant design data from plant records and engineering reports on design flows and loadings, treatment unit sizes and process flow diagrams and information received during the site visits and follow up calls with plant personnel.

Monthly averages of the plant data were used for the influent and effluent characterization, biological process design data summaries, and plant performance evaluations. The influent and effluent characterization included the following conventional parameters: wastewater flow in million gallons per day (MGD), carbonaceous 5-day biochemical oxygen demand ($CBOD_5$), total suspended solids (TSS), ammonia nitrogen (NH_4-N), nitrite and nitrate nitrogen (NO_2-N and NO_3-N), total phosphorus (TP), temperature, and pH.

Plant information and the data analyses for each plant are summarized in Appendix 2. These summary tables are divided into the following categories: Plant Design Parameters including flows, $CBOD_5$ and TSS loadings, overflow rates and detention time, treatment unit sizes and sludge handling; NPDES Permit Limits and Requirements; Biological Secondary Treatment Process Design

Information; Wastewater Characterization (influent and effluent); Plant Performance (as percent removed); and Probability Analysis of key wastewater parameters (e.g., TSS, $CBOD_5$, TP, NH_4-N, NO_3-N). These data were the basis for the phosphorus removal alternatives analysis. Key parameters from these tables such as food to microorganism ratio (F/M), mixed liquor suspended solids (MLSS), hydraulic residence time (HRT) and solids retention time (SRT) were used in the analysis and are summarized in tables in the discussion of phosphorus removal options for each plant.

Conceptual designs were developed of appropriate phosphorus removal treatment systems to evaluate the effectiveness of retrofitting the existing treatment plants to meet a phosphorus discharge target of 1 mg/L in the final effluent. Process design parameters and the process evaluation protocol developed in Section 4 served as the basis for the evaluation of the phosphorus removal options. Two basic phosphorus removal treatment systems were considered in this analysis, enhanced biological phosphorus removal (EBPR) and chemical treatment. The phosphorus removal options include a no action alternative, source control, enhanced biological phosphorus removal (EBPR), chemical treatment, and a combined EBPR and chemical addition system.

Preliminary budgetary capital and operation and maintenance (O&M) costs were developed for each alternative based on cost information discussed in Section 4. The preliminary capital costs included component costs (installed equipment cost and miscellaneous structures), non-component costs (piping, electrical, instrumentation and site preparation) and non-construction costs (engineering and construction supervision, contractor profit and contingencies). The capital costs assumed that land needed for siting any new tankage was already owned by the municipality and the cost to acquire land was not included. Potential costs items that were not taken into account in this evaluation included the following factors: specific site conditions such as land acquisition, layout constraints for tanks, equipment or piping; treatment system upgrades due to normal tank or equipment wear or age; chemical feed equipment for alkalinity consumption; additional sludge handling and disposal equipment for chemical phosphorus removal; and potential hydraulic constraints such as limited capacity of existing pumps and/or piping or the potential impact of additional tanks or equipment on the existing hydraulic profile or piping routes. A present worth analysis was used to compare the cost effectiveness of the phosphorus removal alternatives.

5.1 ACTIVATED SLUDGE

Three activated sludge plants were evaluated for phosphorus removal; the 3.25 MGD Alexandria Lake Area Sanitary District WWTF, 14.3 MGD Grand Rapids WWTF, and the 6.77 MGD New Ulm WWTF. The following summarizes the evaluation of each plant.

5.1.1 Alexandria Lake Area Sanitary District WWTF

The Alexandria Lake Area Sanitary District Wastewater Treatment Facility (Alexandria Lake WWTF) is a 3.25 MGD conventional activated sludge plant with primary treatment followed by tertiary multimedia filtration, chlorination and dechlorination. The plant was constructed in 1977 and most major mechanical components have been replaced or upgraded. The most recent improvement was an upgrade to fine bubble aeration in 1999. The plant is now operating at 2.6 MGD which is about 80% of its design limit.

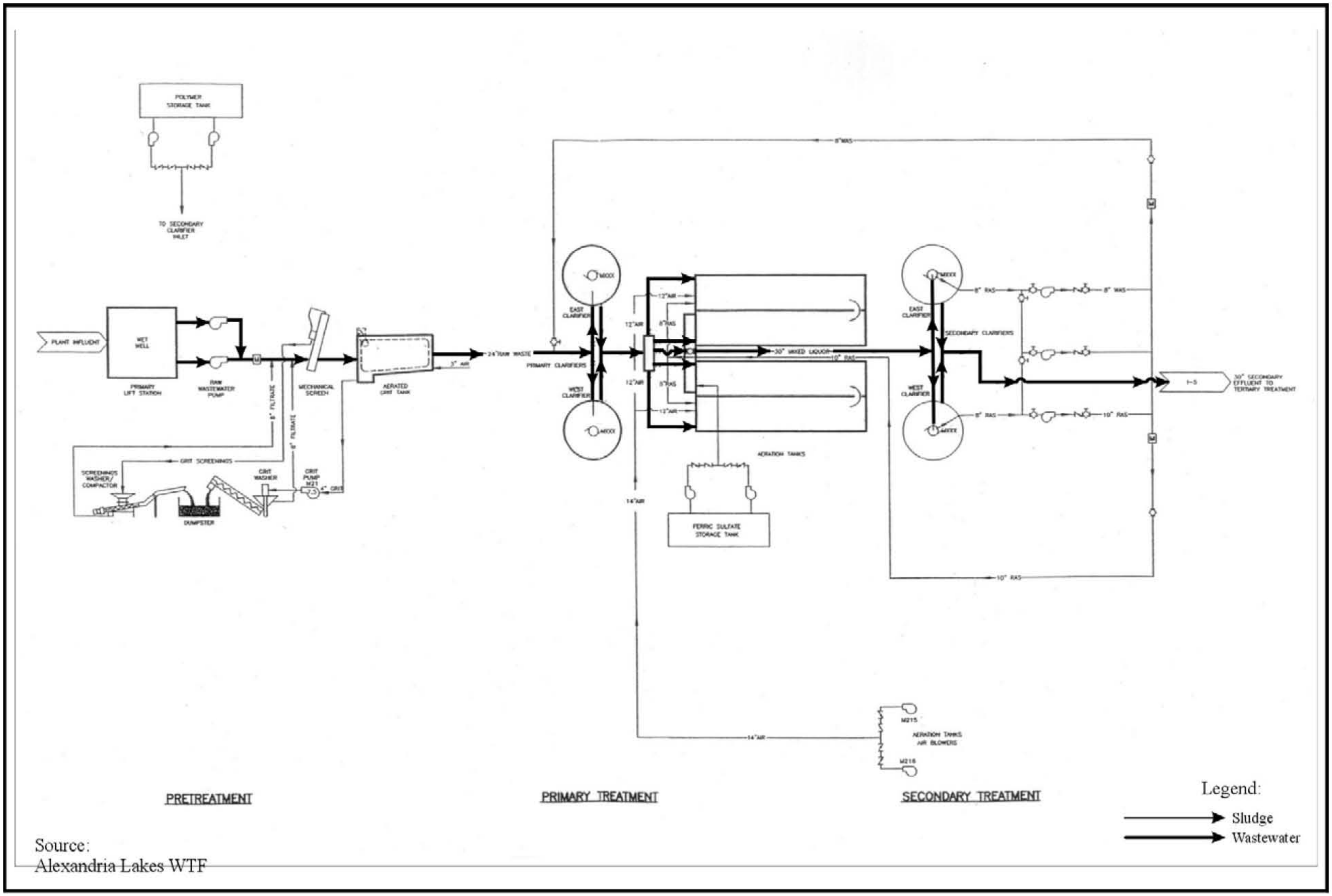
An effluent discharge permit phosphorus limit of 1.0 mg/L has been imposed since 1977 because the plant effluent ultimately impacts a lake. The discharge limit has been met (and exceeded) through ferrous sulfate addition to the aeration basin effluent.

5.1.1.1 Plant Description and Performance

A process flow diagram for the wastewater treatment process and sludge handling is presented on Figures 5.1.1.1a and 5.1.1.1b. Preliminary treatment consists of mechanically cleaned bar screens and aerated grit removal. Following pretreatment the wastewater is split between two 11-ft deep and 45-foot diameter primary clarifiers. The primary clarifier overflow rate is near its design limit, and is about 820 gpd/ft^2 at the average annual influent flow rate. After primary treatment the wastewater is split between two plug flow (92 ft long by 10 ft wide) 103,000 gallon activated sludge aeration tanks with fine bubble aeration and 15-ft operating depth. At the annual average flow rate, the HRT is 1.9 hours. The mixed liquor volatile suspended solids (MLVSS) concentration is typically in the range of 2,400 mg/L. The F/M ratio loading to the aeration tank is about 0.50 g BOD/g MLVSS-d and the SRT varies from 5 to 7 days based on plant data provided for the year 2002.

The mixed liquor from the aeration tanks flows into two 55-ft diameter secondary clarifiers, which operate at an overflow rate of about 550 gpd/ft^2 at the annual average flow rate. The settled secondary sludge is returned to the activated sludge process and a portion of it is wasted to the primary clarifier where it is removed in combination with primary sludge. After clarification the effluent is treated with dual-media (coal/sand) filtration (2.0 to 3.0 gpm/ft^2) and chlorinated for disinfection, and dechlorinated with sulfur dioxide before discharge.

The combined primary and secondary waste sludge is digested in two aerobic digesters with a volume of 410,000 gallons for each tank. The digester solids retention time is between 40 to 50 days. The digested sludge is dewatered using centrifugation and the final sludge is stored at an offsite facility. It is then land applied twice per year to leased farm fields as Class B Biosolids. Sludge disposal costs were given at about $200 per dry ton (information obtained at site visit) and the plant reportedly produces 850 dry tons per year. Figure 5.1.1.2 is a photo of one of the two aeration tank channels.



Source:
Alexandria Lakes WTF

Figure 5.1.1.1a - Schematic Process Flow Diagram, Alexandria Lake WWTF

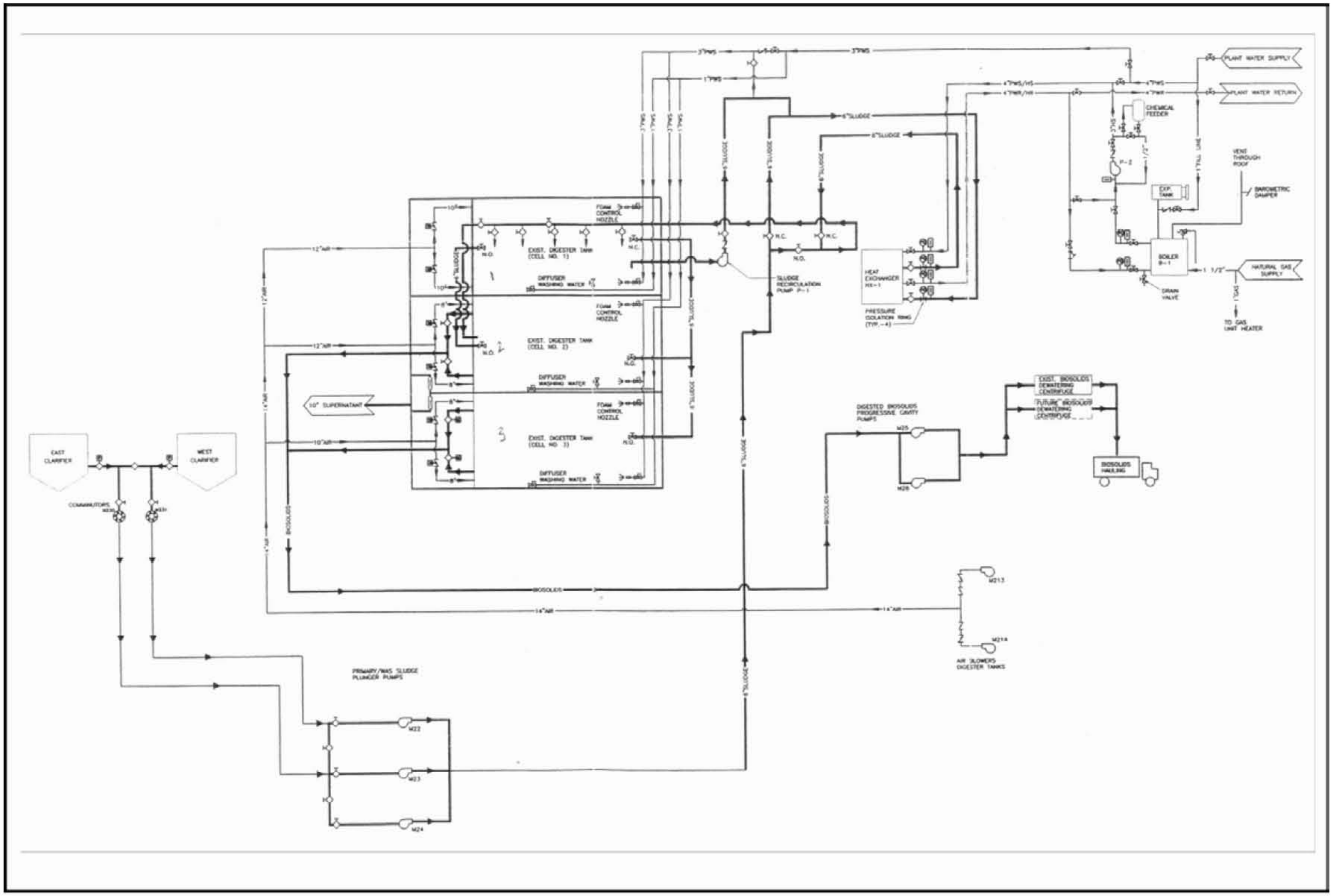


Figure 5.1.1.1b – Schematic Process Flow Diagram, Alexandria Lake WWTF

Figure 5.1.1.2 - WWTP Aeration Tank Channel, Alexandria Lake

Influent and effluent plant data were collected and reviewed to develop raw wastewater characteristics for the phosphorus removal analysis and to observe the present plant performance. Influent wastewater characteristics are summarized in Table 5.1.1.1 for the period of January 2002 through December 2002. These data represent the monthly average values for flow, $CBOD_5$, TSS, ammonia nitrogen and total phosphorus concentrations. Industrial sources contribute approximately 10% of the plant flow and the sources are a dairy (Nelson and Northern Food and Dairy), personal health care company (Nordic Antiseptic) and metals related (TWF Industries, Douglas Metals, Alexandria Extrusion and 3M) industries. The two dairies discharge high phosphorus concentrations (20 to 50 mg/L phosphorus, respectively), but they also discharge appreciable BOD so that the influent BOD/P ratio for these are 31 and 59, respectively.

Table 5.1.1.1 - Monthly Average Raw Wastewater Characteristics
Alexandria Lake WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)	BOD/P
2.6	240	192	N/A	6.6	37

N/A – not available

There was a significant variation in the influent wastewater strength based on monthly average data. For February, the influent $CBOD_5$ concentration was 326 mg/L, while it was down to

202 mg/L for May. The wide range of monthly average $CBOD_5$ concentration values is most likely due to variations in industrial wastewater inputs. For EBPR applications an important wastewater characteristic that relates to phosphorus removal performance is the influent BOD/P ratio, and an influent BOD/P ratio of greater than 30 is desired to produce effluent P concentrations in the 1 to 2 mg/L range. For all months, the monthly average influent BOD/P ratio for Alexandria Lake was above 30. The annual average influent BOD/P ratio was 37, while it was highest (50) when the higher BOD concentration occurred in February (50) and was only lowered to 33 for the weaker wastewater strength in May. These results indicated that the industrial wastewater inputs had substantial BOD along with their phosphorus discharge. There was less variation with the effluent TSS concentration, with monthly averages ranging from 170 to 213 mg/L.

The plant effluent characteristics are summarized on Table 5.1.1.2 below along with permit requirements and percent removals for $CBOD_5$, TSS and phosphorus. The plant has effluent permit limits for $CBOD_5$, TSS, and total phosphorus. Monthly monitoring is required for ammonia. The plant is operating well within permit limits of 25 mg/L monthly averages for $CBOD_5$ and 30 mg/L for TSS. The plant achieved about 99% removal of $CBOD_5$ and TSS with average effluent concentrations of 3.1 mg/L and 2.1 mg/L, respectively. The low values are enhanced by effluent filtration.

Table 5.1.1.2 - Monthly Average Treatment Performance Summary
January 2002 – December 2002
Alexandria Lake WWTF

	Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	NO_3-N (mg/L)	TP (mg/L)
Average Performance	2.6	3.1	2.1	NR	NR	0.4
Permit Requirements	3.25	25	30	NR	NR	1.0
Percent Removal	NA	98.7%	98.9%	NR	NR	93.7%

See Appendix 2.1.1 for detailed monthly plant data analysis
NR – Not required

The facility has had no problem meeting the current phosphorus effluent discharge limit of 1.0 mg/L. Since the early 1990s the plant had voluntarily targeted an effluent phosphorus concentration of 0.3 mg/L. To get to this concentration the ferrous sulfate dosage was doubled compared to that used previously to achieve an effluent phosphorus level of 0.7 mg/L. For 2002, the average effluent phosphorus concentration was 0.41 mg/L, representing a 93.7% removal efficiency. Influent phosphorus concentration ranged from 6.0 to 7.5 mg/L and averaged 6.6 mg/L. The plant currently uses approximately 300 gallons per day of 10% ferrous sulfate at an annual cost of $120,000. The ferrous sulfate solution is supplied by FE3 of Missouri.

5.1.1.2 Design Basis for Modifications for Phosphorus Removal

For the phosphorus removal alternatives evaluation, the return flow from solids processing and dewatering were estimated and included as part of the influent characteristics prior to primary clarification. For the Alexandria Lake WWTP aerobic digestion, with an SRT of 50 days or more, and centrifuge dewatering is used prior to hauling the solids offsite. The assumptions used to calculate return flow rate and concentrations of BOD, nitrogen and phosphorus are summarized in Table 5.1.1.3. Only the general assumptions used are shown as the amount of waste sludge varies with the phosphorus removal alternative. The return flow rate is affected by the amount of solids production, the solids concentration of the waste sludge from the primary or secondary treatment steps, the amount of volatile solids destruction in the digestion process, and the solids concentration after the solids dewatering step. Because the waste activated sludge is returned to the primary clarifier for removal with the settled primary sludge for the Alexandria Lake WWTP, a lower than normal thickening concentration of 3% was assumed for the primary clarifier waste sludge. For the chemical treatment alternatives for phosphorus removal, lower value of 2.5% was assumed due to the production of the lighter hydroxide sludge. Based on the long SRT in the aerobic digester a volatile solids destruction efficiency of 40% was assumed. Aerobically digested sludge is more difficult to dewater and a conservative solids content of 20% was assumed after centrifugation.

An important design issue for phosphorus removal systems is the amount of phosphorus in the return flows. For chemical treatment methods the phosphorus precipitate formed in the liquid processing and contained in the waste sludge is assumed to be stable and remain as precipitated phosphorus with no phosphorus release in the digestion or dewatering process. However, for phosphorus removed via biological steps, including cell synthesis associated with BOD removal and cellular phosphorus storage for EBPR, phosphorus is released as the solids are degraded under aerobic or anaerobic digestion. The amount of phosphorus released is theoretically proportional to the amount of biological solids destroyed in the digestion process and the amount stored in PAOs.

Table 5.1.1.3 - Assumptions Used to Estimate Return Flow Volume and Parameter Concentrations
Alexandria Lake WWTF

Parameter	Chemical Treatment Alternative	EBPR Alternative
Waste Solids Concentration		
Primary (% solids)	2.5	3.0
Secondary (% solids)		
Sludge Digestion Method	Aerobic	Aerobic
% VS Destruction in Digestion	40.0	40.0
Type of Dewatering	Centrifuge	Centrifuge
Dewatering Solids Conc. (%)	20.0	20.0
Dewatering Solids Capture (%)	99.0	99.0
Released Phosphorus Available (%)	75.0	75.0
Approx % of Removed P in Recycle	35	3
Available TKN of Return Flow, mg/L	2.0	2.0

Based on literature results, only a portion of this released phosphorus is returned due to precipitation processes that occur at the high phosphorus concentrations in the respective digestion processes. These experiences were used to estimate the amount of phosphorus released and remaining in solution for the phosphorus removal alternatives. For the aerobic digestion used for the Alexandria Lake WWTP, as shown in Table 5.1.1.3, 75% of the phosphorus released in aerobic digestion is assumed to remain as dissolved and available phosphorus in the return stream flow. The table also shows that much more of the phosphorus initially removed in the liquid treatment step is recycled in the return flow for the EBPR removal alternative compared to chemical treatment only (~35% versus 3%).

A minimal amount of available nitrogen was assumed for the return flows, based on the assumption that the aerobic digester can be operated with an on/off aeration cycle to accomplish nitrate removal during the off cycle, so that no buildup of nitrate occurs in the aerobic digester. Another advantage of this operating mode is that it returns alkalinity during nitrate reduction to support a higher pH in the aerobic digester. The return flow suspended solids concentration was based on the solids capture efficiency for the dewatering process.

The influent wastewater characteristics used to evaluate phosphorus removal alternatives for the Alexandria Lake WWTP were based on the annual average data and are summarized in Table 5.1.1.4. The influent $CBOD_5$, TSS, and TP concentrations were taken from the 2002 average monthly influent data summary. No TKN data was available, so an influent TKN concentration of 35 mg/L was assumed based on typical influent BOD/TKN ratios for domestic wastewater. The amount of soluble BOD (sBOD) in the influent BOD was assumed to be 40%, based on the modest amount of industrial input to the wastewater facility. Without the industrial wastewater inputs, an assumed influent soluble BOD ratio would be 33% for these analyses. The fraction of influent soluble BOD is important parameter that affects the predicted performance for the EBPR alternative. The phosphorus removal efficiency and EBPR is related to the amount of the readily biodegradable COD (rbCOD), as described in the technology summary in Section 2.0. Because such data is not normally measured at wastewater treatment plants, and was not available in this study, the rbCOD content was based on a review of the wastewater sources to the facility. The rbCOD content is also some fraction of the influent sBOD concentration. For these analysis, it was assumed that 70% of the influent sBOD was available to the bacteria as truly dissolved organic matter or rbCOD.

Dimensions and loading rates for the existing liquid unit processes at the design flows and loadings are also summarized in Table 5.1.1.4. For these analysis, the plant design flow was the annual average design flow of 3.25 MGD. The table shows the units available for a retrofit to phosphorus removal and indicates if excess capacities exist.

At the 3.25 MGD average design flow rate, the primary and secondary clarifiers are operating at near their maximum hydraulic capacity. The aeration tank has a relatively short HRT and can only be operated for BOD removal. The alternative evaluation showed that without the present operation of chemical addition to the primary clarifiers, the BOD loading to the aeration tanks would be at a high enough level to exceed the available activated sludge treatment capacity. Thus, for the EBPR only alternative, an external anaerobic contact tank would need to be installed. In addition, with that alternative additional aeration tank volume would be required to handle the higher influent BOD concentration resulting from no chemical addition to the primary clarifiers.

Table 5.1.1.4 - Process Design Basis Used for Evaluation of Phosphorus Removal Alternatives
Alexandria Lake WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	Percent sBOD	TSS (mg/L)	TKN (mg/L)	TP (mg/L)
3.25	239	40	192	35	6.6

Process Step	Dimensions	Design Loading	Comment
Primary Clarifiers	2 - 45 ft diameter, 11 ft deep	820 gpd/ft^2	Can accept chemical addition
Activated Sludge	2 – 0.103 MG Plug flow aeration tanks	F/M = 0.5 g BOD/g MLVSS-d, HRT = 1.9 hrs	Highly loaded aeration tanks. No capacity for EBPR anaerobic tank
Secondary Clarifiers	2 – 55 ft diameter, 12 ft deep	550 gpd/ft^2	Can accept chemical addition
Dual Media Polishing Filters	Coal/sand filter	2.0 to 3.0 gpm/ft^2	Provides low effluent TSS concentration

See Appendix 2.1.1 for summary of the design basis

The aeration tank capacity and operating SRT possible for the existing system is a function of the influent BOD concentration, the solids yield assumptions, and the MLSS concentration for the system. In the design alternative analysis an MLSS concentration of 3,500 mg/L was assumed for the EBPR system due to the improved settling characteristics associated with EBPR processes and the fact that the secondary clarifiers can be operated at conventional overflow rates. Without the EBPR process, the maximum MLSS concentration assumed was 3,000 mg/L due to the different settling characteristics expected for a system with chemical sludge and with no anaerobic contact tank.

The facility has existing dual media polishing filters following secondary clarification, which can produce a low effluent TSS concentration of less than 5.0 mg/L. The additional solids removal by the filters enhances the phosphorus removal efficiency by removing chemically precipitated phosphorus or biological solids that contain phosphorus.

5.1.1.3 Evaluation of Phosphorus Removal Alternatives

Phosphorus removal alternatives evaluated for the Alexandria Lake WWTF were EBPR alone, EBPR with alum addition with primary treatment, alum addition only to either the primary or secondary clarifiers, and alum addition to both the primary and secondary clarifiers. The effluent goal in all cases was between 0.80 and 1.0 mg/L to meet the less than 1.0 mg/L effluent target goal. When alum addition to the primary clarifiers was followed by either EBPR or alum addition to the secondary clarifiers, the alum dose was set to accomplish about 50% phosphorus removal in primary treatment and where the dose was close to stoichiometric requirements (1.0 mole Al/mole P) for phosphorus precipitation. The alternative evaluation process included developing conceptual designs followed by preliminary cost estimates for the viable alternatives. The conceptual designs included determining the activated sludge aeration volume requirements to meet the effluent treatment, the activated sludge tank volume needed for the anaerobic contact zone of the EBPR process, the amount of daily sludge production in both the primary and secondary processes, the amount of chemical sludge produced, the amount of phosphorus removed by biomass growth and by the EBPR process, the phosphorus content in the waste sludge, and the fate of solids in solids processing and the characteristics of return flows. For the Alexandria Lake WWTP nitrification is not required for the effluent discharge and thus it was not necessary to include a nitrate removal process such as the A^2O process in the EBPR system. The analysis also showed that the existing secondary system does not have sufficient volume to accommodate a long enough SRT for nitrification.

The results of the alternative analyses are summarized in Table 5.1.1.5 in terms of the effluent phosphorus concentration, chemical requirements (alum and alkalinity), sludge production and additional facility modification requirements (tankage, mixers and piping) for each of the alternatives that were considered. For the alternatives with chemical treatment, an effluent phosphorus concentration of 0.50 to 1.0 mg/L can be normally expected under varying wastewater load conditions. For EBPR only and for wastewater with lower influent BOD/P ratios, the effluent phosphorus concentration has been shown to be higher and less resilient to changing plant loadings. The average influent BOD/P ratio for Alexandria Lake is 37, which is above average, and suggests that an effluent P concentration in the range of 0.75 to 1.5 mg/L is a reasonable expectation. For the EBPR-only alternative, where an effluent P concentration of greater than 1.0 mg/L is possible the plant would need chemical feed equipment available for polishing the effluent phosphorus concentration during times of lower EBPR performance.

Table 5.1.1.5 - Summary of Plant Modifications and Chemical Requirements and Plant Retrofit Needs for Phosphorus Removal Alternatives
Alexandria Lake WWTF

Option	Units	EBPR Only	EBPR+ Chemical Addition to Primary Clarifiers	Chemical Addition to Primary and Secondary Clarifiers	Chemical Addition to Primary Clarifiers	Chemical Addition to Secondary Clarifiers
Effluent P	mg/L	0.75 to 1.5	0.75 to 1.0	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0
Chemical Addition	lb/d	0	1705	3817	4324	5269
Additional Sludge Production(1)	lb/d	0	283	753	875	1091
Alkalinity Used	mg/L	0	28	63	71	87
Increased Tank Volume	MG	0.33	0.25	0	0	0
Additional Mixers	Yes/ No	Yes	Yes	No	No	No

(1)Alum Sludge

Chemical addition alone is capable of meeting the effluent phosphorus concentration target of 1 mg/L or less. The three alternatives for chemical addition are compared in Table 5.1.1.5. The two-point addition approach, with chemical addition to both the primary and secondary clarifiers, requires less chemical, produces less sludge and consumes less alkalinity. For the two-point chemical addition design, about 50% of the phosphorus removal was accomplished in the primary clarification step and alum was added at the stoichiometric ratio of one mole per mole. By adding chemical in this way in both the primary and secondary treatment steps, the chemical addition and the sludge production was reduced by about 30%, compared to chemical addition to only the secondary aeration tank or clarifiers. Compared to adding chemical to only the primary treatment step, the two-point addition approach reduces the chemical addition by about 12% and sludge production by about 14%.

The use of EBPR alone required a significant addition to the activated sludge system volume, by about 100%. The existing aeration system had no excess capacity so additional tankage was required for the anaerobic contact time for the EBPR process. In addition more aeration tank volume was required for the EBPR-only alternative, because without chemical addition in the primary clarifiers as in the present operation, less BOD and TSS was removed in the primary treatment step, which increases the load on the secondary treatment system. In addition, the EBPR process required a higher SRT than that for BOD removal only, as a longer SRT is needed to maintain the phosphorus storing organisms. Thus about 50% of the additional volume required for the EBPR-only alternative was due to the need for additional aeration tank capacity.

By combining chemical addition to the primary clarifiers with the EBPR process, the additional tank volume requirement was reduced due to more BOD and TSS removal in the primary clarification step. The chemical addition increased the percent BOD and TSS removal efficiencies from 33 and 65% without chemicals to 46 and 74%, respectively. However, this chemical addition was not sufficient to remove a sufficient amount of BOD and suspended solids and additional aeration volume was still required for the combined EBPR and chemical addition process. The addition of the anaerobic contact zone also requires mixers. The addition of aeration tank volume requires some readjustment of the aeration diffuser system to accommodate the different spatial oxygen demand.

When chemical addition occurs in the primary treatment step, enough BOD and TSS removal occurs so that additional aeration volume is not needed. When chemical treatment is only done in the secondary treatment step, more aeration volume is needed as shown in Table 5.1.1.6 because a higher BOD and TSS loading occurs from the primary clarifier effluent. While chemical addition does avoid the need to add more tank volume, it does produce more sludge and consumes more alkalinity than processes that include EBPR. Chemical addition can be accomplished as single or two-point addition. Any retrofit of chemical addition for phosphorus removal should include facilities that would permit the feasibility of two-point addition.

For the chemical treatment options the amount of alkalinity destruction, based on the influent flow rate of 3.25 MGD ranged from 28 mg/L to 87 mg/L as $CaCO_3$. Because the facility is not required to produce a nitrified effluent, the drop in pH due to this alkalinity consumption may not be of concern unless the influent alkalinity is too low and the effluent discharge pH is reduced to below effluent standards. However alkalinity addition to match these alkalinity consumption rates would not be required. A detailed site-specific analysis could more precisely determine the alkalinity requirements. For this reason the cost analysis will not include alkalinity costs.

A preliminary cost comparison between the most promising chemical treatment approach (two-point addition) and the EBPR processes is presented in Table 5.1.1.6. The costs were rounded to the nearest $1,000. The capital cost includes the cost for the chemical feed system, the aeration tank modifications, and the anaerobic contact tank additions including the mixers. For the chemical treatment system the major operating costs are associated with chemical costs, labor cost and the disposal/reuse of the additional sludge production. The alternative with the lowest capital cost is for chemical treatment only with chemical addition to the primary and secondary treatment systems. However, that alternative has the highest operating costs, which then causes the alternative to have the highest present worth cost. The present worth calculation is based on a 5% interest rate and a 20-year pay back period and no escalation in operation costs such as chemicals and sludge disposal. The estimated annual operating cost for the chemical-only alternative is about 9 times that of the EBPR-only alternative: $181,000/year versus about $21,000/year.

The alternative with the lowest present worth cost would be the EBPR-only system. However, the capital costs were about 6 times more than that for the chemical treatment-only system. The combination of primary chemical treatment followed by EBPR would not result in any significant cost savings compared to chemical treatment only. Its operating cost would be about half of that for chemical treatment only, but the capital cost was over 6 times more.

Table 5.1.1.6 - Preliminary Cost Estimates for Retrofit for Phosphorus Removal
With Different Process Options
Alexandria Lake WWTF

Parameter	EBPR Only	EBPR + Chemicals in Primary	Chemicals only, to Primary and Secondary Clarifiers
Preliminary Capital Costs			
EBPR Tank	$722,000	$722,000	-
Aeration Tank Modification	$96,000	$48,000	-
Chemical system	$154,000[1]	$154,000	$154,000
Total Capital Costs	$972,000	$924,000	$154,000
Daily Operating Costs, $/d			
Alum	0	171	382
Sludge disposal	0	25	67
EBPR operation	57	57	0
Annual Labor Cost – Chemicals Only	0	0	$17,000
Total Annual Operating Costs	$21,000	$92,000	$181,000
Present Worth Operating Costs 5% @ 20 years	$262,000	$1,147,000	$2,256,000
Total Present Worth	$1,234,000	$2,071,000	$2,410,000

(1)Backup chemical feed system for EBPR

These results suggest that the EBPR process would be the most cost-effective alternative for converting the high rate conventional activated sludge system for phosphorus removal. However, the high capital costs may discourage its application in a plant that already has successful chemical treatment. Based on the difference in operating costs between the EBPR-only and chemical treatment, if the savings were applied to pay the capital costs of the EBPR system the pay back period would be about approximately 13 years. The feasibility and final cost for the actual conversion to an EBPR process would depend on more site-specific evaluations, including considerations for the site hydraulic profile, tank access, and site layout. Since the Alexandria Lake WWTF is currently meeting its permit limit of 1 mg/L with chemical addition, no additional treatment requirements are recommended and a no action alternative designation was assigned to the plant.

The preliminary cost information in Table 5.1.1.6 also shows that, for the two EBPR alternatives, there is a potential for significant cost saving for a phosphorus discharge concentration greater than 1 mg/L (1.5 mg/L) (EBPR only) compared to the target concentration of 1 mg/L (EBPR + chemicals in the primary). The present worth analysis shows that a potential cost saving of 1.7 for the EBPR only system compared to the treatment system to meet 1 mg/L.

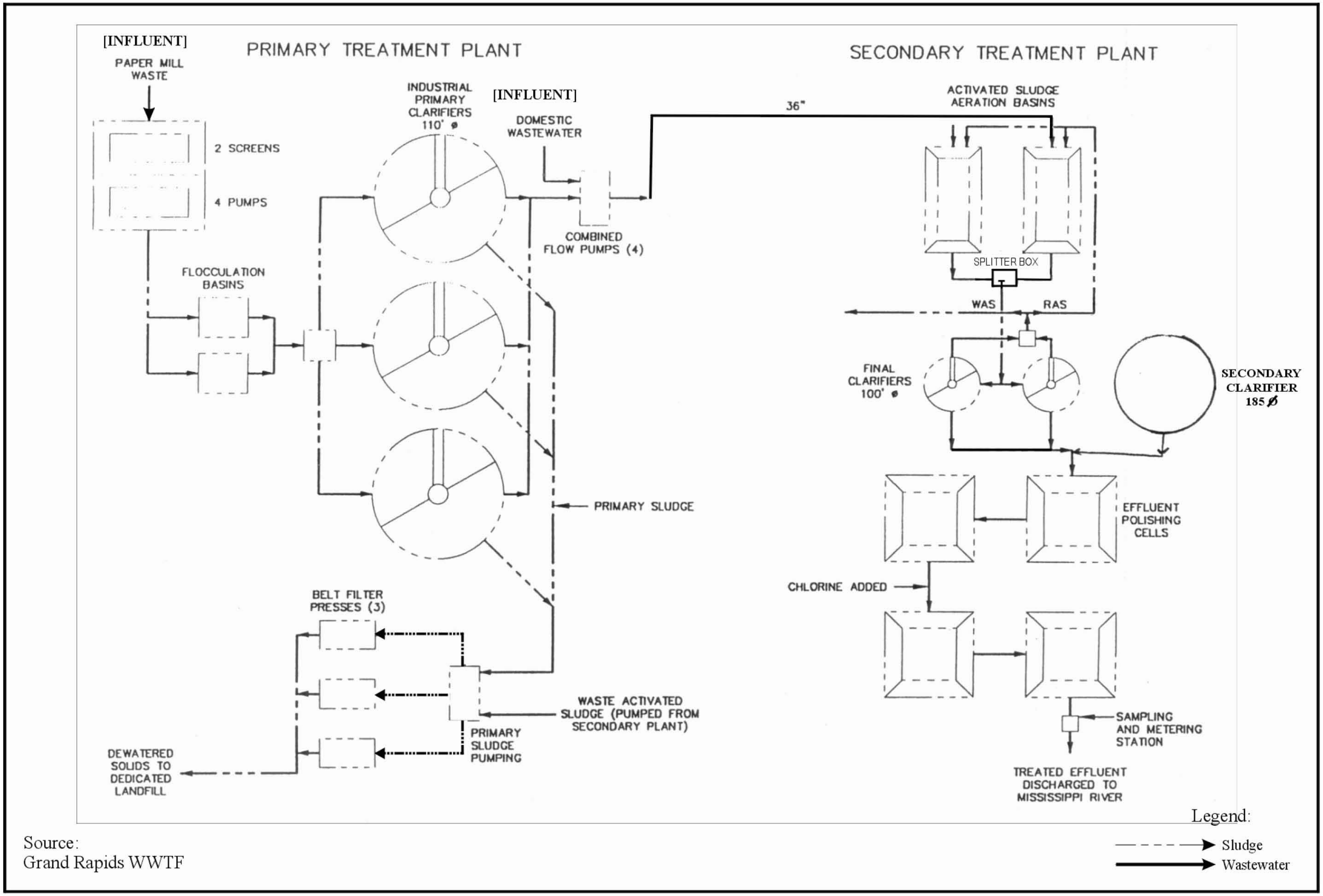
5.1.2 Grand Rapids WWTF

The Grand Rapids Wastewater Treatment Facility (Grand Rapids WWTF) has a design dry weather flow of 14.3 MGD and currently receives a daily average flow of 8.8 MGD. The original domestic plant dates prior to 1962 with the industrial waste treatment train added in the mid to late 1960's and was later upgraded to secondary treatment in the early 1970's.

5.1.2.1 Plant Description and Performance

The wastewater treatment plant is an activated sludge system which includes separate industrial pretreatment step and screening of the domestic wastewater. These wastewaters are commingled in the primary effluent pump station which pumps the combined effluent to the conventional secondary treatment processes and disinfection. A process flow diagram for the wastewater and sludge handling is presented in Figure 5.1.2.1. Industrial flow from the local paper mill is screened at the paper mill using a Parkson™ traveling screen before it is pumped through 6000 feet of 30 inch force main to the industrial pretreatment plant located at the Grand Rapids WWTF. The on-site industrial pretreatment at the Grand Rapids WWTF consists of primary clarification and nutrient addition. The existing diffused air flocculation basins are no longer in service. Primary clarification consists of three 110 foot diameter circular, center feed clarifiers. At the time of the plant visit only one of the three primary clarifiers was in service. After primary clarification, nutrients (nitrogen and phosphorus as a liquid fertilizer) are added to the primary industrial effluent and then combined with the screened domestic wastewater in the primary effluent pump station. Primary effluent is then pumped through 4,200 feet of 36 inch force main to the secondary treatment plant.

The secondary plant consists of two aeration basins, three secondary clarifiers and four polishing ponds in series. Disinfection is accomplished through chlorine addition to the influent of the third polishing pond. The activated sludge system includes two 18.7 million gallon (each) earthen aeration basins that are equipped with eight air-sparged Lightnin™ turbine aerators. The activated sludge system is operated as a complete mix process plant. An upgrade plan includes an operational change to the step feed activated sludge process. A set of aeration basins is not in service and is used for sludge storage. These basins are located between the current aeration basin



Source:
Grand Rapids WWTF

Figure 5.1.2.1 - Schematic Process Flow Diagram, Grand Rapids WWTF

and the secondary clarifiers. The secondary clarification system includes two-100-foot diameter and one-185-foot diameter clarifiers. The clarified effluent is polished in a series of four tertiary ponds operated in series. Each of these ponds is an earthen basin with a 13-foot side water depth and provides a one-day detention time in each pond. At the time of the site visit, only one of the two aeration basins and one of the smaller secondary clarifiers were in service while all of the polishing ponds were in service. Figure 5.1.2.2 is a view of one of the two earthen aeration basins with the mixing equipment support bridges. Figure 5.1.2.3 is a view of two of the four tertiary polishing ponds, pond number three is on the left and pond four (final) is on the right.

Sludge processing facilities are located on the site of the primary plant. Sludge processing consists of three belt filter presses with each press capable of processing of 70 dry tons of sludge per day. Both waste activated sludge and primary sludge are processed by the belt filter press operation with dewatered sludge trucked to a local landfill that is owned and operated by Grand Rapids Utilities.

Influent and effluent data were reviewed to develop the raw wastewater and final effluent characteristics to evaluate the plant performance, and for the phosphorus removal analysis. Influent wastewater and final effluent characteristics are summarized on Tables 5.1.2.1 and 5.1.2.2 for the period of October 2002 through September of 2003. These data represent the annual monthly average flow, $CBOD_5$, and TSS for the combined domestic and industrial plant flow. Influent ammonia nitrogen and phosphorus are not monitored, however the influent is nutrient deficient and liquid fertilizer is added to the plant flow upstream of the biological processes. The local paper mill flow and load is on the order of 80 to 90% of the flow and $CBOD_5$ load to the treatment plant, and 60 to 70% of the total TSS load. The total plant influent characteristics were as follows:

Table 5.1.2.1 - Monthly Average Raw Wastewater Characteristics
Grand Rapids WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	Total P (mg/L)	$CBOD_5$:P
8.8	307	268	Not Sampled	Not Sampled	NA

The influent flow and $CBOD_5$ data showed wide variation based on changes related to the industrial input for the paper mill. There was also wide variation in TSS concentration. These data are summarized in Appendix 2.1.2. The influent flow varied from 6.5 MGD in May to 11.5 in November and December with above average flow from October (10.6 MGD) through January

Figure 5.1.2.2 - Earthen Basin, Grand Rapids WWTF

Figure 5.1.2.3 - Ponds 3 & 4, Grand Rapids WWTF

(10.4 MGD). Influent $CBOD_5$ varied from 214 mg/L in August to 444 mg/L in October. As with flow, October through January saw the highest influent $CBOD_5$ concentrations. TSS varied between 214 mg/L in October to 337 mg/L in June.

The plant's effluent characteristics are summarized below on Table 5.1.2.2 along with permit requirements and percent removals for $CBOD_5$ and TSS. The plant has monthly effluent limits for $CBOD_5$ and TSS with weekly monitoring for total phosphorus without an assigned permit limit. The plant is operating well within the monthly average permit limits of 25 mg/L and 30 mg/L for $CBOD_5$ and TSS, respectively. The plant achieved greater than 99% removal of $CBOD_5$ and 95% removal of TSS with average effluent concentrations of 2.7 and 11.4 mg/L, respectively. The average phosphorus discharge level was 0.56 mg/L.

Table 5.1.2.2 - Monthly Average Treatment Performance Summary
October 2002 - September 2003
Grand Rapids WWTF

	Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	TP (mg/L)
Average Performance	7.6	2.7	11.4	0.56
Permit Requirements	Monitor Only	25	30	Monitor Only
Percent Removal	NA	99.1%	95.7%	NA

See Appendix 2.1.2 for detailed monthly plant data analysis
NA – Not Applicable

The Grand Rapids WWTF is able to produce an effluent with a low phosphorus concentration because a large portion of its wastewater load is from the paper mill that is nutrient deficient (nitrogen and phosphorus are added to support biogrowth for BOD removal). In this case phosphorus removal technologies are not needed. However, if the industrial wastewater load decreases in the future, a phosphorus removal process could be required. At this point careful monitoring of the effluent P concentration and control of the nutrient addition is the appropriate course of action.

5.1.3 New Ulm WWTF

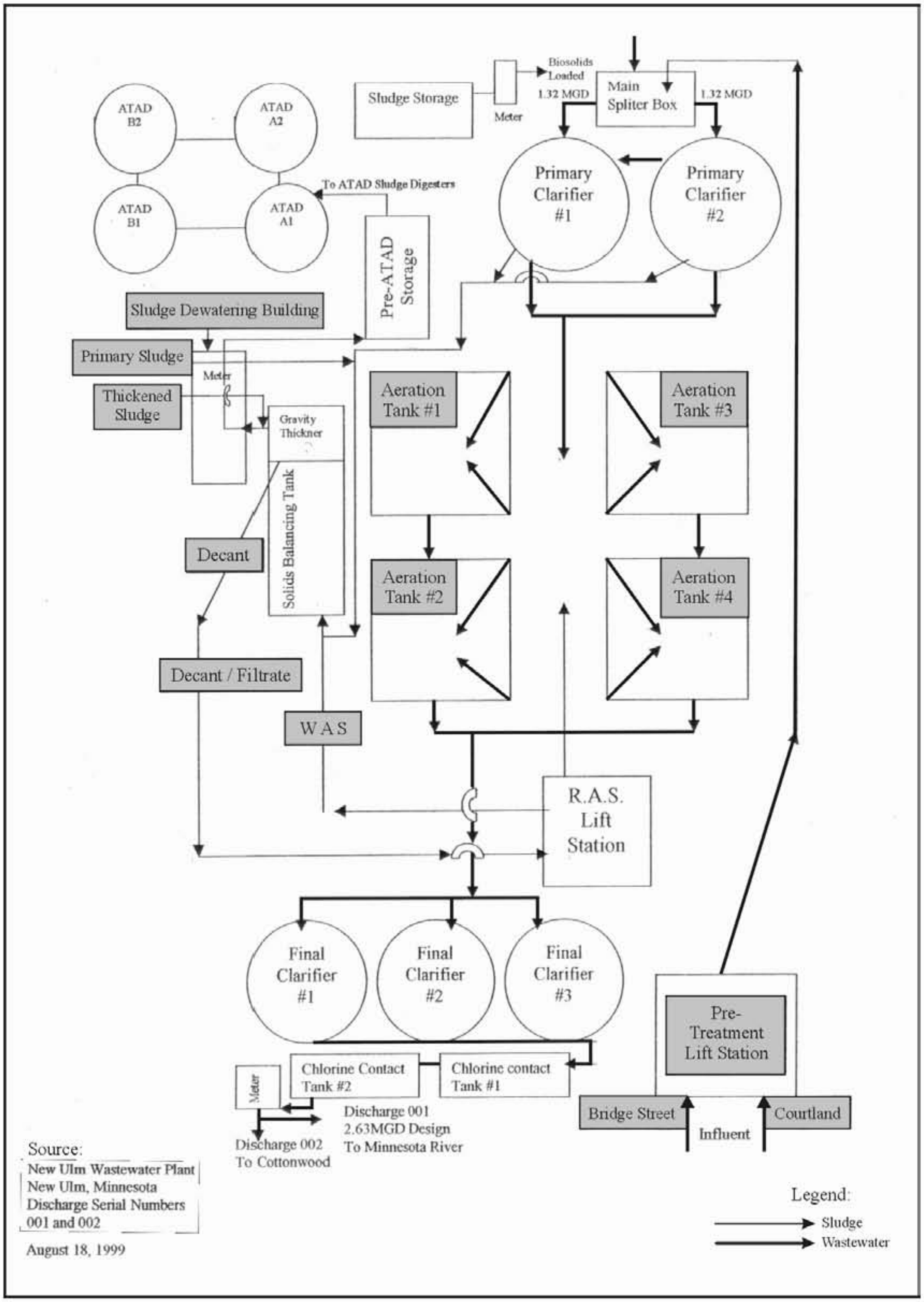
The New Ulm Wastewater Treatment Facility (New Ulm WWTF) is a conventional wastewater treatment plant providing primary and secondary treatment and disinfection. It has a design flow of 6.77 MGD and currently receives a daily average flow of 2.5 MGD. The plant was constructed in 1975. In 1996 and a new autothermophylic sludge digestion process (ATSD) was added for production of Class A sludge for land application.

5.1.3.1 Plant Description and Performance

A process flow diagram for the wastewater and sludge handling is presented in Figure 5.1.3.1. The plant influent is pretreated at one remote (20th Street and South Street) preliminary treatment facility and pump stations. Preliminary treatment consists of mechanically cleaned bar screens, grit removal and comminution. The pretreated flow is then pumped to the wastewater treatment plant where it receives primary treatment for $CBOD_5$ and TSS in two 65-foot diameter primary clarifiers which operate at a design overflow rate of 1020 gpd/sf. This is followed by activated sludge biological treatment in four 810,000-gallon aeration tanks operated in parallel. The design hydraulic detention time of the aeration tanks is 11.5 hours. As currently operated, the plant accomplishes year-round nitrification although it is not required. The mixed liquor from the aeration tanks then flows into three 65-foot diameter covered secondary clarifiers which operate at a design overflow rate of 680 gpd/sf. The settled secondary sludge is returned to the activated sludge process and a portion of it is wasted to the solids balancing tank. After clarification the effluent is chlorinated for disinfection, dechlorinated with sulfur dioxide and then discharged to the Minnesota River with a secondary discharge outlet in the Cottonwood River. Figure 5.1.3.2 is a view of one of the four aeration tanks with the covered secondary clarifier in the background. Figure 5.1.3.3 is a view of one of the primary clarifiers.

The sludge handling operation consists of aerobic digestion, thickening, autothermophylic digestion, storage and land application. Primary and waste activated sludges are combined in a 138,000-gallon aerobic digester/solids balancing tank followed by thickening in a 82,000 gallon gravity thickener. The thickened sludge flows to a storage tank and then to the Kruger Autothermal Thermophilic Aerobic Digestion (ATAD) process which consists of four 59,000 gallon heated and aerated digesters. Digested sludge is stored in four 850,000 gallon storage tanks which provide approximately 180 days of storage. The process produces Class A biosolids which are land applied.

Influent and effluent plant data were reviewed to develop the raw wastewater and final effluent characteristics to evaluate the plant performance, and for the phosphorus removal analysis.



Source:
New Ulm Wastewater Plant
New Ulm, Minnesota
Discharge Serial Numbers
001 and 002

August 18, 1999

Figure 5.1.3.1 - Schematic Process Flow Diagram, New Ulm WWTF

Figure 5.1.3.2 - Aeration Tank, New Ulm WWTF

Figure 5.1.3.3 - Primary Clarifier, New Ulm WWTF

Influent wastewater and final effluent characteristics are summarized on Tables 5.1.3.1 and 5.1.3.2 for the period of September 2002 through September 2003 (excluding October and November 2002). These data represent the annual monthly average flow, $CBOD_5$, TSS, ammonia nitrogen (NH_4-N), and total phosphorus. Industrial wastewater contributions consist of Kraft (foods), Schell's (brewery), Firmenich (seasonings), 3M (abrasives) and AMPI (butter). These industries contribute 37% of the plant's phosphorus load. The plant also receives water treatment sludges containing magnesium and aluminum on a relatively continuous basis. They also receive approximately 12,000 gallons per week of caramel/sugar waste that is trucked to the plant from Wis-Pak in Mankato, MN. The total plant influent characteristics are as follows:

Table 5.1.3.1 - Monthly Average Raw Wastewater Characteristics
New Ulm WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)	$CBOD_5$/P
2.5	387	273	NR	8.9	43

NR – Not Required

The influent did not show any large variations in wastewater characteristics. The $CBOD_5$ concentration averaged 387 mg/L and ranged from 271 mg/L to 462 mg/L; TSS averaged 253 mg/L and ranged between 164 and 364 mg/L; and the phosphorus concentration averaged 8.9 mg/L and ranged between 5.7 and 11 mg/L.

The plant's effluent characteristics are summarized on Table 5.1.3.2 below along with permit requirements and percent removals for $CBOD_5$, TSS and phosphorus. The plant has effluent permit limits for $CBOD_5$ and TSS. Monthly monitoring is the only requirement for total phosphorus (TP). The plant is operating well within permit limits of 25 mg/L monthly averages for $CBOD_5$ and 30 mg/L for TSS. The plant achieved greater than 99% removal of $CBOD_5$ and 98% removal of TSS with an average effluent concentration of 3.5 mg/L and 4.2 mg/L, respectively. The 2002-2003 monthly average discharge concentrations for ammonia was less than (<) 0.13 mg/L and effluent NO_3-N averaged 42.2 mg/L indicating a high degree of nitrification. The plant is meeting all permit requirements year-round. The monthly average phosphorus discharge level was 4.8 mg/L. This suggests that there is currently a phosphorus reduction of 4.1 mg/L, which is related to existing particulate and biological removals.

Table 5.1.3.2 - Monthly Average Treatment Performance Summary
September 2002 – September 2003
New Ulm WWTF

	Flow(MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	NO_3-N (mg/L)	TP (mg/L)
Average Performance	2.5	3.5	4.2	<0.13	42.2	4.8
Permit Requirements	6.77	25	30	NR	NR	Monitor Only
Percent Removal	NA	99.1%	98.4%	NR	NR	44.4%

See Appendix 2.1.3 for detailed monthly plant data analysis
NR – Not required
NA – Not Applicable

5.1.3.2 Design Basis for Modifications for Phosphorus Removal

The evaluation of phosphorus removal alternatives was based on the design parameters presented in Table 5.1.3.3. This basis was used to assess the feasibility of biological and chemical phosphorus removal as well as a combination of both processes. The table summarizes flow and wastewater characteristics used to assess the phosphorus removal alternatives. It also summarizes the facilities available to be retrofitted for phosphorus removal if it is determined that excess capacities exists. The primary and secondary clarifiers can be retrofitted to accept chemical addition for phosphorus removal and the activated sludge process can also be retrofitted to provide EBPR.

The design basis does not include any contributions of plant return streams. The only return stream at the New Ulm plant is from sludge storage decanting which is practiced two to three times per year when 5,000 to 10,000 gallons of decant is returned to the head of the plant. This contributes a relatively insignificant phosphorus load relative to the total daily load of approximately 500 pounds per day. The design low temperature assigned as 12°C and was used in developing biological treatment kinetics.

The New Ulm wastewater is a relatively high strength wastewater due to industrial contributions. The influent wastewater contains 387 mg/L $CBOD_5$ and 8.9 mg/L phosphorus which produces a $CBOD_5$ to P ratio of 43:1 and would support EPBR without having to add an additional carbon source. At design loadings (based on design flow and observed wastewater characteristics) the F/M of the activated sludge system is 0.1 lb $CBOD_5$/lb MLSS at the observed average MLSS concentration of 5,000 mg/L. This F/M is low enough to support nitrification, which regularly occurs year-round, and produces approximately 42 mg/L NO_3-N. The low F/M suggests that there is sufficient aeration tank volume available to support denitrification and EBPR.

Certain wastewater characteristics, removal rates and treatment plant operating conditions were also either assumed or based on plant operating data for this analysis. Biodegradable COD (discussed in Section 4) was assumed to be equal to 1.6 times the $CBOD_5$ and readily biodegradable COD (rbCOD), that fraction of the COD that is easily converted to volatile fatty acids (VFA) which are used by EBPR bacteria, was assumed to be 30% of the biodegradable COD. Also, baseline phosphorus removal by primary treatment (without chemical addition) was assumed to be 10% of the influent concentration.

Table 5.1.3.3 – Process Design Basis Used for Evaluation of
Phosphorus Removal Alternatives
New Ulm WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	TKN (mg/L)	TP (mg/L)	rbCOD
6.77	387	273	68	8.9	125

Process Step	Dimensions	Design Loading	Comment
Primary Clarifiers	2 - 65 ft diameter, 10 ft deep	1020 gpd/sf	Can accept chemical addition
Activated Sludge	4 – 0.81 MG aeration tanks	F/M = 0.1 lb $CBOD_5$/lb MLSS HRT = 11.5 hrs	Accomplishes year-round nitrification. Tanks can accept EBPR retrofit
Secondary Clarifiers	3 – 65 ft diameter, 12 ft deep	680 gpd/sf	Can accept chemical addition

See Appendix 2.1.3 for summary of the design basis.

5.1.3.3 Evaluation of Phosphorus Removal Alternatives

The evaluation of phosphorus removal alternatives included developing conceptual designs and preliminary cost estimates for the viable alternatives. EBPR, chemical addition and a combination of both processes were considered for New Ulm and a summary of the alternatives analysis is presented in Table 5.1.3.4. The table summarizes the potential effluent phosphorus concentration, chemical requirements (alum and alkalinity), sludge production and facility requirements (tankage, mixers and piping) for each of the alternatives that were considered.

Table 5.1.3.4 - Summary of Plant Modifications and Chemical Requirements and Retrofit Needs for Phosphorus Removal Alternatives
New Ulm WWTF

Option	Units	EBPR Only	EBPR+ Chemical Addition to Secondary Clarifiers	Chemical Addition to Primary and Secondary Clarifiers	Chemical Addition to Secondary Clarifiers
Effluent P	mg/L	1.0 to 2.0	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0
Chemical Addition	lb/d	0	2300	9900	14400
Additional Sludge Production	lb/d	0	695	2600	4600
Alkalinity Added	lb/d	0	1040	4450	6480
Increased Tank Volume	1000 ft3	0	0	0	0
Additional Mixers	Yes/No	Yes	Yes	No	No
Pumps/Piping	Yes/No	Yes	Yes	No	No

Using the design approach for denitrification and EPBR presented in Section 4, there would be sufficient aeration tank capacity to provide the necessary tankage for denitrification and EBPR removal. Approximately 0.28 MG of each of the four aeration tanks segregated with baffles for denitrification (0.21 MG) and EPBR (0.07 MG) would be required. These zones would also require mixers to keep the MLSS in suspension while under anoxic and anaerobic conditions.

EBPR would reduce phosphorus concentrations to approximately 1 to 2 mg/L which is higher than the effluent quality target of 1 mg/L; therefore, additional treatment by chemical addition would be needed to ensure compliance with the target. EBPR with chemical addition would be able to consistently reduce effluent phosphorus to 0.5 to 1.0 mg/L. The combined process would produce an additional 800 pounds per day of chemical sludge in the secondary clarifiers. Chemical precipitation of phosphorus in the secondary clarifiers would also consume approximately 1,040 pounds per day of alkalinity (as $CaCO_3$). This corresponds to approximately 37 mg/L of alkalinity which would probably not affect effluent pH.

Chemical addition alone would also be capable of meeting the effluent target of 1 mg/L; however, it does produce more sludge and consumes more alkalinity than processes that include EBPR. Chemical addition can be accomplished as single or two-point addition. Any retrofit of chemical addition for phosphorus removal should include chemical field equipment that would permit the feasibility of two-point addition.

Single point addition should only consider chemical addition to the secondary clarifiers to ensure that there is sufficient phosphorus available for biological treatment. Single point addition to the primary clarifiers could result in creating a phosphorus deficient condition in the activated sludge process if the phosphorus removal process is not carefully maintained. Two-point addition would involve adding chemicals in the primary and secondary clarifiers. Chemical addition to the primary clarifiers has the added benefit of enhancing $CBOD_5$ and TSS removals; however, as previously stated, the process should be closely managed to ensure that there is sufficient residual phosphorus in the primary effluent for biological treatment. For New Ulm, chemical addition to the primary clarifiers was targeted for removal of approximately 5 mg/L phosphorus and approximately 1.4 mg/L is removed by nutrient uptake in the production of MLSS. This left approximately 2.5 mg/L after biological treatment, which was the basis for chemical addition to the secondary clarifiers.

Single point chemical addition to the secondary clarifiers would require 14,400 pounds per day of alum, produce 4,600 pounds per day of sludge and consume 6,480 pounds per day of alkalinity. Two-point chemical addition would require 9,900 pounds per day of alum, produce 2,600 pounds per day of sludge and consume 4,450 pounds per day of alkalinity. The alkalinity demand for single and two-point chemical addition would be high enough to require the addition of alkalinity to ensure that effluent pH would meet permit requirements.

Preliminary budgetary cost estimates were developed based on the information presented in Section 4 and are presented in Table 5.1.3.5. The capital costs are presented as September 2004 US dollars and the present worth costs are based on the annual O&M costs over a 20 year operating period at an interest rate of 5%. The costs have been rounded to the nearest $1,000.

The preliminary capital cost associated with retrofitting existing aeration tankage tanks with baffles and mixers for EBPR is approximately $200,000, the O&M cost is approximately $29,900 per year with a present worth cost of $573,000. This is the least expensive alternative; however, EPBR cannot be relied on to consistently meet a phosphorus discharge level of 1 mg/L as presented in Table 5.1.3.5. The capital cost for a combined process of EPBR with chemical addition to the secondary clarifiers would be $390,000 with an O&M cost of $137,000 and a present worth cost of $2,097,000. This is the most cost effective approach for phosphorus removal for the New Ulm WWTP. Two-point chemical treatment is the lowest cost chemical treatment alternative. It can achieve the effluent limit at a capital cost of $190,000, and annual O&M cost of $654,000 and a present worth cost of $8,340,000. The present worth cost of single point (seconday clarifier) chemical treatment is $14,048,000.

Table 5.1.3.5 – Preliminary Cost Estimates for Retrofit for Phosphorus Removal
With Different Process Options
New Ulm WWTF

Cost Factors	EBPR Only	EBPR with Chemical Addition to Secondary Clarifiers	Chemical Addition to Primary and Secondary Clarifiers	Chemical Addition to Secondary Clarifiers
Effluent P	1.0 to 2.0	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0
Preliminary Capital Cost				
EPBR	$200,000	$200,000	$0	$0
Chemical Treatment	$0	$190,000	$190,000	$190,000
Total	$200,000	$390,000	$190,000	$190,000
Daily Operating Costs $/d				
EBPR	82	82	0	0
Alum	0	231	989	1440
Alkalinity	0	0	494	1108
Sludge Disposal	0	63	232	415
Annual Labor Cost – Chemical Only	0	0	$28,000	$36,000
Total Annual Operating Cost	$30,000	$137,000	$654,000	$1,118,000
Present Worth Operating Cost	$373,000	$1,707,000	$8,150,000	$13,933,000
Total Present Worth	$573,000	$2,097,000	$8,340,000	$14,123,000

The preliminary cost information also indicates that, for the two EBPR alternatives, there is the potential for significant cost savings for a phosphorus discharge concentration greater than 1 mg/L. The EBPR only alternative is for a discharge concentration between 1 and 2 mg/L and the EBPR with chemical addition is for the discharge target of 1 mg/L. The present worth analysis shows a potential cost saving of four times for the EBPR only system to meet a phosphorus limit of 2 mg/L.

5.2 BIOLOGICAL NUTRIENT REMOVAL (BNR)

The two BNR plants evaluated for phosphorus removal were the 13 MGD St. Cloud WWTF and 2.81 MGD Fergus Falls WWTP. The following summarizes the analysis for each plant.

5.2.1 St. Cloud WWTF

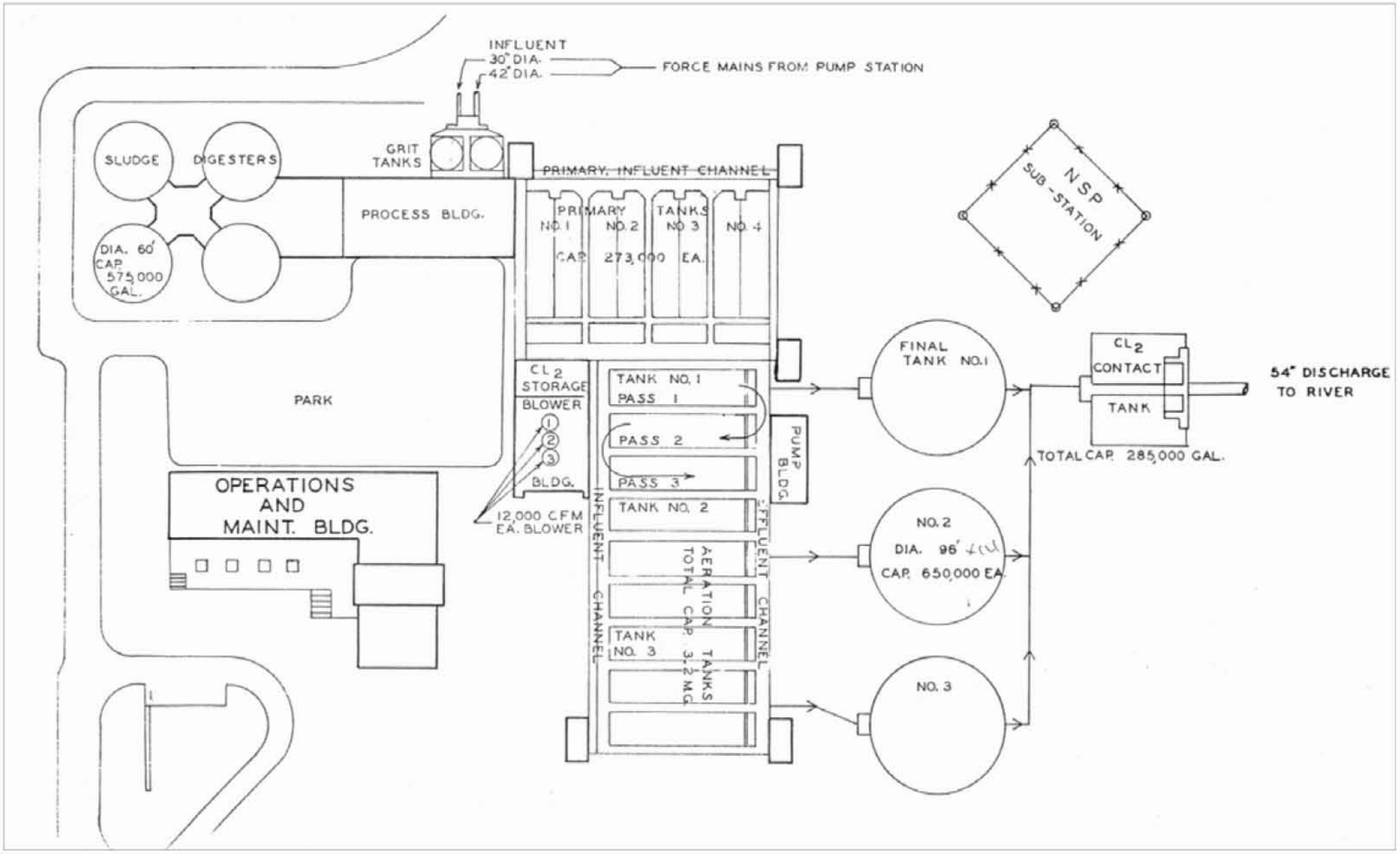
The St. Cloud Wastewater Treatment Facility (St. Cloud WWTF) has a design capacity of 13.0 MGD. It was originally designed as a conventional activated sludge plant with primary treatment. The plant has since been converted to a BNR process by incorporating an anaerobic contact zone at the head of the aeration tanks and the secondary treatment process, which promotes enhanced biological phosphorus removal (EBPR). A unique feature of the plant is that digested sludge is stored in large holding tanks on-site and then removed in the spring and fall for agriculture applications. The decant from the biosolids holding tanks is returned to the head of the treatment plant. At present there is no effluent discharge permit limit on phosphorus or nitrogen, but the facility has been demonstrating a high level of biological phosphorus removal for at least the last three years.

5.2.1.1 Plant Description and Performance

A process flow diagram for the wastewater treatment process and sludge handling is presented in Figure 5.2.1.1. Preliminary treatment consists of mechanically cleaned bar screens and aerated grit removal. Following pretreatment the wastewater is split between four (4) 8-ft deep rectangular clarifiers, which results in an overflow rate of 712 gpd/ft^2 at the design average annual influent flow rate of 13.0 MGD. The waste primary sludge is thickened separately using a gravity belt thickener.

After primary treatment the wastewater can be split between three (3) plug flow, 3-pass aeration basins with fine bubble aeration. Each pass is 105 ft long and the width and depths are 30 and 15 ft, respectively. The total volume per aeration basin train is 1.06 MG to allow an HRT of 5.9 hours with all basins in service. For the 2002-2003 operation two basins were typically in service and the average flow was 10.8 MGD resulting in an average HRT of 4.71 hours. An anaerobic contact zone was created in half the volume of the first pass by reducing the aeration to just that needed for mixing. This provided an anaerobic contact time of 0.8 hours for contact between the influent wastewater and return activated sludge, an anaerobic hydraulic residence time (HRT) within the typical values used for EBPR processes. From the 2002 data, the system was typically operated with a MLSS concentration of 3,000 mg/L, an SRT from 8-9 days and an F/M ratio of 0.10 to 0.20 g BOD/g MLVSS-d.

Figure 5.2.1.2 is a view of the control building and aeration tank from the secondary clarifier. Figure 5.2.1.3 is a photo of an aeration tank showing the unaerated anaerobic contact zone at the head end of the tank.



Source:
St. Cloud WWTF

Figure 5.2.1.1 – Schematic Process Flow Diagram, St. Cloud WWTF

Figure 5.2.1.2 – View from Secondary Clarifier to Control Building and Aeration Tanks
St. Cloud WWTF

Figure 5.2.1.3 – Aeration Tank Showing Initial Unaerated Anaerobic Contact Zone
St. Cloud WWTF

The mixed liquor from the aeration tanks can be directed to any of three (3) 96-ft diameter secondary clarifiers with a depth of 12 ft. At the average design condition the overflow rate would be 600 gpd/ft^2. This is a typical overflow rate design value for activated sludge treatment (Tchobanoglous et al., 2003). The settled secondary sludge has a common collection point and is returned to a feed channel for the activated sludge process. The waste activated sludge is thickened by a gravity belt thickener. The secondary effluent is directed to a chlorine contact tank for disinfection prior to discharge.

The thickened primary and secondary waste sludge is processed by mesophilic anaerobic digestion. There are 4 digesters on site, each with a capacity of 0.575 MG. The digested sludge is directed to large holding tanks on-site for land application in the spring and fall.

Influent and effluent plant data were collected and reviewed to develop raw wastewater characteristics for the phosphorus removal analysis and to observe the present plant performance. Influent wastewater characteristics are summarized in Table 5.2.1.1 for the period of October 2002 through September 2003. These data represent the monthly average values for flow, and cBOD, TSS, TKN, and total P concentrations. There are minor industrial wastewater loads and the wastewater is relatively weak. The average BOD/P ratio is 28, which is a moderate to low value and would suggest an effluent P of 1.5 to 2.0 mg/L for an EBPR process.

Table 5.2.1.1 - Monthly Average Raw Wastewater Characteristics
St. Cloud WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	TKN (mg/L)	TP (mg/L)	BOD/P
10.8	144	153	28.4	5.2	28

There was a significant variation in the influent wastewater strength based on monthly average data. For March, the influent BOD concentration was 171 mg/L, while it was down to 101 mg/L for September. The TKN concentration values ranged from 23 to 34 mg/L. With these variations the BOD/P ratio did not vary much, and was generally from 26 to 28.

The monthly average effluent concentrations for one year from October 2002 through September 2003 were used to develop an annual average effluent concentration value for key parameters, and these results are summarized on Table 5.2.1.2 below. The table also includes discharge permit requirements and percent removals for $CBOD_5$, TSS, and phosphorus. The plant presently does not have an effluent limit for phosphorus, but it is to be monitored. The plant is operating well within the permit limits of 25 mg/L monthly averages for $CBOD_5$ and 30 mg/L for TSS. The plant achieved about 96 and 95% removal of $CBOD_5$ and TSS, with average effluent concentrations of 5.7 mg/L and 7.8 mg/L, respectively. The annual average phosphorus removal (79%) was very good and the average effluent concentration was 1.1 mg/L. The values ranged from a high of 2.0 mg/L to a low of 0.29 mg/L. No chemical addition was used. The phosphorus removal therefore is attributed to the EBPR process, which was incorporated into the activated sludge system by converting the first half of the first aeration pass into an anaerobic contact zone. However, the effluent phosphorus concentrations was lower than could be expected on many occasions, based on the modest influent BOD/P ratio. Thus, the basis for the P removal performance was evaluated further. The evaluation also found that waste alum sludge from the local water treatment plant was being discharged to the St. Cloud WWTF.

The plant performance data for the period October 2002 through September 2003 was evaluated to determine if the variations in phosphorus removal were related to the key biological phosphorus removal parameters, notably the influent BOD/P ratio and the effluent NO_3-N concentration. The plant experiences seasonal nitrification at its operating SRT and thus effluent nitrate concentrations are higher at that time. Higher nitrate concentrations, as described in Section 2, can decrease EBPR performance by consuming substrate desired by the phosphorus accumulating organisms (PAOs). A comparison of the effluent soluble phosphorus and nitrate concentrations on Figure 5.2.1.4 shows no conclusive correlation between the effluent phosphorus concentration and nitrate concentrations. For example, the lower monthly average phosphorus concentrations (Months 6 and 11) were associated with higher effluent nitrate concentrations, above 8 mg/L. Also higher effluent phosphorus concentrations (Months 1 and 2) are shown with much lower effluent nitrate concentrations. For higher influent wastewater BOD/P ratios, a lower effluent phosphorus concentration is expected for EBPR processes as more food is expected to be available to grow more PAOs. The results on Figure 5.2.1.4 do not support a correlation between the effluent phosphorus concentrations and influent BOD/P ratios. In fact the influent BOD/P ratio did not very greatly, while the effluent P concentration did. Thus these results suggest that operating conditions or other factors affected the EBPR performance. It is possible that a more consistent lower effluent phosphorus removal performance could have been achieved if the anaerobic contact zones were better controlled by using mechanical mixers to prevent any dissolved oxygen from entering the contact zones.

Based on the fact that the St. Cloud WWTF was receiving waste alum sludge from the water treatment plant which may have impacted phosphorus removal, a literature and laboratory study was done to determine the efficacy of waste alum sludge for phosphorus removal. Literature reports

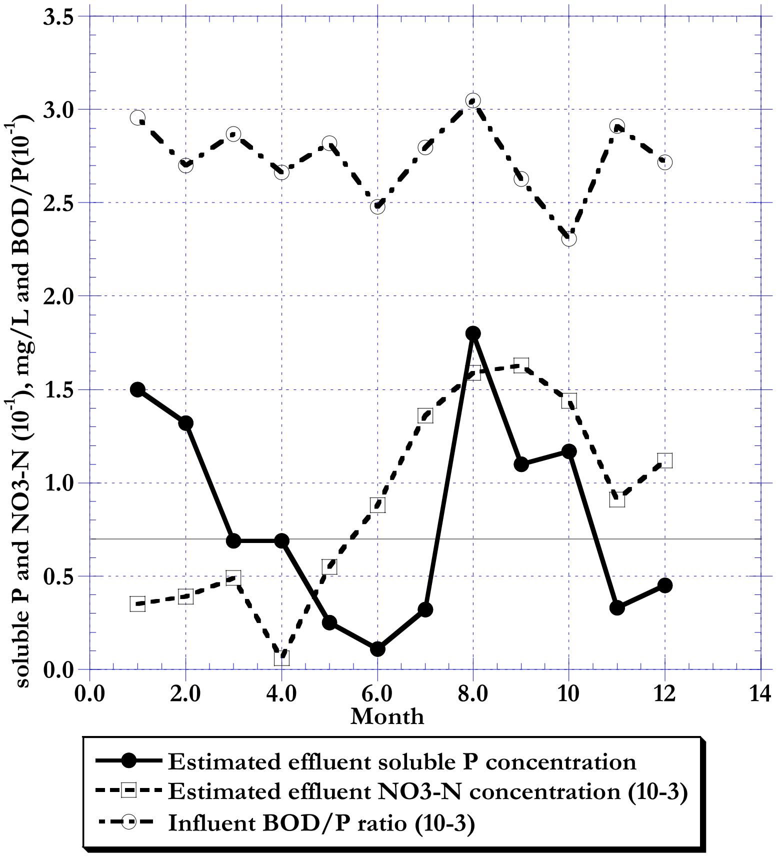


Figure 5.2.1.4 - Comparison of Effluent Estimated Soluble P Concentration to Influent BOD/P and Effluent Estimated NO_3-N Concentration for St. Cloud WWTF (Estimated NO_3-N based on data on influent N and effluent NH_3-N and estimate of N used for biomass growth. Estimated effluent soluble P based on effluent total P data and estimate of solids P content)

Table 5.2.1.2 - Monthly Average Treatment Performance Summary
October 2002 – September 2003
St. Cloud WWTF

	Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)
Average Performance	10.8	5.7	7.8	12.0	1.1
Permit Requirements	13.0	25	30	NR	Monitor Only
Percent Removal	NA	96.0%	94.9%	NR	78.9%

See Appendix 2.2.1 for detailed monthly plant data analysis
NR – Not Required
NA – Not Applicable

showed that waste alum sludge can be used to remove phosphorus, though at a much lower efficiency than fresh alum addition. In a study by Huang and Chiswell (2000), it was found that alum sludge could rapidly remove phosphate in wastewater. The variation of nitrogen species present in the wastewater showed a negative correlation with the amount of phosphate removed. The author proposed it was due to ionic exchange of nitrate on the alum sludge. According to a review by Barr (1992), the ability of alum sludge to remove phosphorus is not as great as that of fresh alum addition, but it is an effective means for phosphorus removal. The phosphorus removal decreased with increasing age of the alum sludge. The phosphorus removal at the same Al/P molar ratio for alum sludge was about 10-15% of that for fresh alum addition (Hsu, 1975).

Laboratory tests were done with waste on sludge from St. Cloud and synthetic aluminum hydroxide sludge produced in the University of Washington laboratories. For the St. Cloud water treatment plant sludge, the test objective was to determine the phosphorus removal capacity of the waste sludge. The TSS and VSS concentrations were determined for the waste sludge and the phosphorus removal was determined for two samples with P additions of 10 and 40 mg/L, respectively after 30 minutes of slow mixing on a jar testing device. For the aluminum hydroxide versus alum addition experiments, influent wastewater from the Seattle West Point treatment plant was used in jar testing. Phosphorus was added at 20 mg/L P concentration and the Al concentration was varied in each jar with the addition of $Al(OH)_3$ sludge or alum at Al/P molar ratios of 0.5, 1, 2, 4, and 8. All phosphate and aluminum determinations were carried out according to HACH test procedures.

For the St. Cloud tests, the results in Table 5.2.1.3 show that the water treatment plant sludge did have phosphorus removal capacity and based on the TSS concentration it was 0.01 to 0.04 g P/g TSS. The variation in g P/g TSS reflects the low amount of phosphorus removed in the testing due to the low solids concentrations in the samples received.

Table 5.2.1.3 - Removal of Wastewater P with Waste Alum Sludge from the St. Cloud Water Treatment Plant (September 2004)

Initial P (mg/L)	TSS (mg/L)	VSS (mg/L)	Aluminum (mg/L)	pH	Al/P molar ratio	P removal efficiency (%)	g P removed per g inorganic solids (TSS-VSS)	g P removed per g TSS
10	43	30	0.984	8.04	0.11	6.17	0.051	0.015
40	63	48	1.068	7.97	0.03	6.17	0.176	0.041

The jar test results with the aluminum hydroxide sludge and fresh alum with West Point wastewater are summarized on Figure 5.2.1.5. The dashed lines represent the phosphorus adsorption with freshly precipitated aluminum hydroxide at pH 7, whereas the solid line represents phosphorus removal results using alum at pH 7.

These results show that for the same Al/P ratio the phosphorus removal efficiency of the alum sludge was about 10 to 15% of that for fresh alum. Thus for a wastewater plant condition where waste alum sludge is mixed with influent wastewater and the Al/P ratio is 1.0 or less (stoichiometric ratio), the phosphorus removal may be 0.10-0.15 mole of P/mole of Al added. This is within the magnitude of the phosphorus removal efficiencies for the Al/P ratios in the St. Cloud samples for the results in Table 5.2.1.3. Thus the evaluation of the effect of waste alum sludge addition to the St. Cloud WWTF is based on a removal efficiency of 0.15 mole of P/mole of Al added or 0.05 mg P/mg TSS added. For both parameters the more optimistic results are used to evaluate the P removal in the existing facility.

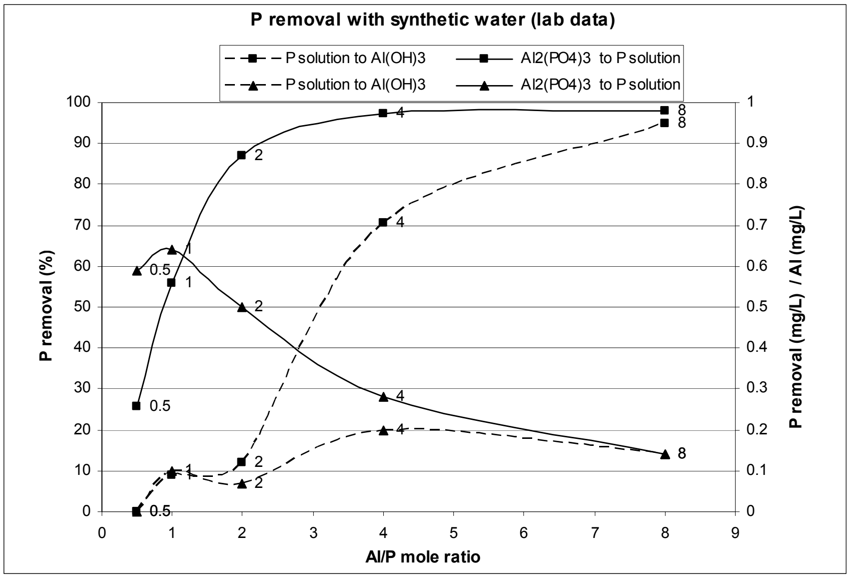


Figure 5.2.1.5 - Phosphorus Removal with Synthetic Water: (—) Aluminum Solution Added to Phosphate Solution; (---) Phosphate Solution Added to Aluminum Precipitate; (-□-) P Removal Rate (%); (-Δ-) P Removal Efficiency with Al (P removal (mg/L) / Al (mg/L))

The amount of phosphorus that could be removed in the influent wastewater due to receiving waste alum sludge from the water treatment plant was estimated, and the results are shown in Table 5.2.1.4 below. Information was provided by the City of St. Cloud on the monthly use of alum as $Al_2(S04)_3{\cdot}(14H_20)$ for the time period 2002 to 2003. These values are summarized in the table below for each month along with the average daily influent flow rate to the wastewater treatment facility. The average amount entering as aluminum in lb/day was then calculated from the monthly alum data.

Table 5.2.1.4 - Estimated P Removal From St. Cloud Influent Based on Amount of Waste Alum Received from the Water Treatment Plant

Month	Alum Used lb/month	Used as Al lb/d	Est. P Removed lb/day	Avg Daily Flow MGD	P Removed Mg/L
January	79,736	241.6	41.6	10.2	0.49
February	71,062	215.3	37.1	10.1	0.44
March	72,495	219.7	37.8	9.8	0.46
April	80,854	245.0	42.2	10.6	0.48
May	85,676	259.6	44.7	10.9	0.49
June	104,490	316.6	54.5	10.9	0.60
July	138,195	418.8	72.1	11.0	0.78
August	136,250	412.9	71.1	10.6	0.80
September	93,636	283.7	48.9	10.6	0.55
October	76,688	232.4	40.0	12.7	0.38
November	69,609	210.9	36.3	11.7	0.37
December	71,826	217.7	37.5	10.5	0.43
				average	0.52

Alum used as $Al_2(S04)_3$ ($14H_20$)

From the estimate of the amount of aluminum entering the influent, the amount of phosphorus removal was estimated in lb/day (based on 0.15 mole of P removed/mole of Al added). The phosphorus removal was then converted to mg/L P as shown in the last column, based on the influent flow rate. The amount of phosphorus removal is significant and ranged from 0.37 mg/L to 0.80 mg/L, with an average removal of 0.52 mg/L. The average value was used in the phosphorus alternative design evaluation for the St. Cloud WWTF.

5.2.1.2 Design Basis for Modifications for Phosphorus Removal

The influent wastewater characteristics used to evaluate phosphorus removal alternatives for the St. Cloud WWTF were based on the annual average data and are summarized in Table 5.2.1.5. The influent BOD, TSS, TKN, and TP concentrations were taken from the 2002-2003 average monthly influent data summary. The wastewater appeared to be a weaker wastewater than average and no significant industrial wastewater contribution with a high level of soluble BOD was identified, so the percent soluble BOD selected for the design analysis was set at the lower level of 25%. Again it should be stressed that an actual engineering analysis and design would include a wastewater characterization study that would determine the influent rbCOD among other factors. The rbCOD content is also some fraction of the influent sBOD concentration. For these analyses, it was assumed that 70% of the influent sBOD was available to the bacteria as truly dissolved organic matter or rbCOD.

Dimensions and loading rates for the existing liquid unit processes at the design flows and loadings are also summarized in Table 5.2.1.5. The table shows the units available for a retrofit to phosphorus removal and indicates if excess capacities exist. In this phosphorus removal alternatives evaluation only two of the three aeration trains were assumed to be in-service at the 13 MGD influent flow rate, as this is the normal situation with the present facility that is demonstrating good EBPR performance. The existing primary and secondary clarification capacity results in very conservative overflow rates, which improves the reliability of any of the phosphorus removal alternatives that could be selected.

Operation with only two of these activated sludge aeration basins still provides sufficient capacity for the anaerobic contact zone within the first pass at each aeration train. The aeration tank volume is also sufficient to support nitrification under warmer wastewater conditions (late spring, summer, and early fall). Because nitrification is not required for the effluent discharge permit and the increase in nitrate would decrease the EBPR phosphorus removal efficiency, the operating SRT must be lowered during the warmer operating months to prevent nitrification.

Table 5.2.1.5 - Process Design Basis Used for Evaluation of
Phosphorus Removal Alternatives
St. Cloud WWTP

Flow (MGD)	$CBOD_5$ (mg/L)	Percent sBOD	TSS (mg/L)	TKN (mg/L)	TP (mg/L)
13.0	144	25	153	28.4	5.2

Process Step	Dimensions	Design Loading	Comment
Primary Clarifiers	4 - rectangular 4563 ft^2 each	712 gpd/ft^2	Can accept chemical addition
Activated Sludge	3 – 1.07 MG plug flow, 3 pass aeration tanks	SRT 5-10 days, HRT = 5.92 hrs	Capacity available for anaerobic contact and already shown
Secondary Clarifiers	3 – 96 ft diameter, 12 ft deep, 7,238 ft^2/clarifier	599 gpd/ft^2	Can accept chemical addition Conservative loading

See Appendix 2.2.1 for summary of the design basis

The aeration tank capacity and operating SRT possible for the existing system is a function of the influent BOD concentration, the solids yield assumptions, and the MLSS concentration for the system. In the design alternative analysis for many of the systems reviewed in this project, a maximum MLSS concentration of 3,500 mg/L was assumed. This has been shown acceptable for standard clarifier designs and subject to the improved settling characteristics associated with EBPR processes. Without the EBPR process, the maximum MLSS concentration assumed was 3,000 mg/L due to the different settling characteristics expected for a system with chemical sludge and with no anaerobic contact tank. For the St. Cloud aeration tanks, the design analysis showed that it is possible to operate the EBPR process with chemical treatment at MLSS concentrations well below 3,000 mg/L.

5.2.1.3 Evaluation of Phosphorus Removal Alternatives

Phosphorus removal alternatives evaluated for the St. Cloud WWTF were EBPR alone, EBPR with alum addition in the primary treatment step, EBPR with alum addition in the secondary clarifiers, and alum addition only to both the primary and secondary clarifiers. The effluent P concentration goal in all cases was between 0.80 and 1.0 mg/L to meet the less than 1.0 mg/L effluent permit goal. When alum addition to the primary clarifiers was followed by either EBPR or alum addition to the secondary clarifiers, the alum dose was set to accomplish about 50% phosphorus removal in primary treatment, which was where the dose was close to stoichiometric requirements (1.0 mole Al/mole P) for phosphorus precipitation. The alternative evaluation process included developing conceptual designs followed by preliminary cost estimates for the viable alternatives. The conceptual designs included determining the activated sludge aeration volume requirements to meet the effluent treatment, the activated sludge tank volume needed for the anaerobic contact zone of the EBPR process, the amount of daily sludge production in both the primary and secondary processes, the amount of chemical sludge produced, the amount of phosphorus removed by biomass growth and by the EBPR process, the phosphorus content the waste sludge, and the fate of solids in solids processing and the characteristics of return flows.

Even though the existing system has been operating with an anaerobic contact zone, the retrofit considered a more engineered zone with mechanical mixers to provide better control of the biological phosphorus removal process. For the preliminary cost estimates, this added a minor additional capital cost for that alternative.

The results of the alternative analyses are summarized in Table 5.2.1.6 in terms of the effluent phosphorus concentration, chemical requirements (alum and alkalinity), sludge production and additional facility modification requirements (tankage, mixers and piping) for each of the alternatives that were considered. For the alternatives with chemical treatment, an effluent phosphorus concentration of 0.50 to 1.0 mg/L can be normally expected under varying wastewater load conditions. For EBPR-only, the design analysis predicted an effluent phosphorus (P) concentration of 1.2 mg/L, which is near the annual average value. Table 5.2.1.6 shows a range of 1.0 to 1.5 mg/L for the predicted effluent P concentration to illustrate the magnitude for EBPR-only treatment. For the one-year of data on the phosphorus removal performance for the present system with EBPR, an effluent P concentration of greater than 1.0 mg/L occurred in 6 of the 12 months. This illustrates that the EBPR process alone would not meet a phosphorus target of less than 1.0 mg/L without periods of chemical addition. For the EBPR-only alternative, the capital cost for a chemical feed system was included to provide stand-by chemical addition. The alternatives with chemical addition in the primary or secondary clarifiers with EBPR provided an estimate of the chemical addition needs to assure that the effluent P concentration is kept comfortably below 1.0 mg/L. The results in Table 5.2.1.6 show that the chemical dose requirements for alum addition to the primary treatment step is 15-20% less than that needed for addition to the secondary clarifier. However, in view of the relatively small difference, the preferred chemical dosing point in this application would be to the secondary clarifier for polishing to provide maximum control of the effluent P concentration and other wastewater parameters such as $CBOD_5$ and TSS.

The alternative with chemical addition only is included to illustrate the impact on the operating cost of using the EBPR process versus chemicals only for phosphorus removal. Fortunately for the St. Cloud facility, there is sufficient activated sludge tank volume to easily accommodate the anaerobic contact time required for the EBPR process.

Table 5.2.1.6 - Summary of Plant Modifications and Chemical Requirements and Plant Retrofit Needs for Phosphorus Removal Alternatives
St. Cloud WWTF

Option	Units	EBPR Only	EBPR+ Chemical Addition to Primary Clarifiers	EBPR+ Chemical Addition to Secondary Clarifiers	Chemical Addition to Primary and Secondary Clarifiers
Effluent P	mg/L	1.0 to 1.5	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0
Chemical Addition	lb/d	0	2050	2434	10,275
Additional Sludge Production(1)	lb/d	0	384	521	2036
Alkalinity Used	mg/L	0	10.6	10.1	42.6
Increased Tank Volume	MG	0	0	0	0

(1)Alum Sludge

For the chemical treatment options the amount of alkalinity consumption would range between 11 mg/L and 43 mg/L as $CaCO_3$. Because the facility is not required to produce a nitrified effluent, the drop in pH due to this alkalinity consumption would not be of concern.

It should be noted that if the facility is required at a future date to produce a nitrified effluent with a low ammonia concentration an additional analysis would be required to incorporate a denitrification process, such as the A^2O process for nitrate removal. This would more seriously impact the available activated sludge tank volume.

A preliminary cost comparison between the most promising chemical treatment approach (two-point addition) and the EBPR processes is compared in Table 5.2.1.7. The costs have been rounded to the nearest $1,000. The capital cost includes the cost for the chemical feed system, and modifications to the basins for the anaerobic contact zone, including the mixers. The present worth cost includes the capital costs plus the present worth value of the operating costs. The present worth calculation is based on a 5% interest rate and a 20 year pay back period, with no escalation in the operations costs, such as that for chemicals and sludge disposal. For the chemical treatment-only system, the major O&M costs are associated with chemical usage, labor and disposal/reuse of the additional sludge production.

The difference in the capital costs for the EBPR alternatives and the chemical treatment only alternative is about $180,000 more for EBPR, but the annual operating cost for the system alternative with chemical treatment only is about $340,000 more than that for the EBPR system with chemical polishing. The use of EBPR has a very significant cost savings in a short time in this case. This favorable comparison for the EBPR process is aided by the fact that the capital expenditure is not excessive due to having extra capacity in the aeration basin and the fortuitous layout of the existing aeration basins.

The preliminary cost information also indicates a potential cost savings for phosphorus discharge concentrations greater than 1 mg/L. Similar to the comparison of the EBPR alternative analysis for Alexandria and New Ulm, the present worth analysis shows that the cost would be 2.5 greater for a treatment system to meet a discharge concentration of 1 mg/L compared to a treatment system discharging 1.5 mg/L (EBPR only).

The cost analysis, process analysis, and existing plant operation clearly showed that the EBPR is the preferred alternative, but its implementation would require chemical treatment capability on-site. There would be times where a relatively small amount of chemical addition in the primary treatment step or secondary clarifier step would be required. For the analysis with EBPR plus chemicals the alum dose would be approximately 11 mg/L.

For this analysis many factors favored the use of the EBPR process (with a small amount of chemical addition) in spite of the fact that the wastewater was relatively weak and had a very modest BOD/P ratio of about 28. The key favorable factors are listed as follows:

- receiving waste alum sludge from the water treatment plant;
- available excess activated sludge tankage to accommodate the anaerobic contact zone;
- a favorable activated sludge plug flow layout for easy implementation of the anaerobic contact zone; and
- no permit requirements for nitrification.

Table 5.2.1.7 - Preliminary Cost Estimates for Retrofit of Phosphorus Removal
with Different Process Options
St. Cloud WWTF

Parameter	EBPR Only	EBPR + Chemicals in Primary Clarifiers	EBPR + Chemicals in Secondary Clarifiers	Chemicals only, to Primary and Secondary Clarifiers
Preliminary Capital Costs				
EBPR Tank	$176,000	$176,000	$176,000	-
Aeration Tank Modifications	0	0		-
Chemical System	$250,000[1]	$250,000	$250,000	$250,000
Total Capital Costs	$426,000	$426,000	$426,000	$250,000
Daily Operating Costs, $/d				
Alum	0	205	243	1028
Sludge disposal	0	35	47	183
EBPR operation	65	65	65	0
Annual Labor Cost – Chemicals Only	0	0	0	$30,000
Total Annual Operating Costs	$24,000	$111,000	$130,000	$472,000
Present Worth Operating Costs 5% @ 20 years	$299,000	$1,383,000	$1,620,000	$5,882,000
Total Present Worth	$725,000	$1,809,000	$2,046,000	$6,132,000

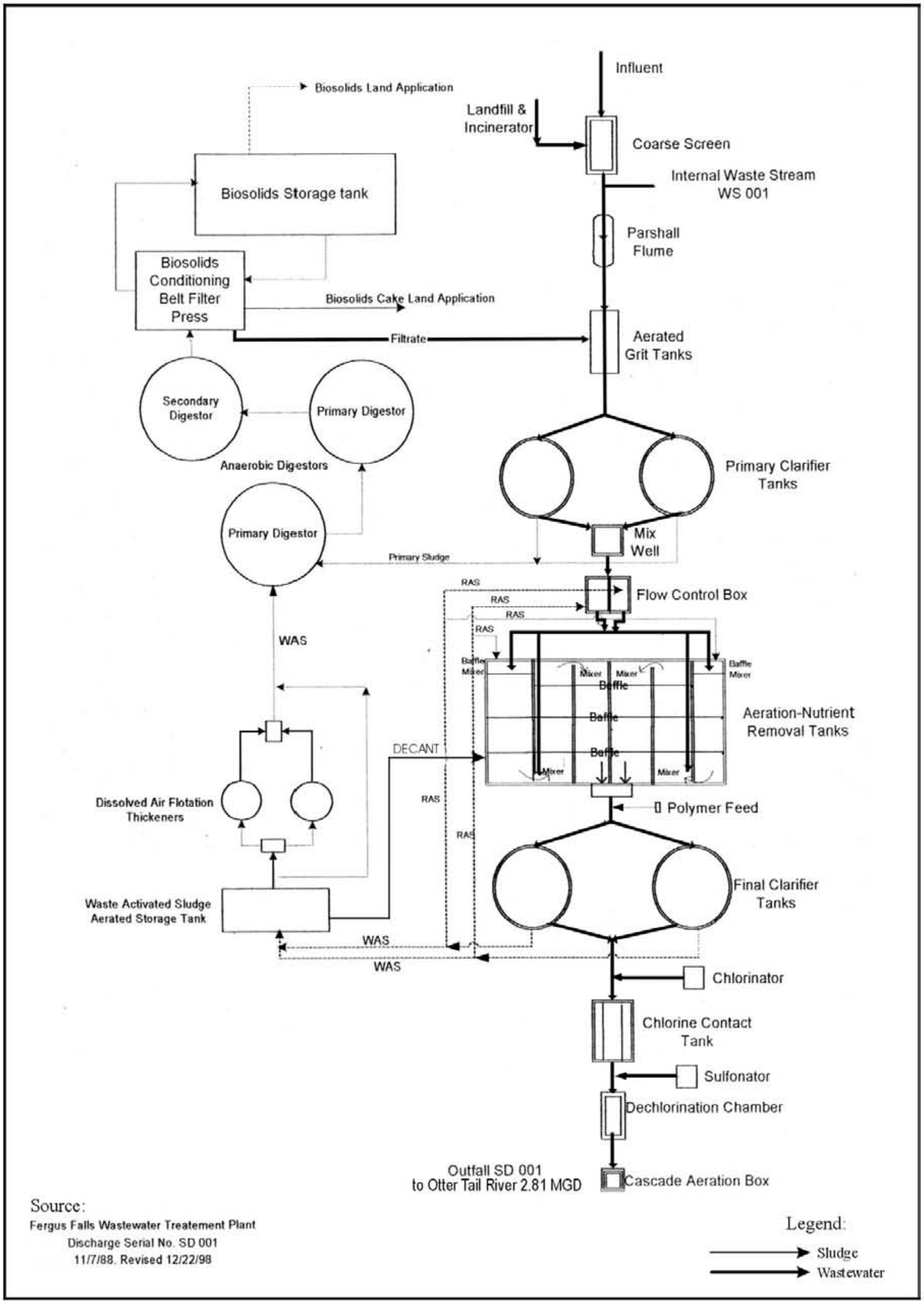
1 – back up chemical feed for EBPR system

5.2.2 Fergus Falls WWTP

The Fergus Falls Wastewater Treatment Plant (Fergus Falls WWTP) is a conventional plug flow activated sludge system providing biological nutrient removal (BNR). This advanced secondary treatment process provides biological nitrogen and phosphorus removal and, when needed, chemical precipitation for additional phosphorus removal. The facility's design flow is 2.81 MGD and the plant is currently operating at 1.76 MGD.

5.2.2.1 Plant Description and Performance

The treatment plant's operation is depicted on the process flow diagram on Figure 5.2.2.1 for the wastewater and sludge handling treatment steps. The first step in the treatment process is screening of the raw wastewater. At this point, the influent is mixed with the flows from the incinerator scrubber water and the landfill leachate. Downstream of the screens, internal waste streams (WS001) enter the treatment system. After flow monitoring and grit removal the wastewater flows to two circular 50 feet diameter primary clarifiers. The effluent from the primary clarifiers flows by gravity to a control box where the wastewater is diverted to the two plug flow aeration –nutrient removal tanks (BNR tanks) for biological nitrogen and phosphorus removal. The



Source:
Fergus Falls Wastewater Treatement Plant
Discharge Serial No. SD 001
11/7/88, Revised 12/22/98

Figure 5.2.2.1 - Schematic Process Flow Diagram, Fergus Falls WWTP

550,000 gallon aeration tanks are baffled to provide for three separate biological processes to take place sequentially in a plug flow mode, i.e. anaerobic, anoxic and aerobic treatment.

The biologically treated wastewater then flows by gravity to the two final 65 foot diameter clarifiers, prior to chlorination, dechlorination and post aeration. The final effluent discharges to the Otter Tail River. The secondary sludge from the final clarifiers is returned (i.e. return activated sludge (RAS)) to the aeration tanks and wasted to the waste activated sludge (WAS) aerated storage tank.

The aerated WAS storage tank is the first treatment step for the sludge handling operation. The decant from the WAS storage tank is returned to the BNR tanks. The aerated WAS is pumped to the first of three anaerobic digesters operating in series. There are two primary digesters and one secondary digester. Each digester has a diameter of 50 feet and a storage volume of 471,000 gallons. In the first primary digester, the primary clarifier sludge is mixed with the WAS. The combinedsludge is pumped to the second primary digester and then to the secondary digester for further digestion and stabilization. The digested sludge is thickened on a belt filter press. The thickened biosolids are stored in the 1.48 MG storage tank for land application during the spring and fall.

Figure 5.2.2.2 is an overview of the treatment plant. It shows the headworks building housing the screens, parshall flume and aerated grit tank; primary clarifiers; the aeration tanks; the WAS tank and dewatering building next to the aeration tanks; and the final clarifiers in the background. Figure 5.2.2.3 shows a portion of an aeration tank where the anaerobic and aerobic zones are separated by a baffle.

Influent and effluent characteristics are summarized on Tables 5.2.2.1 and 5.2.2.2. These data were used to evaluate the plant's performance. Table 5.2.2.1 presents the average influent monthly average concentration of $CBOD_5$, TSS, ammonia nitrogen (NH_4-N) and total phosphorus (TP).

Table 5.2.2.1 - Monthly Average Raw Wastewater Characteristics
Fergus Falls WWTP

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)	$CBOD_5$/P
1.76	184	217	20	5.9	31

Influent wastewater characteristics did not vary significantly over the study period. The treatment plant receives no major industrial loads. The plant does receive sludge incinerator

Figure 5.2.2.2 - Overview of Treatment Plant, Fergus Falls WWTP

Figure 5.2.2.3 - Anaerobic and Aerobic Zones, Fergus Falls WWTP

scrubber water and landfill leachate which is introduced at the head end of the plant. Influent $CBOD_5$ concentration averaged 184 mg/L and ranged between 153 to 205 mg/L; TSS averaged 217 mg/L and ranged between 194 and 272 mg/L; average ammonia concentration was 20 mg/L and ranged between 18 and 27 mg/L; and phosphorus averaged 5.9 mg/L ranging between 5.1 and 6.5 mg/L.

During the period of October 2002 through September 2003, the plant achieved excellent removal of the conventional parameters; 98.3% $CBOD_5$ removal, 96.9% TSS removal, 92.8% ammonia removal and 89.8% total phosphorus removal, as shown on Table 5.2.2.2. The table shows that the annual average concentration of $CBOD_5$, TSS, and total phosphorus which are well within the monthly permit limits. As stated in the table, the ammonia limit of 4.3 mg/L is a seasonal limit from June through September, and the corresponding average ammonia level in the effluent was 1.4 mg/L during the June to September period, which reflects the 92.8% ammonia removal during that period. Also the monthly average ammonia nitrogen concentration was less than 4.3 mg/L for each month during the June to September period. The yearly average effluent ammonia concentration was 7.2 mg/L.

Table 5.2.2.2 - Monthly Average Treatment Performance Summary
October 2002 – September 2003
Fergus Falls WWTP

	Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)(1)	TP (mg/L)(2)
Average Performance	1.76	3.0	6.7	1.4	0.60
Permit Requirements	2.0	25.0	30.0	4.3	1.0
Percent Removal	--	98.3%	96.9%	92.8%	89.8%

See Appendix 2.2.2 for detailed monthly plant data analysis.

(1) Permit limit of 4.3 mg/L is for period of June through September. For period of June through September in 2003, the monthly average NH_4-N level was 1.4 mg/L with a range of 0.9 to 2.3 mg/L which was well below the permit limit. The annual average ammonia nitrogen (NH_4-N) was 7.2 mg/L.

(2) All monthly phosphorus levels were less than 1 mg/L.

5.2.2.2 Design Basis for Modifications for Phosphorus Removal

The Fergus Falls WWTP is currently practicing EBPR and achieving a low level of total phosphorus of 0.60 mg/L P in the final effluent. The plant also has a backup chemical treatment system for phosphorus removal, if needed. Considering its performance to date the need for additional phosphorus removal is unwarranted.

A review was performed to see if additional EBPR capacity was available at Fergus Falls. The Fergus Falls wastewater is a medium strength domestic wastewater with no major industrial inputs. The actual influent wastewater characteristics presented in Table 5.2.2.1 show that the plant is at roughly two-thirds of its design hydraulic capacity and the influent is 20-30% weaker in strength than its design basis. The actual $CBOD_5/P$ ratio is 31 which would support EPBR without the need for an additional carbon source. At the time of the plant visit, the plant was operating in conventional activated sludge mode with one aeration basin in service. The actual operating data indicate a food to microorganism ratio F/M of 0.14 (target 0.3) at an average MLSS concentration of 6,445 mg/L which is more characteristic of the extended aeration mode of the activated sludge process. Currently, the second basin is in service and the plant is operating in extended aeration mode. The F/M is low enough to support nitrification year round but the low temperatures observed in the winter months would make full nitrification difficult to achieve. The low F/M also suggests that there is significant aeration volume available to support denitrification and EPBR.

The evaluation of phosphorus removal alternatives was based on the process design parameters presented in Table 5.2.2.3. The design parameters included design flow and wastewater characteristics, and design conditions (e.g., overflow rates, F/M, HRT) for the clarifiers and activated sludge system. This design basis was used to look at the expected removals for the various phosphorus removal alternatives that could be employed at the plant. There are three return streams at the Fergus Falls plant including: WAS storage tank supernatant which is returned to the aeration basins; secondary digester supernatant which is returned to the head of the plant; and filtrate from belt filter press operations which have been suspended. There were no data available on these waste streams, however, assumptions were made to account for the digester supernatant returns. Based on plant communications, a design low temperature of 10^{O} C was selected for use in developing biological nutrient kinetics.

Certain wastewater characteristics, removal rates and treatment plant operating conditions were either assumed or based on plant operating data for this analysis. Biodegradable COD (discussed in Section 4) was assumed to be equal to 1.6 times the $CBOD_5$ and readily biodegradable COD (rbCOD), that fraction of the COD that is easily converted to volatile fatty acids (VFA) which are used by EBPR bacteria, was assumed to be 30% of the biodegradable COD. Also baseline phosphorus removal by primary treatment (without chemical addition) was assumed to be 10% of the influent concentration.

Table 5.2.2.3 – Process Design Basis Used for Evaluation of Phosphorus Removal Alternatives
Fergus Falls WWTP

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH4- N (mg/L)	TP (mg/L)	rbCOD (mg/L)
2.81	282	266	30	8	122

Process Step	Dimensions	Design Loading	Comment
Primary Clarifiers	2-50 ft. diameter 9.5 ft. SWD	715 gpd/sf	Already designed for chemical addition as needed
Activated Sludge	2 trains @ 0.556 MG; 3 passes/train (1+ unaerated, 2-aerated)	F/M = 0.1 lb $CBOD_5$/lb MLSS; HRT = 9.4 hrs	Seasonal Nitrification; Presently retro-fit for EBPR with low effluent P (~0.60 mg/L)
Secondary Clarifiers	2-65 ft. diameter 12.0 ft. SWD	423 gpd/sf	Already designed for chemical addition as needed

See Appendix 2.2.2 for summary of the design basis
SWD – side water depth

5.2.2.3 Evaluation of Phosphorus Removal Alternatives

The evaluation of phosphorus removal alternatives for the Fergus Falls plant involved reviewing whether additional phosphorus removal could be achieved with the current phosphorus removal practices (ie. EBPR with chemical addition as needed). The analysis affirmed that EBPR is effective without the use of additional tankage. It also indicated that the plant is performing better than basic EBPR process kinetics would predict. Therefore, the operating process should be left as is and no modification undertaken at this time. Therefore, the recommended phosphorus removal alternative is a No Action Alternative. To fully understand the high rate of phosphorus removal achieved by the Fergus Falls plant, a more detailed engineering design review would be required of the process operation, return streams, incinerator scrubber and leachate waters and data collection that is beyond the scope of this study.

5.3 OXIDATION DITCH

The 0.50 MGD Wadena WWTF and the 0.80 MGD Whitewater River PCF were evaluated for phosphorus removal. The following presents a summary of the analysis for each plant.

5.3.1 Wadena WWTF

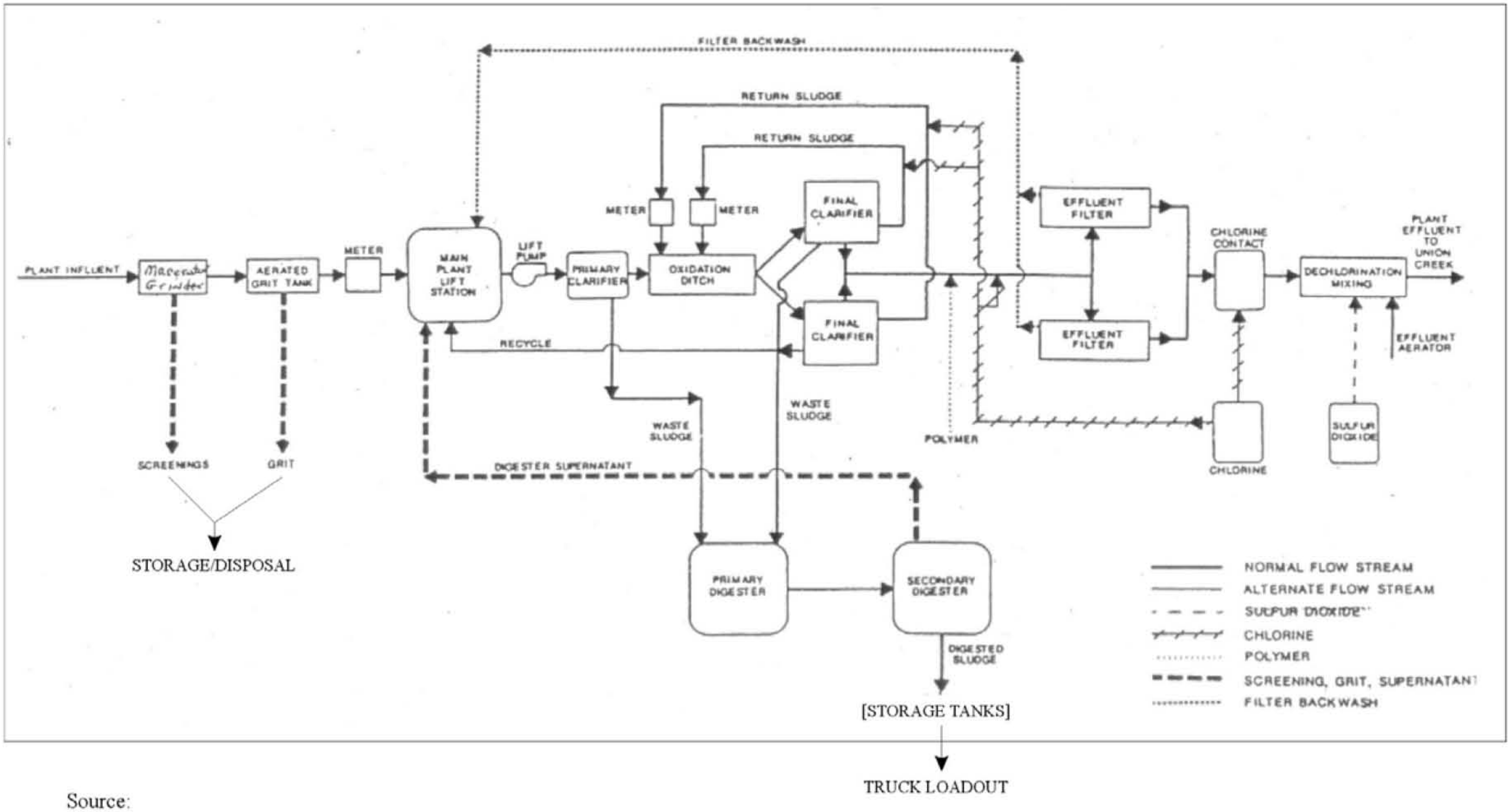
The Wadena Wastewater Treatment Facility (Wadena WWTF) plant is a suspended growth biological treatment system using the oxidation ditch process for secondary treatment and two gravity filters following the secondary clarifiers for tertiary treatment. The plant has a design flow rate of 0.5 MGD and a wet weather design flow of 0.75 MGD. The plant is currently operating at a wastewater flow of 0.32 MGD.

5.3.1.1 Plant Description and Performance

A process flow diagram for the wastewater and the sludge handling treatment process is presented on Figure 5.3.1.1. The influent entering the plant is involving a macerator grinder followed by grit removal, and flow metering prior to entering the main pump station. The wastewater is pumped to the 40 foot diameter primary clarifier for initial $CBOD_5$ and TSS removal followed by biological treatment in the 396,000 gallon oxidation ditch. The 4 pass oxygen ditch provides advanced secondary treatment including nitrification year round, meeting the seasonal ammonia nitrogen permit limits. The treated wastewater then flows to the two 40 foot diameter final (secondary) clarifiers. The thickened secondary sludge (RAS) is returned to the oxidation ditch and also wasted to the primary digester along with the primary clarifier sludge. The clarified effluent flows by gravity to the two-dual media filters operating in parallel for additional TSS and $CBOD_5$ control and removal. The backwash from the filters is pumped back to the main pump station. Following filtration, the treated effluent passes through disinfection, dechlorination and post aeration prior to discharging into Union Creek. Figure 5.3.1.2 is a view of the 4 pass oxidation ditch with one of the 30 hp aeration mixers shown in the background along with the two covered secondary clarifiers. Figure 5.3.1.3 is a view of the inside of one of the dual media filters showing the effluent trough, the media area, and the traveling bridge used for backwashing operations.

The sludge handling operation shown on Figure 5.3.1.1 starts with the pumping of the primary and secondary clarifier thickened sludges to the heated 189,000 gallon primary anaerobic digester. From the primary digester, the sludge is pumped to the unheated 140,000 gallon secondary anaerobic digester for additional digestion. The digested sludge is then stored in two 250,000 gallon biosolids tanks. The digester supernatant from the secondary digester and the decant from the sludge storage tanks are returned to the main pump station. The biosolids are stored in the 250,000 gallon tanks in the summer and winter and land applied during the spring and fall.

Influent and effluent plant data were reviewed to develop the raw wastewater and final effluent characteristics to evaluate the plant performance, and for the phosphorus removal analysis. Influent wastewater and final effluent characteristics are summarized on Tables 5.3.1.1 and 5.3.1.2 for the period of October 2002 through September 2003. These data represent the annual monthly average flow, $CBOD_5$, TSS, ammonia nitrogen (NH_4-N), and total phosphorus. Industrial



Source:
Wadena WWTF

Figure 5.3.1.1 - Schematic Process Flow Diagram, Wadena WWTF

Figure 5.3.1.2 - Oxidation Ditch, Wadena WWTF

Figure 5.3.1.3 - Dual Media Filter, Wadena WWTF

wastewater contributions are minor and include several car washes, Homecrest Metal finishing which provides pretreatment, a fertilizer plant, laundromat/cleaners, a nursing home, the local hospital and the new water treatment plant. The influent characteristics are as follows:

Table 5.3.1.1 - Monthly Average Raw Wastewater Characteristics
Wadena WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N mg/L)	TP (mg/L)	$CBOD_5$/P
0.32	153	204	23	6.9	24

The influent did not show any large variations in wastewater characteristics. The $CBOD_5$ concentration averaged 153 mg/L and ranged from 127 mg/L to 183 mg/L; TSS averaged from 204 mg/L and ranged between 147 and 237 mg/L; NH_4-N concentration averaged 23 mg/L and ranged between 17 and 28 mg/L; and the phosphorus concentration averaged 6.9 mg/L and ranged between 3.6 and 11 mg/L.

The plant effluent characteristics are summarized on Table 5.3.1.2 along with permit requirements and percent removals for $CBOD_5$, TSS and ammonia nitrogen. The plant has effluent permit limits for $CBOD_5$, TSS and ammonia nitrogen. Monthly monitoring is the only requirement for total phosphorus (TP). The plant is operating well within permit limits of 10 mg/L monthly averages for $CBOD_5$ and 30 mg/L for TSS. The plant achieved greater than 98% removal of $CBOD_5$ and TSS with an average effluent concentration of 2.3 mg/L and 1.5 mg/L, respectively. The 2002-2003 yearly monthly average discharge concentration for ammonia was 1.2 mg/L. The plant has seasonal monthly average limits for ammonia nitrogen as shown in the table. The plant is meeting these requirements year round. Weekly monitory is required for total phosphorus and the monthly average is reported. The monthly average phosphorus discharge level was 6.2 mg/L.

Table 5.3.1.2 – Monthly Average Treatment Performance Summary
October 2002 – September 2003
Wadena WWTF

	Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)
Average Performance	0.32	2.3	1.5	1.2	6.2
Permit Requirements	0.50	10	30	(1)	Monitor Only
Percent Removal	----	98.5%	99.2%	90.6%	----

See Appendix 2.3.1 for detailed monthly plant data analysis.

Note (1)

- NH_4-N limit is 15 mg/L from December through March; actual monthly average NH_4-N level was 5.3 mg/L
- NH_4-N limit is 8 mg/L from April through May; actual monthly average NH_4-N was 0.43 mg/L
- NH_4-N limit is 2 mg/L from June through September; actual monthly average NH_4-N level was 0.54 mg/L
- NH_4-N limit is 8 mg/L from October through November; monthly average NH_4-N was 0.61 mg/L.

5.3.1.2 Design Basis for Modifications for Phosphorus Removal

The evaluation of phosphorus removal alternatives was based on the design parameters presented in Table 5.3.1.3. This design basis was used to look at the expected removals for the various phosphorus removal alternatives that could be employed at the plant. There are two continuous return streams at the Wadena plant, the digester supernatant and the filter backwash which are returned to the head of the plant. There is also a seasonal return from the sludge holding tanks decent. Digester supernatant flows average 7,200 gpd with a phosphorus concentration ranging between 8 and 12 mg/L. The filter backwash flow is 20,000 gpd and the phosphorus level would be low and, therefore, was not included in the analysis. For the anaerobically digested sludge recycle streams, $CBOD_5$, TSS and TKN concentrations were assigned at 500 mg/L for $CBOD_5$ and 3,400 mg/L for TSS and 158 mg/L of TKN. The sludge holding tank decant returns only occur twice per year in the spring and fall prior to initiating land application of the digested sludge. The waste volume from these operations was estimated to be 125,000 gallons returned twice per year over the course of a few days. These flows were addressed in the conceptual design analysis, considering sidestream treatment or bleeding of this stream back into the plant, such that any retained phosphorus load would have minimal impact on biophosphorus removal. Based on plant communications a design low temperature of 12°C was selected for use in developing biological nutrient kinetics.

Table 5.3.1.3 - Process Design Basis Used for Evaluation of Phosphorus Removal Alternatives
Wadena WWTF

Flow	$CBOD_5$ (mg/L)	TSS (mg/L)	NH4- N (mg/L)	TP (mg/L)	rbCOD (mg/L)
0.50	200	210	23	6.9	46

Process Step	Dimensions	Design Loading	Comment
Primary Clarifiers	1 @ 40 ft. diameter 7.0 ft. SWD	400 gpd/sf	Possible point of chemical addition
Activated Sludge - Oxidation Ditch	396,000 w/ 14.0 ft. SWD	HRT = 19.0 hrs SRT = 21.1 days F/M = 0.07 lb $CBOD_5$/lb MLSS (calculated)	Consider an EBPR retrofit
Secondary Clarifiers	2 @ 40 ft. diameter 11.0 ft. SWD	200 gpd/sf	Possible point of chemical addition

See Appendix 2.3.1 for summary of the design basis

Certain wastewater characteristics, removal rates and treatment plant operating conditions were either assumed or based on plant operating data for this analysis including ammonia and phosphorus which were based on observed plant data and bCOD and rbCOD which were based on theoretical assumptions. Biodegradable COD (discussed in Section 4) was assumed to be equal to 1.6 times the $CBOD_5$ (of the primary effluent) and readily biodegradable COD (rbCOD), that fraction of the COD that is easily converted to volatile fatty acids (VFA) which are used by EBPR bacteria, was assumed to be 25% of the biodegradable COD. Also baseline phosphorus removal by primary treatment (without chemical addition) was assumed to be 10% of the influent concentration.

5.3.1.3 Evaluation of Phosphorus Removal Alternatives

The evaluation of phosphorus removal alternatives included developing conceptual designs and preliminary cost estimates for the viable alternatives. The design analysis is summarized in Table 5.3.1.4. The alternatives reviewed included EBPR alone, single point alum addition in either the primary or secondary clarifiers or two point alum addition. The analysis indicated that EBPR alone can not meet the effluent phosphorus target of 1 mg/L if the $CBOD_5/P$ ratio is less than 30, and must be used in conjunction with chemical precipitation.

Chemical precipitation is a reliable means of phosphorus removal and can be effectively applied to either clarifier or to both clarifiers as a two point chemical addition scenario. In the case of the Wadena plant, the conceptual design for alum addition indicated that effluent goals could be met for the three scenarios. The conceptual design analysis indicated that two point addition would have the lowest chemical requirements and lowest sludge production compared with chemical addition to the primary or secondary clarifiers alone. Alum addition to the secondary clarifier alone had the next lowest chemical requirements and sludge production with primary chemical addition producing the most sludge and the highest chemical requirements. Alum addition would also result in the destruction of alkalinity. Since the plant nitrifies, the need for supplemental alkalinity should be reviewed and would most likely be needed if alum addition to the primary or secondary clarifiers alone were considered but may not be needed in the two point scenario due to the lower depletion rate noted. A review of influent wastewater alkalinity characteristics as well as bench scale testing of alum dosage requirements as part of a detailed design would help determine the need for supplemental alkalinity addition for pH control. At the time of evaluating a phosphorus removal system for Wadena, consideration should be given to determining the need for different chemical requirements to maintain effective overall treatment.

A summary of the preliminary cost analysis for the three phosphorus removal alternatives is presented in Table 5.1.3.5. The table includes capital and O&M costs as well as the present worth of each alternative. The capital costs are presented as September 2004 US dollars and the present

Table 5.3.1.4 - Summary of Plant Modifications and Chemical Requirements and Retrofit Needs for Phosphorus Removal Alternatives
Wadena WWTF

Operating Condition	Units	EBPR Only	Alum Addition Primary Clarifier	Alum Addition Secondary Clarifier	2 Pt. Alum Addition Primary & Secondary
Effluent P	mg/L	5.80	0.5 to1.0	0.5 to1.0	0.5 to1.0
Chemical Addition	lb/d	0	1020 (alum)	910 (alum)	600 (alum)
Alkalinity Depleted	mg/L	0	104	93	61
Equipment Requirements	NA	None, won't work w/o extra carbon	Chem Feed Pumps & Chem Storage	Chem Feed Pumps & Chem Storage	Chem Feed Pumps & Chem Storage
Primary Sludge Production	lb/d	1030	1460	1090	1230
Secondary Sludge Production	lb/d	300	140	300	240
Chemical Sludge Production	lb/d	0	230	300	180
Total Sludge Production	lb/d	1330	1830	1690	1650

worth costs are based on the annual O&M costs over a 20 year operating period at an interest rate of 5%. The costs were rounded to the nearest $1,000. Two-point chemical addition to the primary and secondary clarifiers is the most cost effective choice for implementation at the Wadena plant.

Additional options that Wadena might consider for addressing their phosphorus discharge limitations are source control and phosphorus trading. Based on MPCA phosphorus strategy guidelines, Wadena should investigate source control as a means of reducing phosphorus levels in their discharge. Although their influent phosphorus level of 6.9 mg/L does not indicate a large

Table 5.3.1.5 – Preliminary Cost Estimates for Retrofit for Phosphorus Removal
With Different Process Options
Wadena WWTF

Cost Factors	Alum Addition Primary Clarifier	Alum Addition Secondary Clarifier	Chemical Addition to Primary and Secondary Clarifiers
Effluent P (mg/L)	0.5 to1.0	0.5 to1.0	0.5 to1.0
Preliminary Capital Costs	$103,000	$103,000	$103,000
Annual O&M Costs	$58,000	$55,000	$40,000
Present Worth	$826,000	$788,000	$601,000

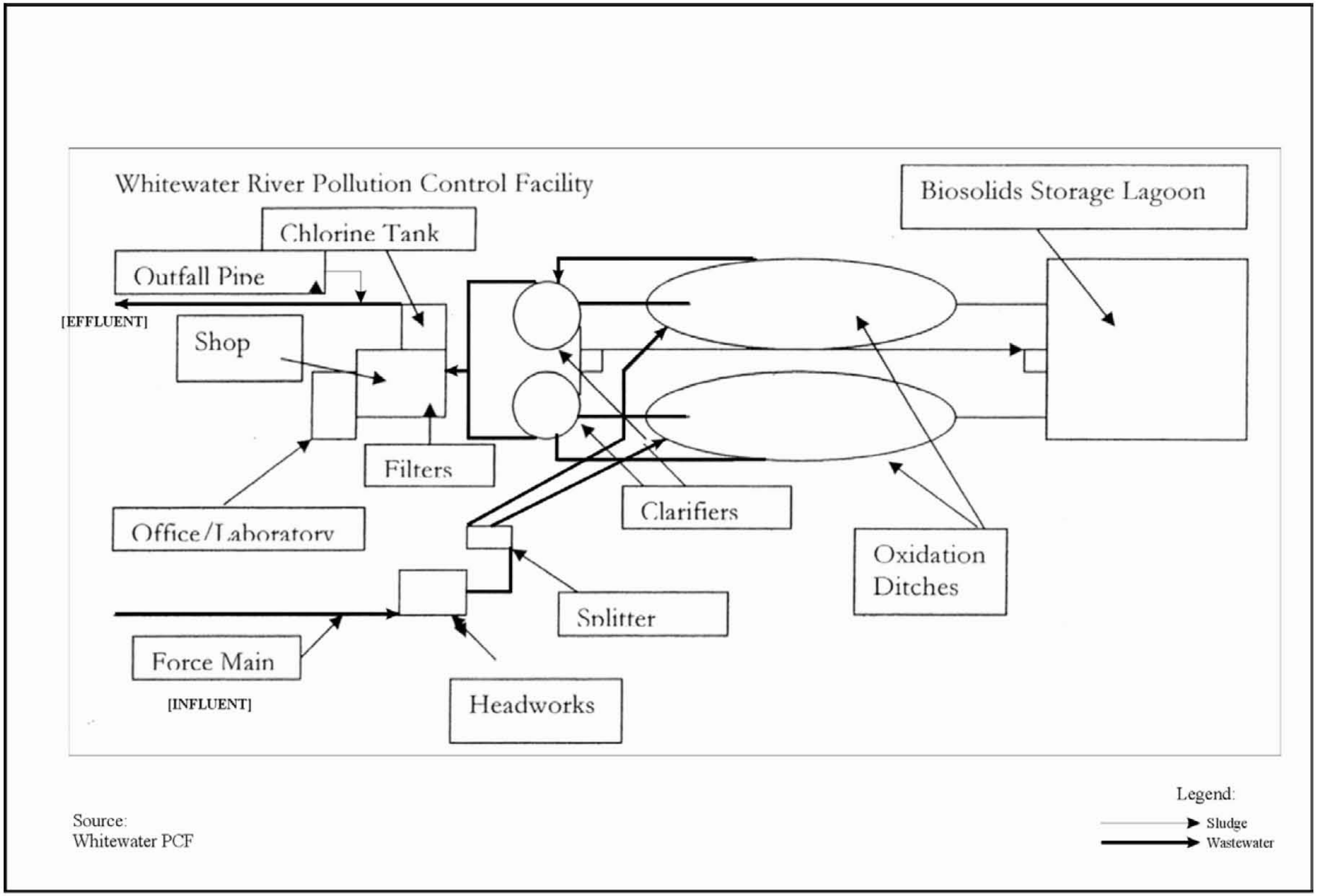
industrial contribution of phosphorus, the plant did identify a fertilizer plant, multiple car washes and a metal finishing shop as industrial inputs. A review and confirmation of their possible industrial sources of phosphorus is prescribed by the MPCA phosphorus management planning guidelines. Phosphorus trading would involve purchasing phosphorus removal capacity from another plant. If excess phosphorus capacity were available from a nearby wastewater treatment plant their excess capacity would be purchased like a commodity.

5.3.2 Whitewater River PCF

The Whitewater River Pollution Control Facility (Whitewater River PCF) serves the cities of Dover, Eyota, and St. Charles and has a design capacity of 0.80 MGD. This system is an extended aeration oxidation ditch plant with polishing filters. The waste sludge is stored in a lagoon on-site and then removed in the spring and fall for agriculture applications. At present there is no effluent discharge permit limit on phosphorus, but nitrification is required to produce a low ammonia concentration and the effluent $CBOD_5$ concentration limit is very stringent at 5.0 mg/L.

5.3.2.1 Plant Description and Performance

A process flow diagram for the wastewater treatment process and sludge handling is presented in Figure 5.3.2.1. Preliminary treatment consists of mechanically cleaned bar screens and grit removal. Following pretreatment the wastewater is split between two (2) oxidation ditch tanks,



Source:
Whitewater PCF

Figure 5.3.2.1 – Schematic Process Flow Diagram, Whitewater River PCF

with each one equipped with 2-60 Hp brush rotor aerators. Each ditch is about 180 ft. by 70 ft. with a relatively shallow liquid depth at 6.25 ft. The working volume for each ditch is 0.598 MG.

The mixed liquor from the oxidation ditch is directed to two (2) 52-ft diameter secondary clarifiers with a depth of 12 ft. At the average design condition the overflow rate is 188 gpd/ft^2. This relatively conservative overflow rate provides protection against high peak flows that can occur at the facility in wet weather. The settled secondary sludge from each clarifier is returned to the oxidation ditch associated with each treatment train. The waste activated sludge is pumped to the sludge holding lagoon and thickened. Supernatant from the lagoon is returned to the aeration tanks.

Three dual media (anthracite/sand) polishing filters are used to remove suspended solids from the clarifier effluent prior to disinfection in a chlorine contact tank and discharge. With two of the three filters in operation the hydraulic application rate is 2.45 gpm/ft^2, which is an acceptable range for this type of filtration. The filters are of a metal tank design and are in need of repair or replacement. The filtered effluent is chlorinated and dechlorinated prior to discharging into the South Fork of the Whitewater River. A photo of the Whitewater facility is shown in Figures 5.3.2.2.

Influent and effluent plant data were collected and reviewed to develop raw wastewater characteristics for the phosphorus removal analysis and to observe the present plant performance. Influent wastewater characteristics are summarized in Table 5.3.2.1 for the period of September 2002 through August 2003. These data represent the monthly average values for flow, and CBOD$_5$, TSS, and TP concentrations. The facility receives a significant industrial wastewater contribution from North Star Foods, which accounts for about 33% of the influent BOD and 45% of the influent phosphorus load. The average influent BOD concentration (463 mg/L) is high for a domestic wastewater and the influent BOD/P ratio is also high at a value of 46.3. The higher influent BOD/P ratio favors a higher P removal efficiency by an EBPR process.

Table 5.3.2.1 - Monthly Average Raw Wastewater Characteristics
Whitewater River PCF

Flow (MGD)	CBOD$_5$ (mg/L)	TSS (mg/L)	TKN (mg/L)	TP (mg/L)	BOD/P
0.66	463	344	NA	10.0	46.3

NA – Not Applicable

There was a significant variation in the influent wastewater strength based on monthly average data. For January, the influent CBOD$_5$ concentration was 690 mg/L, while it was as low as 312 mg/L for May. These were likely due to load variations from the industrial wastewater. Fortunately for a EBPR process the influent BOD/P ratio increased with higher influent

Figure 5.3.2.2 - Two Oxidation Ditches and Covered Secondary Clarifier, Whitewater River PCF

$CBOD_5$concentrations. The highest BOD/P ratio was 68, which was in January at the highest influent $CBOD_5$ concentration.

The monthly average effluent concentrations for one year from September 2002 through August 2003 were used to develop an annual average effluent concentration value for key parameters, and these results are summarized on Table 5.3.2.2 below. The table also includes discharge permit requirements and percent removals for $CBOD_5$, TSS, and phosphorus. The plant presently does not have an effluent limit for phosphorus, but it is monitored. The plant is operating well within the permit limits of 5 mg/L monthly averages for $CBOD_5$ and the lowest value for NH_3-N of 1.3 mg/L in the summer months. The plant achieved about 99% removal of $CBOD_5$ and TSS, with average effluent concentrations of 2.7 mg/L and 5.0 mg/L, respectively. Phosphorus removal averaged 33%, which is typical of activated sludge processes without EBPR treatment or chemical addition. The average effluent P concentration was 7.0 mg/L.

Table 5.3.2.2 – Monthly Average Treatment Performance Summary
September 2002 – August 2003
Whitewater River PCF

	Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)
Average Performance	0.66	2.7	5.0	0.29	7.0
Permit Requirements	0.80	5.0	30	1.3	monitor
Percent Removal	--	99.4%	98.5%	NA	33%

See Appendix 2.3.2 for detailed monthly plant data analysis
NA – Not available

5.3.2.2 Design Basis for Modifications for Phosphorus Removal

The influent wastewater characteristics used to evaluate phosphorus removal alternatives for the Whitewater PCF were based on the annual average data and are summarized in Table 5.3.2.3. The influent $CBOD_5$, TSS, and TP concentrations were taken from the 2002-2003 average monthly influent data summary. Without influent wastewater characterization, as would be done for a final design analysis for a given wastewater treatment system, values for two key design parameters, the influent TKN concentration and percent soluble BOD (sBOD), had to be assumed. A TKN concentration of 45 mg/L was assumed based on the fact that the influent appears to be a strong domestic wastewater. A slightly above average percent soluble BOD concentration of 40% was assumed was in view of the significant industrial wastewater contribution the WWTP influent and the high BOD/P ratio measured. Again it should be stressed that an actual engineering analysis and design would include a wastewater characterization study that would determine the influent rbCOD among other factors. The rbCOD content is also some fraction of the influent sBOD concentration. For these analysis, it was assumed that 70% of the influent sBOD was available to the bacteria as truly dissolved organic matter or rbCOD. The design temperature was 10°C.

Table 5.3.2.3 - Process Design Basis Used for Evaluation of Phosphorus Removal Alternatives
Whitewater River PCF

Flow (MGD)	$CBOD_5$ (mg/L)	Percent sBOD	TSS (mg/L)	TKN (mg/L)	TP (mg/L)
0.66	463	40	344	45.0	10.0

Process Step	Dimensions	Design Loading	Comment
Oxidation ditch	2 - 0.598 MG	SRT > 25 days	Can be used to accomplish nitrogen removal within ditch operation
Secondary Clarifiers	2 - 52 ft diameter	200 gpd/ft^2	Can accept chemical addition Conservative loadings improves efficiency
Polishing Filters	3 - 12 ft diameter,	2.5 gpm/ft^2 with 2 operating	Effluent polishing of solids improves P removal

See Appendix 2.3.2 for summary of the design basis

Phosphorus loads from recycle streams must be considered when developing designs for phosphorus removal alternatives. A recycle flow would occur from the sludge storage lagoon since it is used for solids thickening as well as storing the sludge prior to land application. The recycle flow rate is based on the assumption that the waste activated sludge solids are thickened from 0.8% to 6% solids content in the storage lagoon. There are times when the lagoon sludge is greater than 6% requiring the addition of final effluent to dilute the sludge for pumping. The phosphorus content of this return flow is based on the assumption that 20% of the phosphorus removed by an EBPR process is released and returned with the lagoon overflow. For chemical phosphorus removal no phosphorus release would be expected.

Dimensions and loading rates for the existing liquid unit processes at the design flows and loadings are also summarized in Table 5.3.2.3. The table shows the units available for a retrofit to phosphorus removal and indicates if excess capacities exist. For all of the Whitewater phosphorus removal design alternatives, the phosphorus removal efficiency is favored by the conservative secondary clarification loading at the plant and the use of polishing filters. By removing solids to very low concentrations in the polishing filters the effluent phosphorus concentration associated with effluent TSS is minimized.

The oxidation ditch has sufficient volume so that it can be operated to accomplish a significant amount of nitrate removal and thus minimize the amount of nitrate entering the anaerobic contact zone of the EBPR process. The phosphorus removal efficiency of an EBPR process is improved when less nitrate or oxygen enters the anaerobic contact zone. For the retrofit evaluation, the design considered the amount of ditch volume needed to accomplish nitrification. The amount of nitrate removal was calculated based on the excess volume that could be operated under anoxic conditions. To accomplish this, the oxidation ditch would have to be operated with dissolved oxygen (DO) control so that oxygen can be depleted at some point in the channel downstream from the aeration zone to create anoxic zones for nitrate reduction. This type of operation is common for oxidation ditch systems.

The aeration tank capacity and operating SRT possible for the existing system is a function of the influent BOD concentration, the solids yield assumptions, and the MLSS concentration for the system. In the design alternative analysis MLSS concentration of 3500 mg/L was assumed. This is a common MLSS concentration used for oxidation ditch operations, and can be expected in view of the secondary clarifier capacity and the good settling characteristics that would result from the EBPR process.

5.3.2.3 Evaluation of Phosphorus Removal Alternatives

Phosphorus removal alternatives evaluated for the Whitewater River PCF involved two basic approaches. The first is using the oxidation ditch with EBPR-only, EBPR with chemical addition, and chemical addition only. For the EBPR alternative it is necessary to add an external anaerobic contact tank because the ditch operation with the recirculating channel flow must remain in place.

The second approach that was evaluated was shown in Figure 4.2(f) in Section 4 for oxidation ditch alternatives. In this case, no external tank is added; instead, the oxidation ditch is converted to an A^2O process for biological phosphorus and nitrogen removal. This type of modification is only feasible if sufficient tank capacity exists for the design flows used. For the Whitewater evaluation there was not sufficient tank capacity for conversion to the A^2O process at the design flow of 0.80 MGD but it was possible at a flow rate of 0.70 MGD.

The effluent P concentration goal in all cases was between 0.80 and 1.0 mg/L to meet the less than 1.0 mg/L effluent permit goal. For the alternative with chemical addition only, chemical was added to the influent of the oxidation ditch at a dose that would accomplish 50 to 60% phosphorus removal such that the alum dose was close to stoichiometric requirements (1.0 mole Al/mole P) for phosphorus precipitation. The alternative evaluation process included developing conceptual designs followed by preliminary cost estimates for the viable alternatives. The conceptual designs included determining the activated sludge aeration volume requirements to meet the effluent treatment, the activated sludge tank volume needed for the anaerobic contact zone of the EBPR process, the amount of daily sludge production in both the primary and secondary processes, the amount chemical sludge produced, the amount of phosphorus removed by biomass growth and by the EBPR process, the phosphorus content of the waste sludge, and the fate of solids in solids processing and the characteristics of return flows.

The results of the alternative analyses are summarized in Table 5.3.2.4 in terms of the effluent phosphorus concentration, chemical requirements (alum and alkalinity), sludge production and additional facility modification requirements (tankage, mixers and piping) for each of the alternatives that were considered. For the alternatives with chemical treatment, an effluent phosphorus concentration of 0.50 to 1.0 mg/L can be normally expected under varying wastewater load conditions. For EBPR-only, the design analysis predicted an effluent P concentration of 1.2 mg/L, which does not meet the target limit. Thus, the EBPR process alternative would require chemical polishing. This is shown as the second alternative in Table 5.3.2.4. The amount of alum addition would be 120 lb/day to meet the effluent P concentration requirement. Both of these alternatives would require the construction of an external anaerobic contact tank before the oxidation ditch. Preliminary cost estimates are shown for the cost of this tank, but actual site conditions and final engineering designs would be needed to finalize such costs.

The third alternative, chemical addition only, is based on adding alum to the influent of the oxidation ditch and to the flow to the secondary clarifiers. This two-point addition design would minimize chemical requirements. Compared to the second alternative the chemical requirements are much higher, by a factor of 10. Of significance is the alkalinity depletion of about 85 mg/L at this chemical dose. Because nitrification is required to meet the discharge permit limit, the alternative analysis includes a cost for adding alkalinity to the influent to offset this alkalinity depletion. This is needed to maintain the proper pH for nitrification.

Table 5.3.2.4 - Summary of Plant Modifications and Chemical Requirements and Plant Retrofit Needs for Phosphorus Removal Alternatives
Whitewater River PCF

Option	Units	EBPR Only	EBPR+ Chemical Addition to Secondary Clarifiers	Chemical Addition to Influent and Secondary Clarifiers
Effluent P	mg/L	1.2 to 2.0	0.5 to 1.0	0.5 to 1.0
Chemical Addition	lb/d	0	130	1300
Additional Sludge Production(1)	lb/d	0	27	248
Alkalinity Used	mg/L	0	8	85
Increased Tank Volume	MG	0.034	0.034	0

(1)Alum Sludge

The preliminary cost analysis for the different alternatives is summarized in Table 5.3.2.5. The costs were rounded to the nearest $1,000. The capital cost includes the cost for the chemical feed system, the cost for adding an external anaerobic contact zone, and the cost for converting the oxidation ditch to the A^2O process. The present worth cost includes the capital costs plus the present worth value of the operating costs. The present worth calculation is based on a 5% interest rate and a 20 year pay back period, with no escalation in the operations costs, such as that for chemicals and sludge disposal. For the chemical treatment-only system the major costs are associated with chemical requirements, labor and the disposal/reuse of the additional sludge production.

The EBPR process alone cannot meet the effluent discharge requirements but is shown in Table 5.3.2.5 for comparison to the EBPR plus polishing chemicals alternative. For the lowest present worth costs, the preferred option would be EBPR plus polishing chemicals. This option would have a capital cost that is about three times that for the chemical-only alternative. However its operating costs would be about one fifth of that for the chemical treatment-only approach.

In summary, phosphorus removal for the Whitewater River PCF oxidation process can be done more cost-effectively by installing an external anaerobic contact tank with polishing chemicals. Final engineering design analysis based on site conditions is necessary to determine the feasibility and cost-effectiveness of this approach. The high influent BOD/P ratio for the Whitewater River PCF is favorable for the EBPR process, such that only a small chemical dose is needed to meet the effluent discharge requirement. For oxidation ditch processes with much lower influent BOD/P ratios, the cost analysis would become more favorable for chemical treatment-only as the influent BOD/P ratio decreases.

Table 5.3.2.5 - Preliminary Cost Estimates for Retrofit for Phosphorus Removal With Different Process Options Whitewater River PCF

Parameter	EBPR Only	EBPR + polishing chemicals	Chemicals only, to influent and secondary clarifiers
Preliminary Capital Costs			
EBPR Tank	$260,000	$260,000	-
Aeration Tank Modification	0	0	-
Chemical System	0	129,000[(1)]	$129,000
Total Capital Costs	$260,000	$389,000	$129,000
Daily Operating Costs, $/d			
Alum	0	13	130
Alkalinity	0	0	0
Sludge disposal	0	2	22
EBPR operation	19	19	0
Annual Labor Cost – Chemicals Only	0	0	$13,000
Total Annual Operating Costs	$6,800	$13,000	$69,000
Present Worth Operating Costs 5% @ 20 years	$85,000	$156,000	$860,000
Total Present Worth	$345,000	$545,000	$989,000

(1)Back up chemical feed for EBPR system

The cost analysis, process analysis, and existing plant operation clearly showed that the EBPR would be the preferred alternative, but its implementation would require chemical treatment capability on-site. There would be times where a relatively small amount of chemical addition in the primary treatment step or secondary clarifier step would be required. For the analysis with EBPR plus chemicals, the alum dose would be only 27 mg/L. For this analysis many factors favored the use of the EBPR process (with a small amount of chemical addition) in spite of the fact that the wastewater was relatively weak and had a very modest BOD/P ratio of about 28.

The preliminary cost analysis also shows the potential cost savings for a discharge phosphorus concentration greater than 1 mg/L. For the two EBPR alternatives presented in Table 5.3.2.5, the present worth analysis shows that for the EBPR system to meet a target concentration of 1 mg/L, the cost would be 1.6 times greater than for an EBPR system (EBPR only) meeting a phosphorus discharge of 2 mg/L.

5.4 HIGH PURITY OXYGEN (HPO)

Two high purity oxygen (HPO) biological processes were evaluated for phosphorus removal. The following summarizes the evaluation of the 6 MGD Moorhead WWTF and the 19.1 MGD Rochester WRP.

5.4.1 Moorhead WWTF

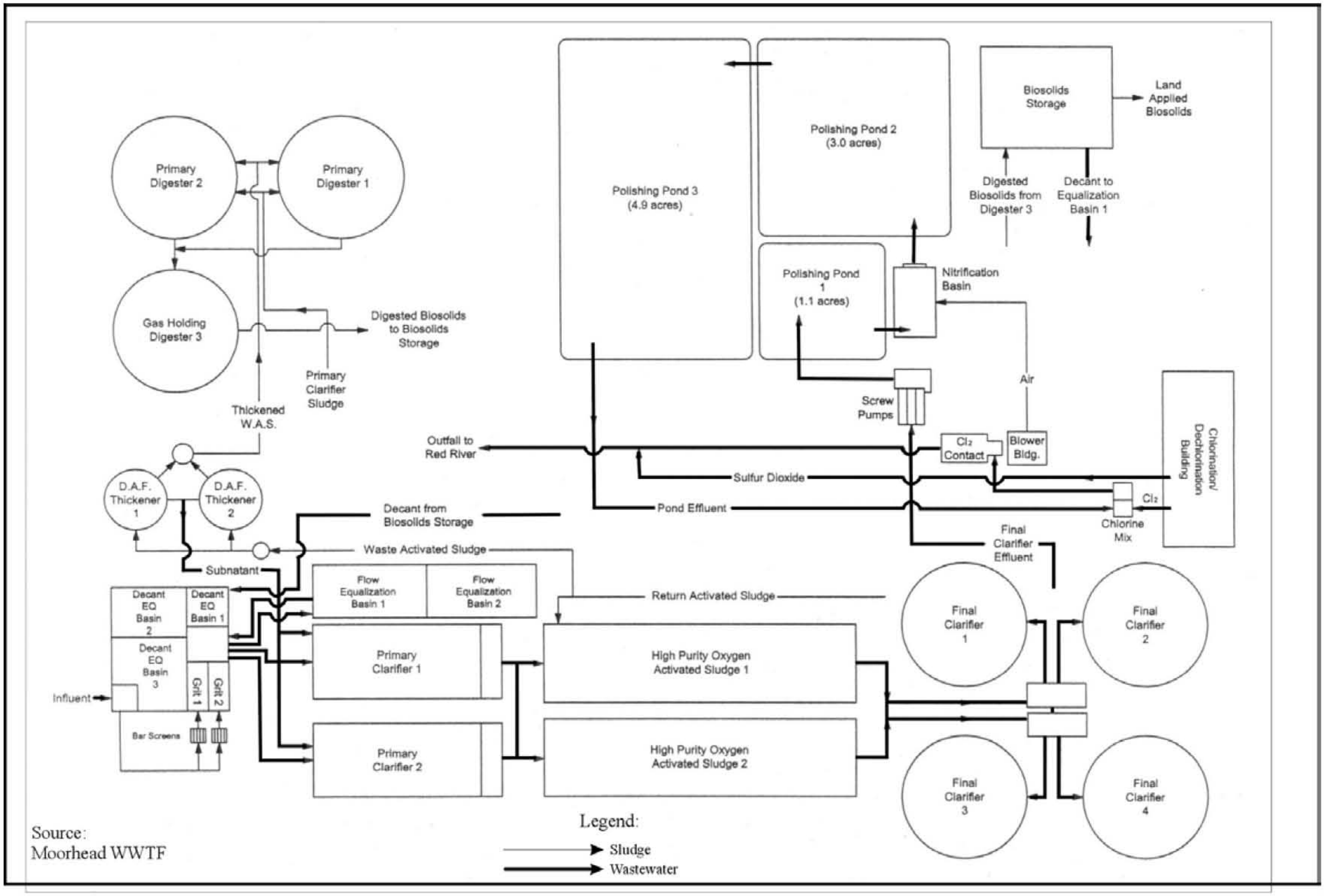
The Moorhead Wastewater Treatment Facility (Moorhead WWTF) is a 6.0 MGD activated sludge plant providing advanced secondary treatment using the high purity oxygen activated sludge process with advanced treatment for nitrogen removal and final effluent polishing. The existing plant was put into service in 1983. The major unit operations are configured in two parallel trains and include: screening; aerated grit chambers; rectangular traveling bridge primary clarifiers; high purity oxygen activated sludge biological treatment; secondary clarification; tertiary effluent polishing ponds which include a moving bed biofilm reactor nitrification cell; and effluent chlorination and dechlorination. Plant effluent is continuously discharged to the Red River of the North.

5.4.1.1 Plant Description and Performance

A process flow diagram for the Moorhead WWTF is presented in Figure 5.4.1.1. The plant influent is pretreated by screening through 3/4 inch automatically cleaned bar screens followed by grit removal. The pretreated effluent flows into two rectangular (90 ft x 36 ft) primary clarifiers operating at an overflow rate of 925 gpd/ft^2. The primary effluent enters the high purity oxygen activated sludge process which consists of two 510,000-gallon tanks providing 4 hours of hydraulic detention time at the plant design flow of 6.0 MGD. The plants pure oxygen system consists of enclosed staged aeration basins and mechanical mixers. Oxygen is generated on site by a UNOX^{TM} pressure swing adsorption (PSA) system. Dissolved oxygen levels in the aeration tanks are maintained between 8 and 9 mg/L. The mixed liquor from the activated sludge process is clarified in four 60-ft diameter clarifiers operating at an overflow rate of 530 gpd/ft^2.

Secondary effluent then passes through three tertiary effluent polishing ponds with a total volume of 26.2 million gallons providing a hydraulic detention time of 4.3 days. The nitrification cell is an aerated, mixed-bed suspended biological reactor containing 33,000 cubic feet of Hydroxyl Systems^{TM} plastic media that was retrofitted into the lead polishing basin to promote nitrification. The final effluent is disinfected by chlorination followed by dechlorination before discharge to the Red River of the North. The plant also has new flow equalization facilities which will be used to moderate nitrogen loads returned from the biosolids storage tank.

The plant receives two continuous industrial loads and three intermittent industrial loads. Continuous dischargers include Busch Agricultural Resources (Malting) and Pactiv Corporation



Source:
Moorhead WWTF

Figure 5.4.1.1 - Schematic Process Flow Diagram, Moorhead WWTF

(paper); intermittent dischargers include American Crystal Sugar Technical Services Center (sugar beets), the Clay County Landfill (leachate) and the Burlington Northern Santa Fe (BNSF) Railroad (railway yard). The plant also receives septage from private haulers. The plant has industrial pretreatment permit agreements with all major industrial discharges. The permits require periodic sampling and analysis for a number of parameters including flow, pH, $CBOD_5$, TSS, total phosphorus, and nitrogen compounds (industry specific) at frequencies varying from semi-annual to bi-monthly depending on the industry and its discharge rate (with daily flow monitoring and at least weekly pH monitoring). A review of the pretreatment permits indicates that Crystal Sugar is permitted to discharge up to 720,000 gallons of wastewater per day and the railway yard is permitted to discharge up to a daily average of 2,000 gpd of high strength sugar waste ($CBOD_5$ - 250,000 mg/L discharge maximum and TSS 25,000 mg/L monthly average). Based on data on the industrial discharges, it appears that the industrial waste accounts for about 50% of the influent BOD and that a significant portion of the industrial wastewater BOD is soluble.

Sludge handling facilities include two primary anaerobic digesters in parallel followed by a gas holding digester. Primary sludge is pumped directly to the primary digesters while the waste activated sludge is thickened using dissolved air flotation (DAF) units prior to digestion in the primary digesters. Digested solids is pumped to the biosolids storage tank. Biosolids are thickened to 4% in the storage tank. DAF subnatant is returned to the head of the primary clarifiers while the biosolids storage tank supernatant is returned to a series of equalization basins prior to mixing with aerated grit chamber effluent and DAF subnatant upstream of the primaries. Supernatant from the biosolids storage tank contains approximately 109 mg/L TP and 40 mg/L of soluble P. Biosolids are disposed of by land application. Figure 5.4.1.2 presents a photograph of the mixed-bed suspended media nitrification system and Figure 5.4.1.3 presents a photograph of a final clarifier.

Influent and effluent plant data were reviewed to develop the raw wastewater and final effluent characteristics to evaluate the plant performance, and for the phosphorus removal analysis. Influent wastewater and final effluent characteristics are summarized on Tables 5.4.1.1 and 5.4.1.2 for the period of January through December 2002. These data represent the annual monthly average flow, $CBOD_5$, TSS, ammonia nitrogen (NH_4-N), and total phosphorus. The total plant influent characteristics are as follows:

Table 5.4.1.1 - Monthly Average Raw Wastewater Characteristics
Moorhead WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)	BOD/P
3.9	267	187	20	6.3	42

Figure 5.4.1.2 - Photograph of the Mixed-bed Suspended Media Nitrification System, Moorhead WWTF

Figure 5.4.1.3 - Photograph of a Final Clarifier, Moorhead WWTF

The influent did not show any large variations in wastewater characteristics. The $CBOD_5$ concentration averaged 267 mg/L and ranged from 219 mg/L to 310 mg/L; TSS averaged 187 mg/L and ranged between 162 and 206 mg/L; and the phosphorus concentration averaged 6.3 mg/L and ranged between 4.9 and 7.2 mg/L.

The plant effluent characteristics from 2002 are summarized on Table 5.4.1.2 along with permit requirements and percent removals for $CBOD_5$, TSS, ammonia nitrogen and phosphorus. The plant is operating within permit limits of 12 mg/L monthly average for $CBOD_5$ and 30 mg/L for TSS. The plant has both a discharge concentration limit of 19 mg/L for ammonia nitrogen and a discharge ammonia load limit in kilograms per day (Kg/d) based on river flow. The permit limits are presented in Table 5.4.1.2. Phosphorus monitoring is also required.

The plant achieved 96% or greater removal of $CBOD_5$ and TSS with average effluent concentrations of 8.7 mg/L and 7.0 mg/L, respectively. The monthly average discharge concentration for ammonia was 19 mg/L. The data presented in Table 5.4.1.2 are from January-December 2002. In 2003, a nitrification system was placed in operation in the lead polishing basin. Based on information from the plant, the treatment system is achieving nitrification. The average phosphorus discharge level was 3.9 mg/L. This suggests that there is currently a phosphorus reduction of 2.4 mg/L, which is likely related to existing particulate and biological removals.

Table 5.4.1.2 - Monthly Average Treatment Performance Summary
January – December 2002
Moorhead WWTF

	Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)
Average Performance	3.9	8.7	7.0	19(1)	3.9
Permit Requirements	6	12 (85% Rem.)	30 (80% Rem.)	19(2)	Monitor Only
% Removal	NA	96.7%	96.1%	3.2%	38.3%

(1) The 2002 plant data do not show plant nitrification as treatment scheme went on line in 2003.

(2) Permit limit of 19 mg/L is for the June-September period and includes the following:

- NH_4-N permit discharge load is 647 Kg/d for river flow greater than 50 cfs.

NH_4-N permit discharge load is 108 Kg/d for river flow less than 50 cfs.

5.4.1.2 Design Basis for Modifications for Phosphorus Removal

The influent wastewater characteristics used to evaluate phosphorus removal alternatives for the Moorhead WWTF were based on the annual average data and are summarized in Table 5.4.1.3. The influent BOD, TSS, and TP concentrations were taken from the 2002-2003 average monthly influent data summary. Without influent wastewater characterization, as would be done for a final design analysis for a given wastewater treatment system, the value for the percent soluble BOD, which is a key parameter that affects EBPR process efficiency, had to be assumed. A TKN concentration of 30 mg/L was also assumed based on the reported average influent ammonia concentration of 20 mg/L. However, since nitrification is not required in this design, this is not an important parameter.

A high average percent soluble BOD concentration of 60% was assumed based on the significant industrial wastewater contribution and its soluble nature as well as the high influent BOD/P ratio measured. Again it should be stressed that an actual engineering analysis and design would include a wastewater characterization study that would determine the influent rbCOD among other factors. The rbCOD content is also some fraction of the influent sBOD concentration. For the alternative analyses completed here, it was assumed that 70% of the influent sBOD was available to the bacteria as truly dissolved organic matter or rbCOD. The design temperature was 14°C.

Phosphorus loads from recycle streams must be considered when developing designs for phosphorus removal alternatives. A recycle flow would occur from the biosolids storage tank since it is used for solids thickening of digested sludge as well as storing the sludge prior to land application. The recycle flow rate was based on the assumption that digested sludge solids are thickened from 2% to 4% solids content in the biosolids storage tank. The phosphorus content of this return flow was based on the assumption that 30% of the phosphorus removed by an EBPR process was released and returned in the digester sludge. For alternatives with chemical treatment only the digester return flow was assumed to contain 110 mg/L total P and 40 mg/L soluble P. For a final engineering analysis and design, measurements would be needed to verify this design parameter. For chemical phosphorus removal no phosphorus release in the lagoon would be expected.

Dimensions and loading rates for the existing liquid unit processes at the design flows and loadings are also summarized in Table 5.4.1.3. The table shows the units available for a retrofit to phosphorus removal and indicates important issues related to the retrofit design alternatives. The design SRT for the aeration tank was set at 4.5 days, which provides a sufficient SRT for EBPR and is at an SRT which is low enough to prevent nitrification for the design temperature of 14°C. Besides the low temperature at this SRT, nitrification is also inhibited by low pH in the high purity oxygen system. For alternatives with chemical treatment only, a lower SRT can be used with the pure oxygen activated sludge system. A SRT of 3.0 to 3.5 days is more typical in this case. For the EBPR alternative design SRT and design loading, the MLSS concentrations in the aeration tanks were in the range of 3,000 mg/L. That suggests that the pure oxygen activated sludge tank has only a small amount of excess capacity, as MLSS concentrations in the range of 3,000-3,500 mg/L are feasible. However, even if excess tankage were available, an external EBPR anaerobic contact tank is still required, because it is not realistic to modify the enclosed pure oxygen basins, with their requirements of staged reactors in series for efficient oxygen utilization.

Some factors appear to favor more efficient phosphorus removal with an EBPR process. These are 1) the wastewater has a relatively high BOD/P ratio and appears to have a high soluble BOD content, 2) dissolved air flotation is used for waste activated sludge thickening which minimizes phosphorus release and recycle back to the treatment system from activated sludge thickening, and 3) the short SRT used for the activated sludge improves EBPR efficiency.

Table 5.4.1.3 - Process Design Basis Used for Evaluation of Phosphorus Removal Alternatives
Moorhead WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	Percent sBOD	TSS (mg/L)	TKN (mg/L)	TP (mg/L)
6.0	265	60	187	30	6.3

Process Step	Dimensions	Design Loading	Comment
Primary Clarifiers	2 rectangular at 3240 ft^2 each	925 gpd/ft^2	Can accept chemicals
Pure Oxygen Aeration Basins	2 @ 0.510 Mgal	HRT=4.1 hrs SRT= 4.5 days	External anaerobic tank for EBPR alternative
Secondary Clarifiers	4– 60 ft diameter (2826 ft^2 each)	530 gpd/ft^2	Can accept chemical addition

See Appendix 2.4.1 for summary of the design basis

5.4.1.3 Evaluation of Phosphorus Removal Alternatives

Feasible phosphorus removal alternatives for the Moorhead WWTF were EBPR-only, chemical addition to the primary and secondary clarifiers (two-point addition) and chemical addition to the secondary clarifier only. For the EBPR alternative it is necessary to add an external anaerobic contact tank. The design analysis showed that EBPR alone could meet the effluent phosphorus concentration requirements, and thus EBPR plus chemical addition was not necessary. However, chemical addition feed equipment was added as a backup to the EBPR system.

The effluent P concentration goal in all cases was between 0.80 and 1.0 mg/L to meet the less than 1.0 mg/L effluent goal. For the alternative with chemical addition only, chemical was added to the primary clarifier at a dose that would accomplish 50 to 60% phosphorus removal such that the alum dose was close to stoichiometric requirements (1.0 mole Al/mole P) for phosphorus precipitation.

The alternative evaluation process included developing conceptual designs followed by preliminary cost estimates for the viable alternatives. The conceptual designs included determining the activated sludge aeration volume requirements to meet the effluent treatment, the activated sludge tank volume needed for the anaerobic contact zone of the EBPR process, the amount of daily sludge production in both the primary and secondary processes, the amount chemical sludge produced, the amount of phosphorus removed by biomass growth and by the EBPR process, the phosphorus content the waste sludge, and the fate of solids in solids processing and the characteristics of return flows.

The results of the alternative analyses are summarized in Table 5.4.1.4 in terms of the effluent phosphorus concentration, chemical requirements (alum and alkalinity), sludge production and additional facility modification requirements (tankage, mixers and piping) for each of the alternatives considered. For the alternatives with chemical treatment, an effluent phosphorus concentration of 0.50 to 1.0 mg/L can be normally expected under varying wastewater load conditions. For EBPR-only, the design analysis predicted an effluent soluble P concentration of 0.30 mg/L, which is sufficient to expect good reliability for meeting the permit limit. Thus, the EBPR process alternative should not require chemical polishing, but chemical feed equipment is included in the design for back up.

The major impacts of the retrofit for the phosphorus removal alternatives are shown in Table 5.4.1.4. As shown for other retrofit examples in this project, the two-point chemical addition approach, with chemical addition in both the primary and secondary treatment steps in contrast to adding chemicals only for polishing in the secondary step, results in a lower chemical requirement and less sludge production. Thus two-point chemical addition is preferred to adding chemicals only to the secondary treatment. As will be shown in Table 5.4.1.4 the comparison between the EBPR process alternative and the two-point chemical addition alternative is related to trade-offs of operating and capital costs.

Table 5.4.1.4 - Summary of Plant Modifications and Chemical Requirements and Plant Retrofit Needs for Phosphorus Removal Alternatives
Moorhead WWTP

Option	Units	EBPR Only	Chemical Addition to Primary and Secondary Clarifiers	Chemical Addition to Secondary Clarifiers
Effluent P	mg/L	0.50 to 1.0	0.5 to 1.0	0.5 to 1.0
Chemical Addition	lb/d	0	6130	8490
Additional Sludge Production(1)	lb/d	0	1200	1730
Alkalinity Used	mg/L	0	55	76
Increased Tank Volume	MG	0.25	0	0

(1)Alum Sludge

Preliminary cost estimates are presented in Table 5.4.1.5 for the different options. The costs were rounded to the nearest $1,000. The results in Table 5.4.1.5 below show that on a present worth basis, the EBPR process alone is the preferred alternative. Its present worth value was 50% of that for the least cost chemical treatment alternative. However, the capital investment cost was about 6 times higher at $1,176,000 versus $180,000 for chemical treatment only. The annual operating cost for labor, electrical, chemicals and sludge disposal for the EBPR process would be about 13% of that for chemical treatment based on this preliminary analysis. More detailed site information and engineering would be required to develop a more exact comparison and further indicate the potential reliability of the EBPR process. Wastewater characterization would be an important part of further analysis. Based on information provided for the industrial wastewater inputs, a high soluble BOD was assumed for the influent wastewater, which is favorable for the EBPR process.

Table 5.4.1.5 - Preliminary Cost Estimates for Retrofit for Phosphorus Removal
with Different Process Options
Moorhead WWTF

Parameter	EBPR Only	Chemical Addition to Primary and Secondary Clarifiers	Chemical Addition to Secondary Clarifiers
Preliminary Capital Costs			
EBPR Tank	$996,000	-	-
Aeration Tank Modification	0	-	-
Chemical System	$180,000[(1)]	$180,000	$180,000
Total Capital Costs	$1,176,000	$180,000	$180,000
Daily Operating Costs, $/d			
Alum	0	490	680
Alkalinity	0	0	0
Sludge disposal	0	108	158
EBPR operation	81	0	0
Annual Labor Cost – Chemicals Only	0	$13,000	$15,000
Total Annual Operating Costs	$30,000	$232,000	$321,000
Present Worth Operating Costs 5% @ 20 years	$374,000	$2,892,000	$4,001,000
Total Present Worth	$1,550,000	$3,072,000	$4,181,000

(1)Back up chemical feed system for EBPR process

For this analysis many factors favored the use of the EBPR process. The key favorable factors are listed as follows:

- dissolved air flotation thickening of the waste activated sludge;

- a relative short design SRT can be used; and
- a high influent BOD/P ratio.

5.4.2 Rochester WRP

The Rochester Water Reclamation Plant (Rochester WRP) is a 19.1 MGD high purity oxygen activated sludge plant. The current plant was built in 1983. It includes mechanically cleaned bar screens, grit removal, primary clarification, two-stage high purity activated sludge with secondary clarification after each stage, chlorination and dechlorination. The plant also operates an equalization tank that receives screened and pumped influent and can transfer this wastewater back to the screens or to the chlorine contact tank. The plant currently removes phosphorus by two-point chemical addition using ferric chloride in the primary clarifiers and alum in the secondary clarifiers.

5.4.2.1 Plant Description and Performance

A process flow diagram for the wastewater treatment facility is presented in Figure 5.4.2.1. The plant influent is first pretreated by in an aerated grit tank then passes through two 68 ft x 154 ft rectangular primary clarifiers which operate at a hydraulic overflow rate of 910 gpd/sf at design flow. Ferric chloride is added to the primary influent for phosphorus removal. The primary effluent then flows into the first stage high purity oxygen activated sludge system consisting of two 594,000 gallon aeration tanks operating at a hydraulic detention time of 1.4 hours at design flow. The mixed liquor then passes through four 90 ft diameter intermediate clarifiers operating at an overflow rate of 750 gpd/sf. The clarified effluent from the first aeration system stage passes into the second stage system which is operated at a hydraulic detention time of 3.5 hours at design flow. Alum is added to the second stage effluent prior to entering four 120 ft diameter final clarifiers operating at an overflow rate of 422 gpd/sf at design flow. The plant operates the first stage activated sludge system at a 1 day solids retention time (SRT) at a MLSS of 2,100 mg/L, and the second stage is operating at a SRT of approximately 40 days at a MLSS of 4,300 mg/L. The F/M for the system is approximately 2.0 lb $CBOD_5$/lb MLSS in the first stage and less than 0.1 $CBOD_5$/lb MLSS in the second stage. The clarified effluent is chlorinated for disinfection and dechlorinated before discharge to the Zumbro River. Figure 5.4.2.2 presents an aerial photo of the Rochester WRP. Figure 5.4.2.3 presents a photo of one of the four final clarifiers.

Waste-activated sludge is thickened by centrifuges before blending with primary sludge in the anaerobic digesters. Digested sludge is also thickened by a gravity belt before going to sludge storage and land application. Gravity belt filtrate is discharged to the grit tanks and averages approximately 0.5 MGD and contains 800 mg/L $CBOD_5$, 300 mg/L ammonia-nitrogen and 65 mg/L phosphorus.

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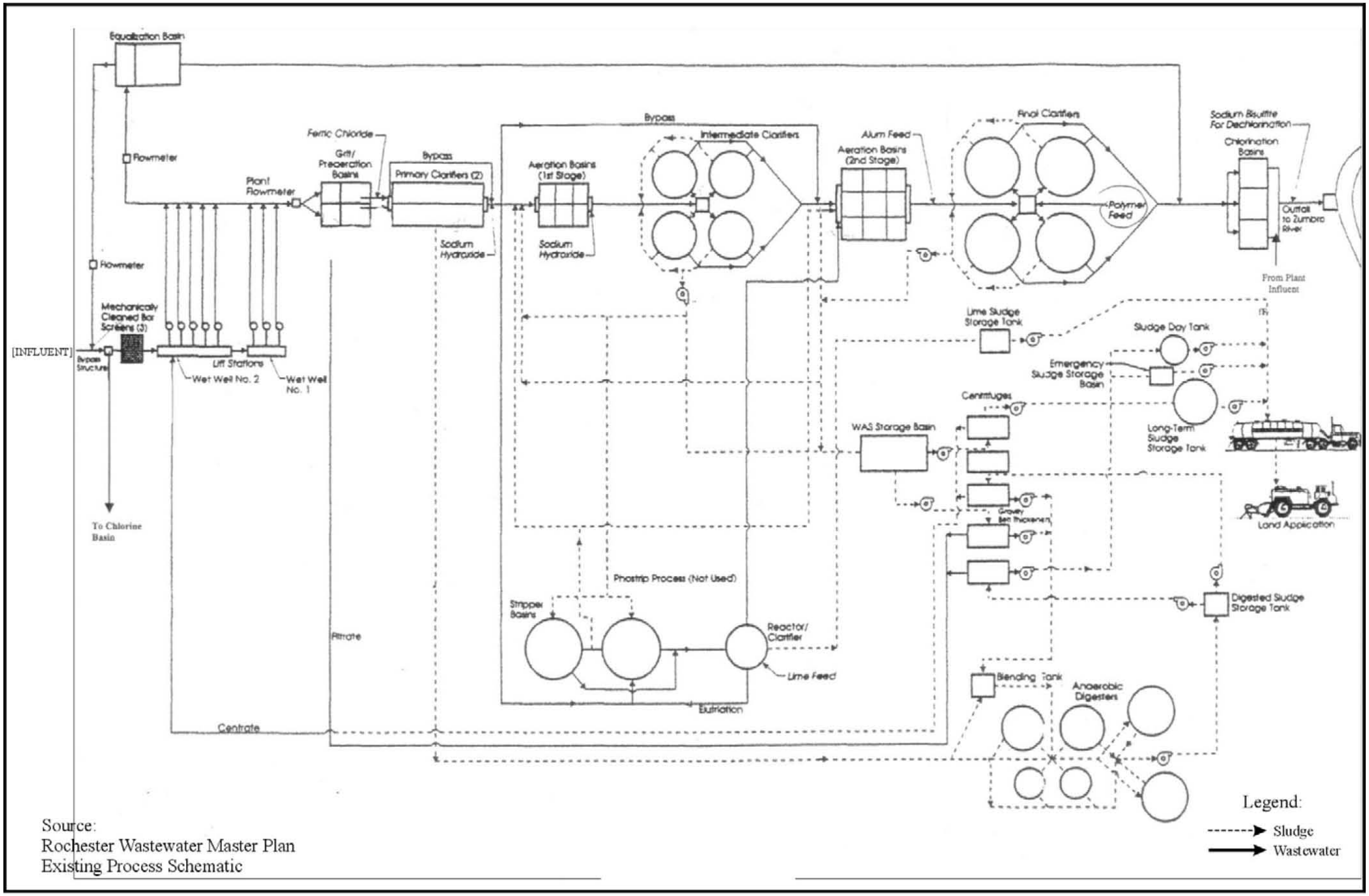


Source:
Rochester Wastewater Master Plan
Existing Process Schematic

Figure 5.4.2.1 - Schematic Process Flow Diagram, Rochester WRP

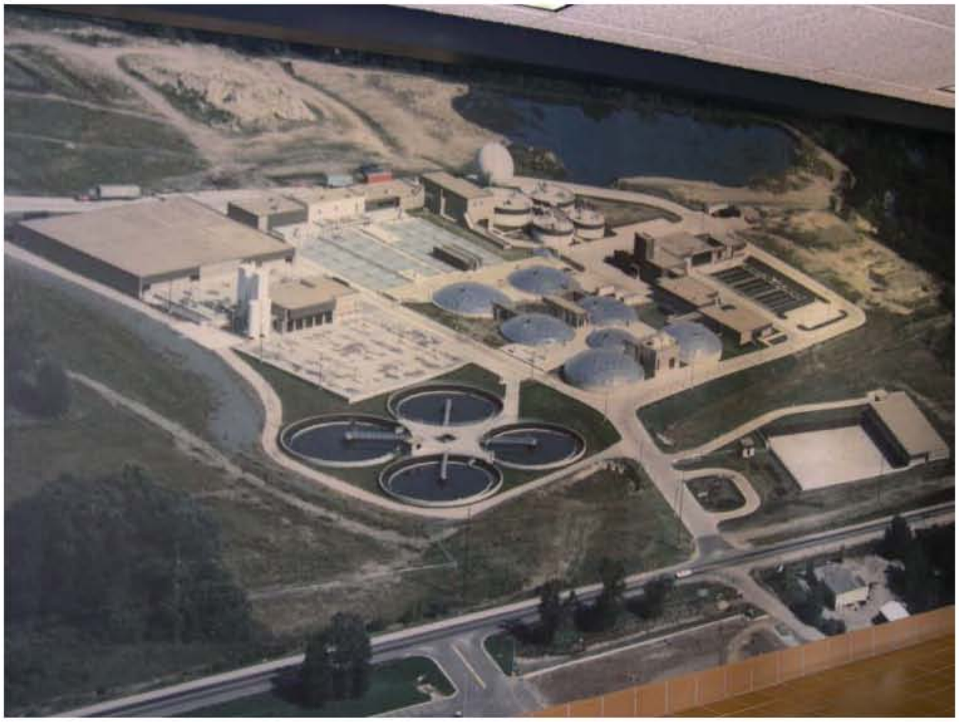


Figure 5.4.2.2 - Plant Aerial View, Rochester WRP

Figure 5.4.2.3 - Final Clarifier, Rochester WRP

Approximately 30% to 40% of the plant organic load is from industrial sources with most of this related to food processing industries. The plant has a pretreatment coordinator and approximately 15 years ago the plant instituted a phosphorus surcharge to control phosphorus loads from dairy operations.

Influent and effluent plant data were reviewed to develop the raw wastewater and final effluent characteristics to evaluate the plant performance, and for the phosphorus removal analysis Influent wastewater and final effluent characteristics are summarized on Tables 5.4.2.1 and 5.4.2.2 for the period of January through December 2003. These data represent the annual monthly average flow, $CBOD_5$, TSS, ammonia nitrogen (NH_4-N), and total phosphorus. The total plant influent characteristics are as follows:

Table 5.4.2.1 - Monthly Average Raw Wastewater Characteristics
Rochester WRP

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)	$CBOD_5$/P
13.2	376	212	21.9	9.4	40

The influent did not show any large variations in wastewater characteristics. The $CBOD_5$ concentration averaged 376 mg/L and ranged from 307 mg/L to 470 mg/L; TSS averaged 212 mg/L and ranged between 177 and 287 mg/L; and the phosphorus concentration averaged 9.4 mg/L and ranged between 8.2 and 10.3 MG/L.

The plant effluent characteristics are summarized on Table 5.4.2.2 along with permit requirements for $CBOD_5$, TSS, ammonia nitrogen and phosphorus. The plant is operating within permit limits of 14 mg/L monthly average for $CBOD_5$, 20 mg/L for TSS, 1.6 mg/L for ammonia-nitrogen and 1 mg/L for phosphorus. The plant achieved 99% or greater removal of $CBOD_5$ and ammonia-nitrogen, 97.1% for TSS and 91.7% for phosphorus. The plant is also achieving a high degree of phosphorus removal by two-point chemical addition (ferric chloride to the primaries and alum to the final clarifiers).

Table 5.4.2.2 – Monthly Average Treatment Performance Summary
January 2003 – December 2003
Rochester WRP

	Flow (MGD)	$CBOD_5$ (MG/l)	Tss (MG/l)	NH_4-N (mg/L)	TP (mg/L)
Average Performance	13.2	3.2	6.0	0.14	0.77
Permit Requirements	19.1	14	20	1.6	1
Observed Percent Removal	-	99.1%	97.1%	99.5%	91.7%

5.4.2.2 Design Basis for Modifications for Phosphorus Removal

The plant already provides a high degree of phosphorus removal as required by its permit; however, a phosphorus removal analysis was conducted to compare the current practice of two point chemical addition to other options. This was intended to provide the plant with comparisons of the other alternatives and also serve as an example for large plants. The Rochester WRP was the largest plant that participated in the program.

The evaluation of phosphorus removal alternatives was based on the design basis presented in Table 5.4.2.3. The table summarizes flow and wastewater characteristics, and design parameters used to assess the phosphorus removal alternatives. It also summarizes the facilities available to be retrofitted for phosphorus removal if it is determined that excess capacity exists.

Table 5.4.2.3 – Process Design Basis Used for Evaluation of Phosphorus Removal Alternatives
Rochester WRP

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH4-N (mg/L)	TP (mg/L)	rbCOD
19.1	376	212	21.9	9.4	109

Process Step	Dimensions	Design Loading	Comment
Primary Clarifiers	2 – 68 ft x 154 ft, 10 ft deep	910 gpd/sf	Can accept chemical addition
Aeration Tanks Stage 1 Stage 2	2 – 594,000 gallon 15 ft deep 3- 930,000 gallon 15 ft deep	First stage F/M approx. 2.0. Overall F/M approx. 0.3 to 0.4 lb $CBOD_5$/lb MLSS	Cannot be retrofitted for EPBR because it is configured as a high purity oxygen system
Intermediate Clarifiers (Stage 1)	2 – 90 ft diameter, 10 and 14 ft deep	750 gpd/sf	Can accept chemical addition
Final Clarifiers (Stage 2)	4 – 120 ft diameter, 14 ft deep	422 gpd/sf	Can accept chemical addition

See Appendix 2.4.2 for summary of the design basis.

This design basis was used to assess the feasibility of biological and chemical phosphorus removal as well as a combination of both processes. The design basis includes contributions of plant return streams. The only significant return stream at the Rochester WRP is from the gravity belt filtrate as discussed previously. The design low temperature was taken to be 12°C and was used in developing biological treatment kinetics.

The Rochester wastewater is a relatively high strength wastewater due to the contribution of industrial wastes. The influent wastewater contains 376 mg/L $CBOD_5$, 9.4 mg/L phosphorus and exhibits a $CBOD_5$ to P ratio of 40:1 which would support EPBR without having to add an additional carbon source. At design loadings (based on design flow and observed wastewater characteristics), the F/M of the activated sludge system is approximately 2.0 lb $CBOD_5$/lb MLSS at the observed average MLSS concentration of 2,100 mg/L in the first stage and less than 0.1 lb $CBOD_5$/lb MLSS for the second stage operating at an average MLSS of 4,300 mg/L. The second stage F/M is low enough to support nitrification, which, based on plant operating data, regularly occurs year-round. The configuration of the aeration system as a high purity oxygen activated sludge treatment system does not allow it to be retrofitted for EBPR because the retrofit would require segregating the tanks to provide for anaerobic and anoxic zones.

Certain wastewater characteristics, removal rates and treatment plant operating conditions were also either assumed or based on plant operating data for this analysis. Biodegradable COD (discussed in Section 4) was assumed to be equal to 1.6 times the $CBOD_5$ and readily biodegradable COD (rbCOD), that fraction of the COD that is easily converted to volatile fatty acids (VFA) which are used by EBPR bacteria, was assumed to be 30% of the biodegradable COD. The estimated rbCOD concentration was estimated to be 109 mg/L. Also, baseline phosphorus removal by primary treatment (without chemical addition) was assumed to be 10% of the influent concentration.

5.4.2.3 Evaluation of Phosphorus Removal Alternatives

The evaluation of phosphorus removal alternatives included developing conceptual designs and preliminary cost estimates for the viable alternatives. EBPR, chemical addition and a combination of both processes were considered for the Rochester WRP.

A summary of the alternatives analysis is presented in Table 5.4.2.4. The table summarizes the potential effluent phosphorus concentration, chemical requirements (alum and alkalinity), sludge production and facility requirements (chemical storage and piping) for each alternative.

Table 5.4.2.4 - Summary of Plant Modifications and Chemical Requirements and Retrofit Needs for Phosphorus Removal Alternatives
Rochester WRP

Option	Units	EBPR Only	EBPR with Chemical Addition to Secondary Clarifiers	Chemical Addition to Primary and Secondary Clarifiers	Chemical Addition to Secondary Clarifiers
Effluent P	mg/L	1.0 to 2.0	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0
Chemical Addition	lb/d	0	12,200	33,500	51,700
Additional Sludge Production	lb/d	0	3,800	8,900	16,600
Alkalinity Added	lb/d	0	5,500	15,100	23,200
Increased Tank Volume	MG	3.2	3.2	0	0
Additional Mixers	Yes/No	Yes	Yes	No	No
Pumps/Piping	Yes/No	Yes	Yes	No	No

Using the design approach for denitrification and EPBR presented in Section 4, there is not enough aeration tank capacity or COD to support EBPR. Approximately 3.2 MG of tankage would be needed to provide for EBPR. The new tanks would be segregated with baffles for denitrification and EPBR and would require mixers to keep the MLSS in suspension while under anoxic and anaerobic conditions. EBPR would be able to reduce phosphorus concentrations to approximately 1 to 2 mg/L which is higher than the effluent quality target of 1 mg/L. Therefore, additional treatment by chemical addition would be needed to ensure compliance with the target. EBPR with chemical addition would be able to consistently reduce effluent phosphorus to 0.5 to 1.0 mg/L. In addition to the tank requirements for EBPR alone, the combined process would require the addition of 12,200 pounds per day of alum and produce an additional 3,800 pounds per day of alum sludge. The addition of alum to the secondary clarifiers would also consume 5,500 pounds per day of alkalinity which translates to 35 mg/L as $CaCO_3$. The existing buffering capacity of the wastewater may be able to satisfy this requirement without the need for alkalinity addition.

Chemical addition alone is also capable of meeting the effluent target of 1 mg/L. Chemical addition can be accomplished as single or two-point addition which is the process the plant currently uses. Single point chemical addition should only consider chemical addition to the secondary clarifiers to ensure that there is sufficient phosphorus available for biological treatment. Single point addition to the primary clarifiers could result in creating a phosphorus deficient condition in the activated sludge process if the phosphorus removal process is not carefully maintained. Two-point addition is practiced in the primary and secondary clarifiers. Chemical addition to the primary clarifiers has the added benefit of enhancing $CBOD_5$ and TSS removals; however, as previously stated, the process should be closely maintained to ensure that there is sufficient residual phosphorus in the primary effluent for biological treatment. For the Rochester WRP, chemical addition to the primary clarifiers was targeted for removal of approximately 6 mg/L phosphorus and approximately 0.6 mg/L is removed by nutrient uptake in the MLSS. This left approximately 3 mg/L after biological treatment, which was the basis for chemical addition to the secondary clarifiers.

Two-point chemical addition would result an additional 8,900 pounds per day of sludge, require 33,500 pounds per day of alum and consume 15,100 pounds per day of alkalinity (92 mg/L). Single point chemical addition to the secondary clarifiers would produce 16,600 pounds per day of sludge, require 51,700 pounds per day of alum and consume 23,200 pounds per day of alkalinity (142 mg/L).

The total sludge production estimate for two-point chemical addition is 68,500 pounds per day or 3600 pounds per MG of wastewater treated. The plant currently produces approximately 42,400 pounds per day of sludge (before anaerobic digestion) at an average daily flow 13.7 MGD. This translated to a sludge production of 3100 pounds per MG of wastewater treated which is reasonably close to the calculated sludge production of 3600 pounds per MG before anaerobic digestion.

Preliminary budgetary cost estimates were developed based on the information presented in Section 4 and are presented in Table 5.4.2.5. The capital costs are presented as September 2004 US dollars and the present worth costs are based on the annual O&M costs over a 20 year operating period at an interest rate of 5%. The costs were rounded to the nearest $1,000.

Table 5.4.2.5 – Preliminary Cost Estimates for Retrofit for Phosphorus Removal
with Different Process Options
Rochester WRP

Cost Factors	EBPR Only	EBPR with Chemical Addition to Secondary Clarifiers	Chemical Addition to Primary and Secondary Clarifiers	Chemical Addition to Secondary Clarifiers
Effluent P	1.0 to 2.0	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0
Preliminary Capital Cost				
EPBR	$3,750,000	$3,750,000	$0	$0
Chemical Treatment	$0	$320,000	$320,000	$320,000
Total	$3,750,000	$4,070,000	$320,000	$320,000
Daily Operating Costs $/d				
EBPR	450	450	0	0
Alum	0	1200	3400	5200
Alkalinity	0	0	0	2100
Sludge Disposal	0	340	800	1500
Annual Labor Cost – Chemicals Only	0	0	$71,000	$104,000
Total Annual Operating Cost	$165,000	$734,000	$1,586,000	$3,297,000
Present Worth Operating Cost	$2,056,000	$9,147,000	$19,765,000	$41,088,000
Total Present Worth	$5,806,000	$13,217,000	$20,085,000	$41,408,000

The capital cost associated with constructing new anoxic/anaerobic tanks with baffles and mixers for EBPR would be $3,750,000, the O&M cost would be $165,000 per year with a present worth cost of $5,806,000. This is the least expensive alternative; however, EPBR cannot be relied on to consistently meet a 1 mg/L phosphorus level. The capital cost for a combined process of EPBR with chemical treatment would be $4,070,000 with an O&M cost of $734,000 and a present worth cost of $13,217,000.

Two-point chemical treatment to the primary and secondary clarifiers is the least expensive chemical treatment alternative and can achieve the effluent 1 mg/L target at a capital cost of $320,000, and an O&M cost of $1,586,000 per year and a present worth cost of $20,085,000. The highest cost alternative is single-point chemical addition to the secondary clarifiers with a capital cost of $320,000, an annual O&M cost of $3,297,000 and a present worth cost of $41,408,000.

Based on an annual O&M cost savings of $852,000 ($1,586,000 - $734,000) for EBPR with chemical addition polishing versus two-point chemical addition, the payback period for the capital investment of the EPBR chemical addition system would be 4.8 years. EBPR with chemical treatment polishing in the secondary clarifiers is the most cost effective alternative for phosphorus removal for the Rochester WRP; although it would require the most significant capital expenditure of all the alternatives considered.

These results suggest that the EBPR process with chemical addition would be the most cost-effective alternative for phosphorus removal. However, the high capital costs may discourage its application for a plant that already has successful chemical treatment. The treatment plant already has the necessary chemical storage and feed equipment and has a long and successful history of chemical treatment for phosphorus removal. Therefore, Rochester should continue with its current phosphorus treatment process and a no further action designation was assigned to the plant.

The preliminary cost analysis presented in Table 5.4.2.5 indicates a potential cost saving for a phosphorus discharge concentration greater than 1.0 mg/L. The two EBPR alternatives represent two discharge scenarios, EBPR only with discharge limit of 2 mg/L and the EBPR process with chemicals for a discharge target concentration of 1 mg/L. To meet a phosphorus discharge target of 1.0 mg/L, the treatment cost would be 2.3 times greater than a treatment system discharging 2 mg/L phosphorus.

5.5 TRICKLING FILTER

The 1.64 MGD Detroit Lakes Wastewater Treatment Facility (Detroit Lakes WWTF) was the only trickling filter system evaluated for phosphorus removal. The following presents a summary of the analysis.

5.5.1 Detroit Lakes WWTF

The Detroit Lakes WWTF is a 1.64 MGD facility providing screening, grit removal, primary clarification and secondary treatment using trickling filters, secondary and tertiary clarifiers and disinfection. The effluent flows through an aerated pond and then to a stabilization pond. The plant has three means of final effluent discharge, a direct discharge to Lake St. Clair, spray irrigation and infiltration. Spray irrigation and infiltration are permitted seasonally while direct discharge is employed during the winter months. The plant also provides chemical precipitation of phosphorus prior to direct discharge to Lake St. Clair to meet an effluent phosphorus limit of 1 mg/L. The original plant was constructed in the 1930's. During the last plant upgrade in 1997 a new pump station, bar screen, grit removal, primary clarifiers, digesters and standby power generation were constructed.

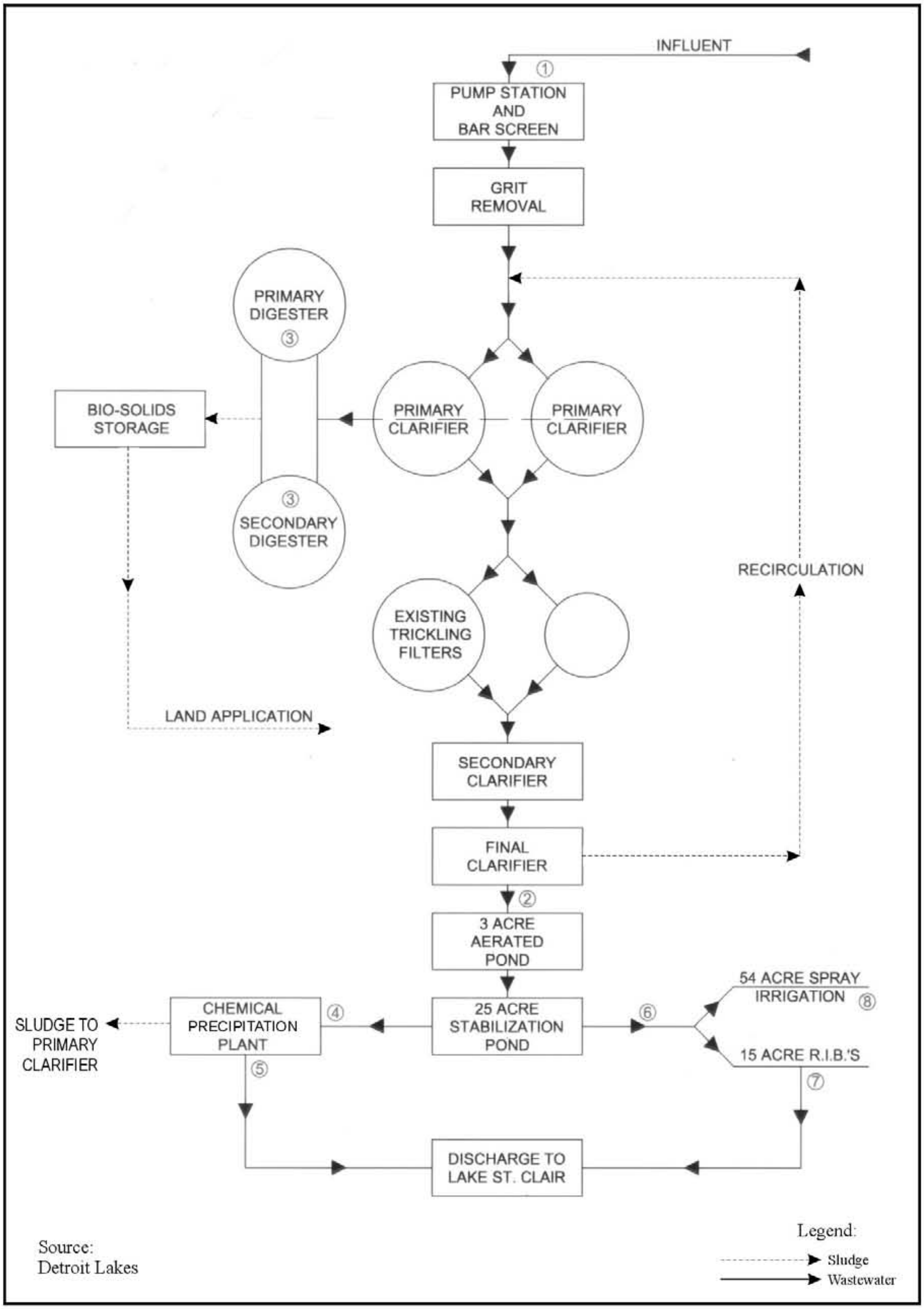
5.5.1.1 Plant Description and Performance

The plant has a design flow of 1.64 MGD (average annual flow) and a design average wet weather flow of 3.0 MGD. Figure 5.5.1.1 presents a process flow diagram for the Detroit Lakes WWTF plant. The bar screens have 3/8 inch spacing. They are automatically cleaned and have a manual bypass. There are two 40 ft diameter primary clarifiers that operate at an overflow rate of 650 gpd/sf at design flow. The plant has two trickling filters. One is a rock filter 91 ft in diameter and the other is a clay tile filter 50 ft in diameter. The secondary clarifier is rectangular (40 ft x 60 ft) and operates at an overflow rate of 680 gpd/sf at design flow. The tertiary clarifier is approximately 30 ft x 50 ft and operates at an overflow rate of approximately 1100 gpd/sf. This clarifier does not have a means of sludge withdrawal and is taken out of service for cleaning annually.

The effluent is discharged to a 3 acre aerated pond (4.75 day detention time) followed by a 25 acre stabilization pond (18 day detention time). The floating aerator in the aerated pond was damaged by lightning and has not been replaced. Effluent disposal is handled in one of three ways spray irrigation, groundwater discharge through infiltration basins and chemical precipitation followed by direct discharge to a 20 acre peat bog area located in the northeast end of St. Clair Lake.

Chemical precipitation for phosphorus removal is accomplished in the Chemical Precipitation Plant, which consists of two treatment trains each consisting of chemical delivery equipment, a flocculating clarifier and dual media gravity filtration. Ferrous sulfate is used for phosphorus precipitation. A small amount of polymer is also used to enhance plant performance. The Chemical Precipitation Plant operates during the colder winter months (January through April) when spray irrigation and infiltration are prohibited. During the warmer months, the plant is shut down and effluent is disposed via infiltration basins and spray irrigation. The stabilization pond is maintained at low operating depths from the middle of spring through early winter. During the winter months, the plant allows the stabilization pond volume to rise, which reduces the daily volume requiring chemical treatment.

Use of the infiltration basins is permitted from April 15 through December 31. The infiltration basins consist of 19 cells totaling 21.75 floor acres. All but one cell have underdrains for capture and removal of groundwater. The underdrains are typically left open unless the effluent exceeds a phosphorus concentration of 1 mg/L, in which case the drains are closed to prevent discharge to the lake. Discharge to the spray irrigation fields is permitted from May 15 through October 31. Crops are grown and harvested from both the spray irrigation fields and the infiltration basins. The plant harvests three crops per season with the product going to local farmers. Figure 5.5.1.2 is a view of the 91 ft diameter rock trickling filter. Figure 5.5.1.3 is a view of the spray fields in operation.



Source:
Detroit Lakes

Figure 5.5.1.1 - Schematic Process Flow Diagram, Detroit Lakes WWTF

Figure 5.5.1.2 - Trickling Filter, Detroit Lakes WWTF

Figure 5.5.1.3 - Spray Irrigation Fields, Detroit Lakes WWTF

Sludge handling facilities include a 289,000 gallon primary digester, a 360,000 gallon secondary anaerobic digester and a 160,000 gallon bio-solids storage tank. Digester decant is returned to the head of the plant. The Chemical Precipitation Plant sludge is also currently returned to the head of the plant by tanker truck. In the future, the chemical sludge will be returned to the head of the plant by way of a gravity sewer. Class B biosolids are land applied in the spring and fall.

Treatment plant performance is monitored by measuring wastewater flows and sampling all the wastewater streams including plant influent, secondary treatment effluent, Chemical Precipitation Plant effluent and spray irrigation effluent. Influent and effluent plant data were reviewed to develop the raw wastewater and final effluent characteristics to evaluate the plant performance, and for the phosphorus removal analysis. The various wastewater streams are analyzed for $CBOD_5$, TSS and total phosphorus. Influent wastewater and final effluent characteristics are summarized on Tables 5.5.1.1 and 5.5.1.2 for the period of October 2002 through September 2003. These data represent the monthly average results for these parameters analyzed and the plant flow. The total plant influent characteristics are as follows:

Table 5.5.1.1 - Monthly Average Raw Wastewater Characteristics
Detroit Lakes WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	TP (mg/L)
1.06	191	168	5.5

The variability of influent $CBOD_5$, TSS and total phosphorus was not very significant. $CBOD_5$ averaged 191 mg/L and ranged from 154 mg/L to 240 mg/L. TSS averaged 168 mg/L with a range of 118 and 206 mg/L. Total phosphorus averaged 5.5 mg/L and ranged from 4.3 to 7.1 mg/L.

Table 5.5.1.2 - Monthly Average Treatment Performance Summary
October 2002 – September 2003 with Supplemental
Data From January – March 2002
Detroit Lakes WWTF

	Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	TP (mg/L)
Average Effluent	1.06	24.1	22.5	4.3
Secondary Treat. Spray Irrigation	0.91	8.1	27.8	2.95
Chemical Precipitation	0.94	12.5	8.9	0.37
Infiltration	0.99	ND	ND	ND
Observed Removal	NR	87 to 96%	83 to 95 %	22 to 93%
Permit Requirement				
Spray Irrigation	130 MG/yr	NR	NR	NR
Chemical Precipitation	Monitor	20	20	1
Infiltration	Monitor	20	20	1

See Appendix 2.5.1 for detailed monthly plant data analysis
NR – Not Required
ND – No Data

The only industrial dischargers to the plant are two metal finishers (aluminum diecasting and metal stamping), a local airport which is home to a number of corporate jets, a nursing home, and the local hospital. All are believed to be minor contributors to the plant's daily load.

The plant's effluent characteristics are summarized on Table 5.5.1.2 along with permit requirements. The limits and effluent concentrations are shown for each discharge location. The plant is operating within permit limits of 20 mg/L monthly averages for $CBOD_5$ and 20 mg/L for TSS. During periods when the Chemical Precipitation Plant is in service, the effluent requirement of 1 mg/L phosphorus is achieved.

5.5.1.2 Design Basis for Modifications for Phosphorus Removal

The evaluation of phosphorus removal alternatives was based on the design basis presented in Table 5.5.1.3. The table summarizes flow and wastewater characteristics used to assess the phosphorus removal alternatives. It also summarizes the facilities available to be retrofitted for phosphorus removal if it is determined that excess capacity exists. The Chemical Precipitation Plant already accomplishes effective phosphorus removal when it is in service and the clarifiers and ponds can be considered for chemical treatment retrofit, especially when a two-point application process is considered.

Table 5.5.1.3 – Process Design Basis Used for Evaluation of
Phosphorus Removal Alternatives
Detroit Lakes WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	TP (mg/L)
1.64	190	168	5.5

Process Step	Dimensions	Design Loading	Comment
Primary Clarifier	2 – 40 ft dia, 10 ft deep	650 gpd/sf	Can accept chemical addition
Trickling Filters	1 – 91 ft dia rock 1- 50 ft dia tile		No opportunity for EBPR
Secondary Clarifier	1 – 40 x 60	680 gpd/sf	Can accept chemical addition
Tertiary Clarifier	1 – 30 x 50	1100 gpd/sf	Not suitable for chemical addition because no means of sludge withdrawal
Aerated Pond	3 acre		Can accept chemical addition
Stabilization Pond	25 acre		Can accept chemical addition
Chemical Precipitation Plant	Chemical addition, flocculation clarifiers, Dual media filters		Uses ferrous sulfate to precipitate phosphorus to less than 1 mg/L
Rapid Infiltration Basin	21.75 acres		Not suitable for chemical addition
Spray irrigation	54 acres		Not suitable for chemical addition

See Appendix 2.5.1 for summary of the design basis.

The design $CBOD_5$ concentration of 320 mg/L (based on the plant's SPDES permit) was used for this analysis along with the observed influent TSS concentration of 168 mg/L and phosphorus concentration of 5.5 mg/L. These concentrations, the design loadings for the clarifiers, and information on the Chemical Precipitation Plant process were used for the phosphorus removal analysis.

5.5.1.3 Evaluation of Phosphorus Removal Alternatives

The Detroit Lakes WWTF plant currently practices chemical phosphorus removal 3 to 4 months per year, as required by the NPDES permit, when the Chemical Precipitation Plant is online and effluent is being directly discharged to Lake St. Clair. During these periods the plant is able to consistently meet the effluent limit of 1 mg/L. In fact the average effluent phosphorus concentration when the Chemical Precipitation Plant is on line is 0.37 mg/L with a range of 0.30 to 0.47 mg/L (see Appendix 2.5.1. Therefore, the plant is already using an appropriate technology for phosphorus removal and no additional action is necessary. The plant would only need to consider other alternatives if it can no longer discharge to the infiltration basins or through spray irrigation.

The only alternatives available to the plant are chemical precipitation based alternatives. EBPR is not a feasible alternative because the secondary treatment system is an attached growth system, which is not conducive to EBPR. The limited use of EBPR for fixed film biological treatment systems is discussed in Section 4. If the plant has to meet a 1 mg/L phosphorus limit continuously, it could do so by keeping the Chemical Precipitation Plant on line at all times or incorporate chemical precipitation into the primary and/or secondary clarifiers. Chemical treatment could also be applied to the aerated and stabilization ponds; however, this is the least attractive of the alternatives since clarifiers with sludge removal are available.

A summary of alum based chemical precipitation alternatives is presented in Table 5.5.1.4. The table summarizes the potential effluent phosphorus concentration, chemical requirements (alum and alkalinity), sludge production and facility requirements (chemical storage and piping) for each alternative.

Chemical addition is capable of meeting the effluent target of 1 mg/L; however it does produce sludge and consumes alkalinity. Chemical addition can be accomplished as single or two-point addition. The process is already successful as a single point addition process at Detroit Lakes WWTF. If chemical precipitation were to be performed at Detroit Lakes WWTF on a full-time basis, the best alternative would be to add chemicals to the primary or secondary clarifiers and use the Chemical Precipitation Plant as a second application point for a two-point addition approach. This would give the plant the alternative of minimizing or eliminating the need to transfer phosphorus sludge to the head of the plant as is currently done.

Table 5.5.1.4 - Summary of Plant Modifications and Chemical Requirements and Retrofit Needs for Phosphorus Removal Alternatives
Detroit Lakes WWTF

Option	Units	Chemical Precipitation Plant (1)	Single-point Chemical Addition	Two-point Chemical Addition
Effluent P	mg/L	0.3 to 0.4	0.5 to 1.0	0.5 to 1.0
Chemical Addition	lb/d	No Data	2800	2000
Additional Sludge Production	lb/d	100 to 400	830	640
Alkalinity Added	lb/d	No Data	1300	900
Chemical Storage	Yes/No	Yes	Yes	Yes
Pumps/Piping	Yes/No	Yes	Yes	Yes

(1) This process is available and is used seasonally by the plant. Values are based on current operation.

Currently, based on plant operating data, biological processes in the trickling filters consume approximately 1.2 mg/L of phosphorus. This nutrient uptake has been taken into account in the analysis of alternatives. Single point addition applied to the primary clarifier, secondary clarifier or the Chemical Precipitation Plant would require removal of approximately 3.5 mg/L of phosphorus. This requires the addition of 2,800 pounds of alum per day. This would produce 830 pounds per day of sludge.

Two-point addition could also be practiced at the Detroit Lakes WWTF plant by applying chemicals to the primary clarifier and Chemical Precipitation Plant or at the secondary clarifier and the Chemical Precipitation Plant. The analysis targeted removal of approximately 2 mg/L of phosphorus in the first application point. After biological treatment, approximately 1.9 mg/L would remain for removal at the second application point. Chemical addition at the Chemical Precipitation Plant was based on an influent phosphorus concentration of 1.9 mg/L. The two-point chemical addition process requires approximately the same quantity of 2,000 pounds per day of alum and will produce approximately 640 pounds per day of sludge. The lower sludge production and chemical requirement for two-point addition is related to the reduced alum requirement in the primary clarifier for two-point addition. Alkalinity consumption would be 1,300 pounds per day for single-point addition and 900 pounds per day for two-point addition, however, the wastewater may have enough buffering capacity to avoid the need to add alkalinity. The consumption would be 92 and 65 mg/L respectively.

Preliminary budgetary cost estimates were developed based on the information presented in Section 4, and are presented in Table 5.5.1.5. The capital costs are presented as September 2004 US dollars and the present worth costs are based on the annual O&M costs over a 20 year operating period at an interest rate of 5%. Costs were rounded to the nearest $1,000. The capital cost for single-point chemical addition would be approximately $140,000 with O&M costs of $284,000 per year which translates to a present worth cost of $3,679,000. The capital cost for two-point chemical addition would also be $140,000 with O&M costs of $204,000 per year and a present worth of $2,682,000. Two-point chemical addition would be the most cost effective alternative.

These results suggest that two-point chemical addition would be the most cost effective alternative for phosphorus removal. However, the plant's current practice of single-point chemical treatment of the polishing pond effluent with the recent addition of continuous chemical sludge return (via new sewer installation) to the head of the plant will essentially achieve the goal. In addition, the treatment plant has a long successful history of seasonal chemical treatment for phosphorus removal. Therefore, Detroit Lakes should continue it's current phosphorus treatment process and a no further action designation was assigned to this plant.

Table 5.5.1.5 – Preliminary Cost Estimates for Retrofit for Phosphorus Removal
with Different Process Options
Detroit Lakes WWTF

Cost Factors	Single-point Chemical Addition	Two-point Chemical Addition
Effluent P (mg/L)	0.5 to 1.0	0.5 to 1.0
Preliminary Capital Cost	$140,000	$140,000
Daily Operating Costs $/d		
EBPR	0	0
Alum	280	200
Alkalinity	380	270
Sludge Disposal	75	58
Annual Labor Cost – Chemicals Only	$15,000	$14,000
Total Annual Operating Cost	$284,000	$204,000
Present Worth Operating Cost	$3,539,000	$2,542,000
Total Present Worth	$3,679,000	$2,682,000

5.6 TRICKLING FILTER/ACTIVATED SLUDGE

Four combined trickling filter and activated sludge treatment systems were evaluated for phosphorus removal. The following summarizes the evaluation of the 7 MGD Faribault WWTF, 3.3 MGD Marshall WWTF, 1.6 MGD Glencoe WWTF, and 2.4 MGD Little Falls WWTF.

5.6.1 Faribault WWTF

The Faribault Wastewater Treatment Facility (Faribault WWTF) is a 7.0 MGD trickling filter/activated sludge facility with significant industrial wastewater loads. It serves a population of about 22,000 people. The trickling filters were installed as roughing towers to remove a portion of the high strength BOD before the activated sludge treatment process. In 1974 the rock media in the two trickling filters was replaced with plastic media, and in 1997 the trickling filters were covered and forced air ventilation was installed. The air is pulled down through the trickling filters from the top and then directed through a granular activated carbon system for odor control. The plant was designed to meet BOD and suspended solids removal treatment standards, and at present no phosphorus standard is in place.

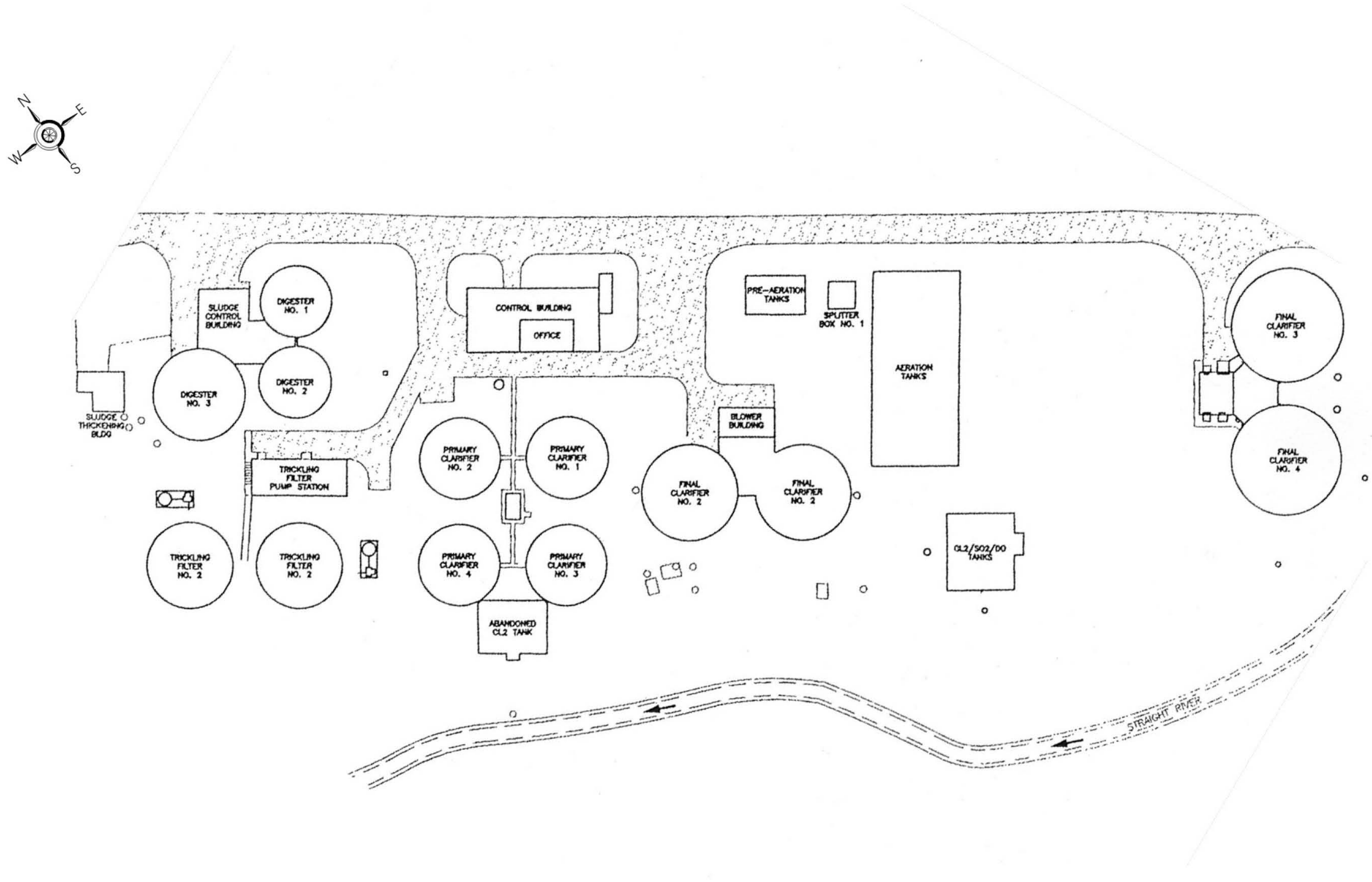
5.6.1.1 Plant Description and Performance

A process flow diagram for the wastewater treatment facility is presented in Figure 5.6.1.1. The plant influent is pretreated by aerated grit removal and screening before flow to the primary treatment area consisting of four 49-ft diameter, 9 ft deep primary clarifiers. The primary effluent is pumped to the two (2) plastic media trickling filters. Each trickling filter tower contains 16 ft. of crossflow plastic media and has a diameter of 62 ft for a total media volume for the two filters of about 96,000 ft^3. There are no intermediate clarifiers and the trickling filter effluent flows to the activated sludge aeration basins. A photo of the trickling filter towers is shown in Figure 5.6.1.2.

There are two activated sludge aeration basins, each with a volume of 0.435 MG to provide a hydraulic retention time on 3.0 hours at the 7.0 MGD design flow. The aeration basins have a depth of 15 ft and in 1997 the aeration system was converted to fine bubble aeration with the installment of ceramic disc diffusers. The aeration tanks have some degree of plug flow with a length to width ratio of about 5:1. A photo of the aeration basin is shown in Figure 5.6.1.3. The activated sludge tanks are typically operated with an MLSS concentration in the range of 2,400 to 3,000 mg/L. In the summer time with warmer temperatures, nitrification generally occurs in the activated sludge process.

Liquid solids separation of the activated sludge mixed liquor is accomplished in the two 1997 secondary clarifiers which are 70 ft-diameter clarifiers with a depth of 14 ft. There are two 1974 clarifiers which are 70 foot diameter tanks with a depth of 11.5 feet. The 1974 clarifiers are used for emergency and only for storage. After chlorine disinfection and dechlorination, the effluent is discharged to the Straight River just prior to the confluence with the Cannon River.

The waste sludge is processed by anaerobic digestion with two heated primary mesophilic digesters followed by a secondary digester that provides sludge storage. The waste activated sludge is thickened in gravity belt thickeners prior to feeding to the digesters. The primary sludge is thickened with the primary clarifiers before transfer to the anaerobic digesters. The volume of the primary digesters is 319,320 gallons each, and the volume of the secondary digester is 537,519 gallons. The waste sludge is not dewatered on-site and is stored in a sludge lagoon before land application.



Source:
Faribault, WWTP

Figure 5.6.1.1 – Schematic Process Flow Diagram, Faribault WWTF

Figure 5.6.1.2 - View of Covered Plastic Media Trickling Filters, Faribault WWTF

Figure 5.6.1.3 - View of Two Parallel Aeration Tanks, Faribault WWTF

The industrial wastewaters are from a food cannery, a turkey processor, blue-cheese manufacturer and a soy protein producer. The industrial wastewater may be able to add about 75% of the influent BOD load to the facility, and the cannery is the largest contributor, accounting for over 75% of the industrial wastewater load. During the plant site visit, it was noted that the turkey processing wastewater is more variable and the facility does not generally discharge on weekends. The cannery also does not discharge on weekends and its wastewater was noted to have a high temperature. No specific data on the amount of phosphorus discharged by the industrial wastewaters were available. It is likely that the industrial wastewater load can be variable with periods of reduced BOD addition.

Influent and effluent plant data were reviewed to evaluate the plant performance and to establish the raw wastewater characteristics for the phosphorus removal analysis. Influent wastewater and final effluent characteristics are summarized on Tables 5.6.1.1 and 5.6.1.2 for the period of September 2002 through July 2003. These data represent the annual monthly average flow, $CBOD_5$, TSS, ammonia nitrogen (NH_4-N), and total phosphorus. The total plant influent characteristics are as follows:

Table 5.6.1.1 - Monthly Average Raw Wastewater Characteristics
Faribault WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)	BOD/P
4.1	345	241	15.0	7.6	46

Of most significance in Table 5.6.1.1 is the relatively low ammonia concentration and high influent BOD/P ratio, as compared to average domestic wastewaters. The average monthly values showed significant variation in the wastewater strength. The highest monthly average $CBOD_5$ concentration was 414 mg/L in July 2003 and the lowest was 258 mg/L in December 2002; TSS averaged 241 mg/L and ranged between 199 and 280 mg/L. The average monthly influent phosphorus concentrations averaged 7.6 mg/L and ranged from 8.5 mg/L for November 2002 to a low of 7.2 mg/L for May 2003. The influent BOD/P ratio also varied widely, but remained above a value of 32. The highest monthly average value was 54 in March 2003 and the lowest was 33 in December 2003.

The plant effluent characteristics are summarized on Table 5.6.1.2 along with permit requirements and percent removals for $CBOD_5$, TSS, ammonia, and phosphorus. The plant is operating within permit limits of 25 mg/L monthly averages for $CBOD_5$ and 30 mg/L for TSS.

Table 5.6.1.2 - Monthly Average Treatment Performance Summary
September 2002 – August 2003 with Supplemental
Data from January – March 2002
Faribault WWTF

	Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)
Average Performance	4.1	8.8	16.0	7.3	4.7
Permit Requirements	7.0	25	30	Monitor	Monitor
% Removal	-	97.4%	93.4%	NR	NR

See Appendix 2.6.1 for detailed monthly plant data analysis
NR – Not required

The plant achieved about 97% and 93% removal of $CBOD_5$ and TSS with average effluent concentrations of 8.8 mg/L and 16.0 mg/L, respectively. The average phosphorus discharge concentrations were 4.7 mg/L and the average removal efficiency was about 38%. This level of phosphorus removal is within the range expected for activated sludge treatment without EBPR or chemical addition.

5.6.1.2 Design Basis for Modifications for Phosphorus Removal

The influent wastewater characteristics used to evaluate phosphorus removal alternatives for the Faribault WWTP were based on the annual average data and are summarized in Table 5.6.1.3. The influent BOD, TSS, and TP concentrations were taken from the 2002-2003 average monthly influent data summary. Recent plant data received from plant personnel indicated that the trickling filter effluent $CBOD_5$ was in the order of 100 mg/L and that the soluble $CBOD_5$ was about 50 mg/L. Without influent wastewater characterization, as would be done for a final design analysis for a given wastewater treatment system, the value for the soluble BOD was based on the recent trickling filter effluent BOD information from the plant. The design temperature was 10^{o}C.

The percent soluble BOD concentration is an important design parameter for EBPR processes. Again, it should be stressed that an actual engineering analysis and design would include a wastewater characterization study that would determine the influent rbCOD among other factors. The rbCOD content is also some fraction of the influent sBOD concentration. For the alternative analyses completed here, it was assumed that 70% of the influent sBOD was available to the bacteria as truly dissolved organic matter or rbCOD.

Phosphorus loads from recycle streams must be considered when developing designs for phosphorus removal alternatives. The major source of phosphorus and recycle streams is from sludge processing. For the Faribault facility the phosphorus returning to the liquid treatment system from recycle streams would be minimal, as the digested solids are not dewatered but instead directed to a sludge storage lagoon prior to agricultural applications.

Dimensions and loading rates for the existing liquid unit processes at the design flows and loadings are summarized in Table 5.6.1.3. The table shows the units available for a retrofit to phosphorus removal and indicates important issues related to the retrofit design alternatives. The design loadings are based on assumed influent conditions shown in Table 5.6.1.3. The BOD volumetric organic loading rate to the trickling filters is at a very high level, typical of a roughing application in which the trickling filter is used for only partial BOD removal. The recent plant data indicated very high BOD removals in the primary clarifiers and trickling filters with effluent BOD in the trickling filter effluent of 100 mg/L.

Table 5.6.1.3 - Unit Process Design Basis Used for Evaluation of
Phosphorus Removal Alternatives
Faribault WWTF

Flow (MGD	CBOD (mg/L)	Percent sBOD	TSS (mg/L)	TKN (mg/L)	TP (mg/L)
7.0	345	50.0	241	25.0	7.6

Process Step	Dimensions	Design Loading	Comment
Primary Clarifiers	4 - 49 ft diameter	930 gpd/ft^2	Can accept chemical addition
Plastic Media Trickling Filter	2 - 62 ft diameter Media depth = 16 ft	340 lb BOD/1000 ft^3-d	Effluent BOD from trickling filter ~ 100 mg/L
Aeration Tanks	2 - 0.435 MG	HRT = 3.0 hrs	Volume may limit ability for nitrification
Secondary Clarifiers	4 – 70 ft diameter	455 gpd/ft^2	Can accept chemical addition Conservative loadings improve efficiency

See Appendix 2.6.1 for summary of the design basis

5.6.1.3 Evaluation of Phosphorus Removal Alternatives

In Section 4 process alternatives for retrofitting a trickling filter/activated sludge process for phosphorus removal were summarized. The phosphorus removal alternatives considered initially for the Faribault WWTF were chemical addition to the primary and secondary clarifiers (two-point addition) or chemical addition only to the secondary process, and EBPR treatment options. In this case, most of the soluble BOD was removed in the trickling filter based on recent treatment plant data so that there would be insufficient, readily biodegradable COD to support a significant level of phosphorus removal with an EBPR process. The EBPR process was not feasible and only chemical treatment was further evaluated.

The effluent P concentration goal was between 0.50 and 1.0 mg/L to meet the less than 1.0 mg/L effluent target concentration. Alum would be added at a dose that would provide phosphorus removal with an effluent P such that the chemical addition is at stoichiometric requirements (1.0

mole Al/mole P) for phosphorus precipitation. The alternative evaluation process included developing conceptual designs followed by preliminary cost estimates for the viable alternatives. Table 5.6.1.4 presents a summary of the conceptual design parameters for the chemical treatment alternatives. Presented are chemical requirements and estimated daily alum sludge production rates.

Table 5.6.1.4 - Summary of Plant Modifications and Chemical Requirements and Plant Retrofit Needs for Phosphorus Removal Alternatives
Faribault WWTF

Option	Units	Chemical Addition to Secondary Clarifiers	Chemical Addition to Primary and Secondary Clarifiers
Effluent P	mg/L	0.5 to 1.0	0.5 to 1.0
Chemical Addition	lb/d	14,000	10,000
Additional Sludge Production(1)	lb/d	2,900	1,900
Alkalinity Used	mg/L	107	77
Increased Tank Volume	MG	0	0

(1)Alum Sludge

The analysis showed that by using two-point chemical addition, the amount of metal salt required for phosphorus removal can be reduced by about 30%. The impact of additional sludge removal on the plant design and capital costs was not included in this analysis. The cost analysis comparing the chemical treatment alternatives is shown in Table 5.6.1.5. Adding the chemical at both the primary and secondary clarifier locations would be the preferred alternative reducing chemical requirements and sludge production.

Table 5.6.1.5 - Preliminary Cost Estimates for Retrofit for Phosphorus Removal with Different Process Options
Faribault WWTF

Parameter	Chemical Addition to Secondary Clarifiers	Chemical Addition to Primary and Secondary Clarifiers
Preliminary Capital Costs Chemical System	$191,000	$191,000
Total Capital Costs	$191,000	$191,000
Daily Operating Costs, $/d Alum Alkalinity Sludge disposal	 1398 0 260	 1005 0 171
Annual Labor Cost – Chemicals Only Total Annual Operating Costs	$36,000 $641,000	$30,000 $460,000
Present Worth Operating Costs, 5% @ 20 years	$7,988,000	$5,733,000
Total Present Worth	$8,179,000	$5,924,000

5.6.2 Marshall WWTF

The Marshall Wastewater Treatment Facility (Marshall WWTF) is a 3.3 MGD trickling filter/activated sludge facility with significant industrial loads. The original plant was built in the 1950's as a 200 acre lagoon, was upgraded to extended air activated sludge lagoon in 1975 then to the current plant, primary treatment, trickling filters, activated sludge and filtration, in 1994. The plant also operates an equalization tank between the primary tanks and the activated sludge system. The equalization tank usually receives any flow in excess of 4 MGD. The equalization tank contents are usually brought through the plant on weekends.

5.6.2.1 Plant Description and Performance

A wastewater process flow diagram for the treatment facility is presented in Figure 5.6.2.1.a, and Figure 5.6.2.1b presents a sludge process flow diagram. The plant influent is pretreated by vortex grit removal and grinding then passes through two 60 ft diameter primary clarifiers which operate at a hydraulic overflow rate of 580 gpd/sf at design flow. The primary effluent is pumped to one of two trickling filters operated in parallel. The second trickling filter is not used in order to keep enough $CBOD_5$ in the trickling filter effluent to sustain the activated sludge system. The trickling filter operates at a recycle rate of 2:1 and accomplishes a substantial reduction of $CBOD_5$. The plant has installed a 4 inch diameter trickling filter bypass line to try to increase $CBOD_5$ loading to the activated sludge system. The line is not metered but the plant estimates bypass as 10 to 15% of their flow.

The trickling filter effluent passes through a 70 ft diameter intermediate clarifier where sloughed trickling filter solids are allowed to settle. The overflow rate of the clarifiers at design flow is 430 gpd/sf. The clarified effluent passes into the activated sludge system which consists of four parallel 269,000 gallon cells operated in step aeration mode. The activated sludge process provides a hydraulic detention time of 7.8 hours at design flow and is designed to operate at a MLSS level 2000 mg/L and a F/M between 0.1 and 0.2. Following the activated sludge process, the wastewater flows to two secondary clarifiers, a solids contact clarifier, and multimedia tertiary filters prior to UV disinfection before discharging to the Redwood River. The biological process provides nitrification year-round and has seasonal effluent ammonia limits. The process occasionally experiences sludge bulking problems and high sludge volume index (SVI's) and operates with high RAS rates. They also experience secondary clarifier denitrification but floating sludge that passes out of the clarifiers is captured by the solids contact clarifier prior to filtration. This clarifier is 90 ft in diameter and operates at an overflow rate of 520 gpd/sf. The clarified effluent is filtered through two traveling bridge multi-media gravity filters that operate at design filtration rates of 1.89 gpm/sf. The filtered effluent is disinfected through a Fisher Porter ultraviolet disinfection unit. Figure 5.6.2.2 is a photo of the Marshall WWTF trickling filters with the aeration tanks in the foreground. Figure 5.6.2.3 is a photo of one of the four aeration tanks.

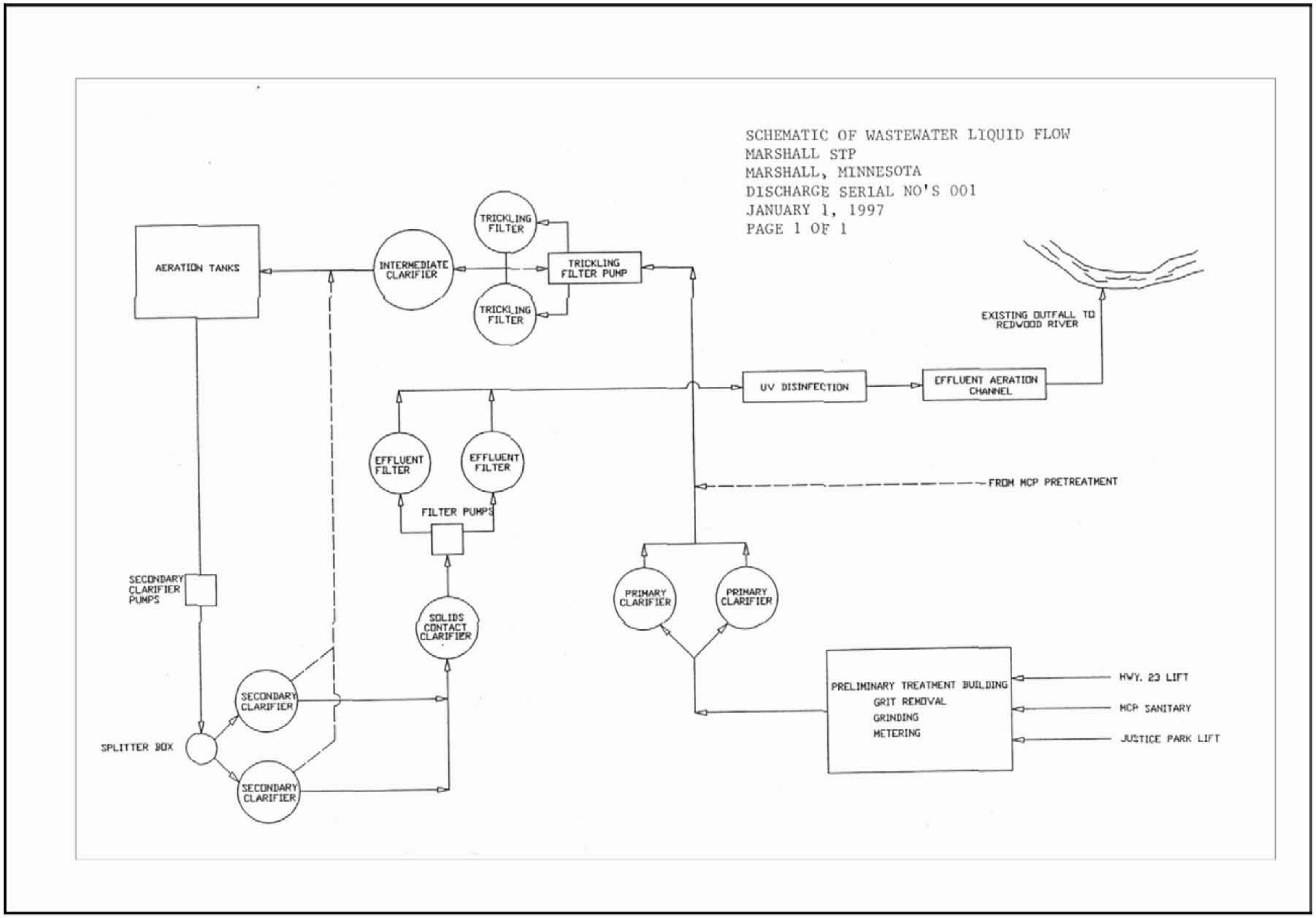
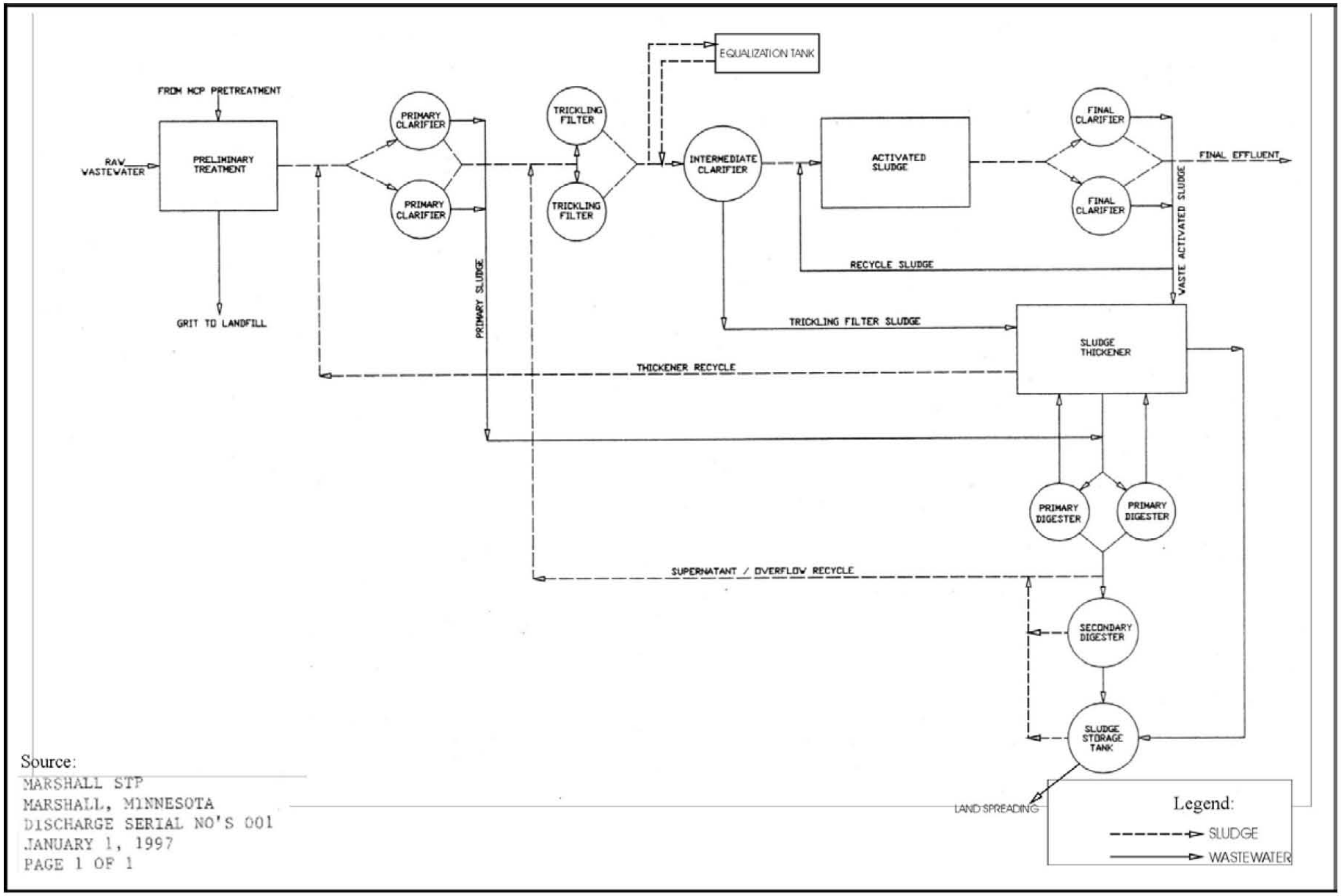


Figure 5.6.2.1a – Schematic Process Flow Diagram, Marshall WWTF



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MARSHALL, MINNESOTA
DISCHARGE SERIAL NO'S 001
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Figure 5.6.2.1b - Schematic Sludge Flow Diagram, Marshall WWTF

Figure 5.6.2.2 - Trickling Filters, Marshall WWTF

Figure 5.6.2.3 - Aeration Tank, Marshall WWTF

The plant digests sludge through two parallel anaerobic digesters which accomplish 40-45% volatile solids destruction (38% is required for land disposal). They store digested sludge in a 3.25 MG storage tank and land apply about 7MG (~700 dry tons) per year. Sludge storage decant usually is sent back to the equalization tank but can be sent to the trickling filters. The plant land applies its sludge using its own Terra Gator and tankers. The fields are as close as right outside the plant fence to 17 miles away. The plant applies sludge in coordination with farming activities.

About 23% of the plant flow, 70% of the plant $CBOD_5$ load and 61% of the plant phosphorus load are associated with industrial sources. The major industries are ADM (ethanol plant) and Schwans (dairy and foods). Schwans pretreates for $CBOD_5$/TSS removal using two dissolved air flotation units. Schwans raw wastewater $CBOD_5$ is 10,000 to 20,000 mg/L and the pretreated effluent is approximately 2000 mg/L. Schwans wastewater also contains approximately 50 mg/L phosphorus and contributes 20% of the plant phosphorus load. ADM provides its own treatment through a Biothane anaerobic system and sends waste suspended solids (~0.3 MGD) to the Marshall WWTF. ADM contributes approximately 38% of the phosphorus load.

Influent and effluent plant data were reviewed to develop the raw wastewater and final effluent characteristics, to evaluate the plant performance, and for the phosphorus removal analysis. Influent wastewater and final effluent characteristics are summarized in Tables 5.6.2.1 and 5.6.2.2 for the period of December 2002 through November 2003. These data represent the annual monthly average flow, $CBOD_5$, TSS, ammonia nitrogen (NH_4-N), and total phosphorus. The total plant influent characteristics are as follows:

Table 5.6.2.1 - Monthly Average Raw Wastewater Characteristics
Marshall WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)	$CBOD_5$/P
2.13	387	455	14.9	13.7	28

The influent did not show any large variations in wastewater characteristics. The $CBOD_5$ concentration averaged 387 mg/L and ranged from 330 mg/L to 464 mg/L; TSS averaged 455 mg/L and ranged between 350 and 567 mg/L; and the phosphorus concentration averaged 13.7 mg/L and ranged between 6.5 and 18.8 mg/L.

The plant effluent characteristics are summarized in Table 5.6.2.2 including permit requirements and percent removals for $CBOD_5$, TSS, ammonia nitrogen and phosphorus. The plant is operating within permit limits of 5 mg/L monthly averages for $CBOD_5$ and 30 mg/L for TSS. In fact, the plant meets the most stringent limit for ammonia (June through September 1.1 mg/L) for the whole year. The plant achieved 99% or greater removal of $CBOD_5$ and TSS with an average effluent concentration of 2.5 mg/L and 4.7 mg/L, respectively. The 2002-2003 monthly average discharge concentrations for ammonia was 0.57 mg/L indicating a high degree of nitrification throughout the year. The plant is meeting all permit requirements. The average phosphorus discharge level was 5.8 mg/L. This suggests that there is currently a phosphorus reduction through the plant of 7.9 mg/L which is related to existing particulate and biological removals. Influent and effluent flows are slightly different and are based on existing flow metering at the influent and effluent to the plant.

Table 5.6.2.2 - Monthly Average Treatment Performance Summary
December 2002 – November 2003
Marshall WWTF

	Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)
Average Performance	2.05	2.5	4.7	0.57	5.8
Permit Requirements	3.3	5 (85% Rem.)	30 (85% Rem.)	June through Sept. 1.1 mg/L Oct. through Nov. 2.3 mg/L Dec. through March 9.4 mg/L April through May 2.4 mg/L	Monitor Only
Percent Removal	NA	99.4%	99.0%	96.8%	57.7%

NA – Not Applicable

5.6.2.2 Design Basis for Modifications for Phosphorus Removal

The evaluation of phosphorus removal alternatives was based on the design basis presented in Table 5.6.2.3. The table summarizes flow and wastewater characteristics used to assess the phosphorus removal alternatives. It also summarizes the facilities available to be retrofitted for phosphorus removal if it is determined that excess capacity exists.

This design basis was used to assess the feasibility of biological and chemical phosphorus removal as well as a combination of both processes. The design basis does not include any contributions of plant return streams. The only return stream at the Marshall WWTF is from sludge storage decanting. No data was available on this return stream. The design low temperature was taken to be 12°C and was used in developing biological treatment kinetics.

Table 5.6.2.3 – Process Design Basis Used for Evaluation of Phosphorus Removal Alternatives
Marshall WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	TKN (mg/L)	TP (mg/L)	rbCOD
3.3	387	455	29.8	13.7	24

Process Step	Dimensions	Design Loading	Comment
Primary Clarifiers	2 - 60 ft diameter, 10 ft deep	580 gpd/ft2	Can accept chemical addition
Trickling Filters	2 – 60 ft diameter 24 ft deep	66 lb $CBOD_5$/1000 ft3/day	Consumes COD needed to support EBPR
Intermediate Clarifiers	2 – 70 ft diameter, 12 ft deep	430 gpd/sf	Can accept chemical addition
Activated Sludge	4 – 0.269 MG aeration tanks	F/M = 0.1 to 0.2 lb $CBOD_5$/lb MLSS, HRT = 6 hrs	Accomplishes year-round nitrification. Tanks can accept EBPR retrofit
Secondary Clarifiers	2 – 70 ft diameter, 12 ft deep	430 gpd/sf	Can accept chemical addition
Solids Contact Clarifier	1 – 90 ft diameter	520 gpd/sf	Can accept chemical addition

See Appendix 2.6.2 for summary of the design basis

The Marshall wastewater is a relatively high strength wastewater due to the contribution of industrial wastes. The influent wastewater contains 387 mg/L $CBOD_5$, 13.7 mg/L phosphorus and exhibits a $CBOD_5$ to P ratio of 28:1 which would support EPBR without having to add an additional carbon source. At design loadings (based on design flow and observed wastewater characteristics) the F/M of the activated sludge system is 0.1 to 0.2 lb $CBOD_5$/lb MLSS at the observed average MLSS concentration of 2,000 mg/L. This F/M is low enough to support nitrification, which, based on plant operating data, regularly occurs year-round. The low F/M suggests that there is sufficient aeration tank volume available to support denitrification and EBPR.

Certain wastewater characteristics, removal rates and treatment plant operating conditions were also either assumed or based on plant operating data for this analysis. Biodegradable COD (discussed in Section 4) was assumed to be equal to 1.6 times the $CBOD_5$ and readily biodegradable COD (rbCOD), that fraction of the COD that is easily converted to volatile fatty acids (VFA) which are used by EBPR bacteria, was assumed to be 30% of the biodegradable COD. The trickling filter provides a significant $CBOD_5$ reduction. Based on the trickling filter loadings it was estimated that the trickling filter would reduce $CBOD_5$ from approximately 256 mg/L in the primary effluent to approximately 95 mg/L in the trickling filter effluent of which 25 mg/L would be considered rbCOD. Because of the high degree of removal accomplished in the trickling filters, it is likely that there will not be enough $CBOD_5$ available for EBPR. Also, baseline phosphorus removal by primary treatment (without chemical addition) was assumed to be 10% of the influent concentration.

5.6.2.3 Evaluation of Phosphorus Removal Alternatives

The evaluation of phosphorus removal alternatives included developing conceptual designs and preliminary cost estimates for the viable alternatives. EBPR, chemical addition and a combination of both processes were considered for the Marshall WWTF. EPBR without the use of the trickling filter was also evaluated. A summary of the alternatives analysis is presented in Table 5.6.2.4. The table summarizes the potential effluent phosphorus concentration, chemical requirements (alum and alkalinity), sludge production and facility requirements (chemical storage and piping) for each alternative.

Table 5.6.2.4 - Summary of Plant Modifications and Chemical Requirements and Retrofit Needs for Phosphorus Removal Alternatives
Marshall WWTF

Option	Units	EBPR w/o Trickling Filter + Chemical Addition to Secondary Clarifiers	Chemical Addition to Primary and Secondary Clarifiers	Chemical Addition to Secondary Clarifiers
Effluent P	mg/L	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0
Chemical Addition	lb/d	5100	8400	10,900
Additional Sludge Production	lb/d	1600	2500	3500
Alkalinity added	lb/d	2300	3800	4900
Increased Tank Volume	MG	1.07	0	0
Additional Mixers	Yes/No	Yes	No	No
Pumps/Piping	Yes/No	Yes	No	No

Using the design approach for denitrification and EPBR presented in Section 4, there is not enough aeration tank capacity to support EBPR. EBPR was considered without the trickling filter in service. This was done to see if there was enough COD in the wastewater to support EBPR. There was enough COD in the wastewater to support a phosphorus reduction of approximately 5 mg/L by EBPR; however, this would require 1.07 MG of additional tankage. The EBPR effluent phosphorus would be approximately 7 mg/L and would require chemical addition to the secondary clarifiers to reduce the effluent phosphorus to less than 1 mg/L. This process would produce approximately 1,600 pounds per day of additional sludge, require 5,100 pounds per day of alum and consume 2,300 pounds per day of alkalinity.

Chemical addition alone is also capable of meeting the effluent target of 1 mg/L. Chemical addition can be accomplished as single or two-point addition. Any retrofit of chemical addition for phosphorus removal should include chemical feed equipment that would permit two-point addition when required. This would provide the flexibility to practice single or two-point addition.

Single point chemical addition should only consider chemical addition to the secondary clarifiers to ensure that there is sufficient phosphorus available for biological treatment and to assist on additional TSS capture. Single point addition to the primary clarifiers could result in creating a phosphorus deficient condition in the activated sludge process if the phosphorus removal process is not carefully maintained. Two-point addition would be practiced in the primary and secondary clarifiers. Chemical addition to the primary clarifiers has the added benefit of enhancing $CBOD_5$ and TSS removals; however, as previously stated, the process should be closely maintained to ensure that there is sufficient residual phosphorus in the primary effluent for biological treatment. For the Marshall WWTF, chemical addition to the primary clarifiers was targeted for removal of approximately 7 mg/L phosphorus and approximately 3.8 mg/L was removed by nutrient uptake in the production trickling filter sludge and MLSS. This left approximately 3 mg/L after biological treatment, which was the basis for chemical addition to the secondary clarifiers.

Two-point chemical addition would produce an additional 2,500 pounds per day of sludge, would require 8,400 pounds per day of alum, and consume 3,800 pounds per day of alkalinity. Single point chemical addition to the secondary clarifiers would produce 3,500 pounds per day of sludge, require 10,900 pounds per day of alum, and consume 4,900 pounds per day of alkalinity. This alkalinity demand for chemical addition may be high enough to require the addition of alkalinity to ensure that the effluent pH would meet effluent requirements.

The conceptual design analysis indicated that two point chemical addition to the primary and secondary clarifiers is more cost effective than single point addition. Two point chemical additions would require less alum addition, produce less chemical sludge and require less alkalinity addition for pH control. This is true for all plants in this project where chemical addition alone was the preferred phosphorus removal treatment alternative. Two point chemical addition is the most cost effective chemical treatment-only alternative.

Preliminary budgetary cost estimates were developed based on the information presented in Section 4 and are summarized in Table 5.6.2.5. The capital costs are presented as September 2004 US dollars and the present worth costs are based on the annual O&M costs over a 20 year operating period at an interest rate of 5%. The costs were rounded to the nearest $1,000.

The EBPR that was considered was to bypass the trickling filters and include chemical addition to the secondary clarifiers to remove residual phosphorus. The capital cost for this alternative would be $1,370,000 with an O&M cost of $278,000 per year and a present worth cost of $4,834,000. The final alternative considered was chemical treatment. The capital cost for two-point

Table 5.6.2.5 – Preliminary Cost Estimates for Retrofit for Phosphorus Removal with Different Process Options
Marshall WWTF

Cost Factors	EBPR w/o Trickling Filter + Chemical Addition to Secondary Clarifiers	Chemical Addition to Primary and Secondary Clarifiers	Chemical Addition to Secondary Clarifiers
Effluent P (mg/L)	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0
Preliminary Capital Cost			
EPBR	$1,200,000	$0	$0
Chemical Treatment	$160,000	$160,000	$160,000
Total	$1,370,000	$160,000	$160,000
Daily Operating Costs $/d			
EBPR	107	0	0
Alum	510	843	1086
Alkalinity	0	303	634
Sludge Disposal	150	224	314
Annual Labor Cost – Chemicals Only	0	$26,000	$30,000
Total Annual O&M Costs	$278,000	$526,000	$772,000
Present Worth Operating Costs	$3,464,000	$6,555,000	$9,621,000
Total Present Worth	$4,834,000	$6,715,000	$9,781,000

chemical treatment would be $160,000 with an O&M cost of $526,000 and a present worth cost of $6,715,000.

The most cost effective approach for phosphorus removal for the Marshall WWTF would be EBPR with chemical addition to the secondary clarifier and bypassing the trickling filters. With an annual O&M cost differential of $248,000 ($526,000-$278,000) between two-point chemical addition and EPBR with the trickling filter out of service and chemical addition to the secondary clarifiers; the payback period for the capital investment of $1,370,000 for the EBPR process would be 5.5 years.

5.6.3 Glencoe WWTF

The Glencoe Wastewater Treatment Facility (Glencoe WWTF) is a 1.6 MGD trickling filter/activated sludge facility with a significant industrial wastewater load from a milk producer. The milk producer discharge represents about 50% of the wastewater plant influent BOD and about 60% of the influent phosphorus. No phosphorus standard is presently in place, but the plant must nitrify to meet effluent ammonia concentration limits that vary seasonally, with the lowest value at 1.0 mg/L from June through September.

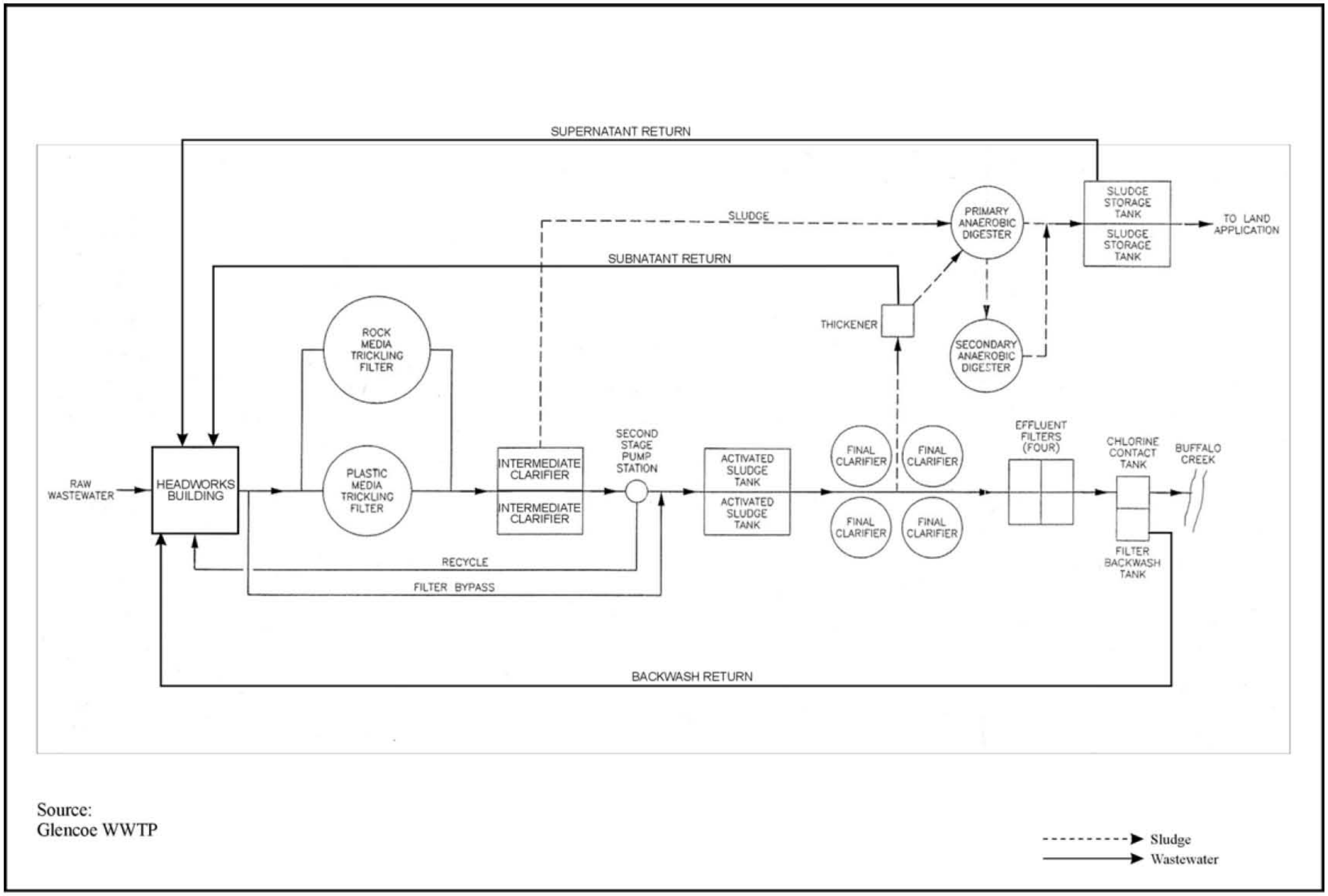
Recently, the major dairy operation, AMPI, closed operations in Glencoe. The closure of the dairy operation has resulted in a significant reduction in wastewater flow and loadings to the Glencoe treatment plant including an approximate 60% reduction in the phosphorus load. Since the initial analysis was already completed and included the dairy operation, another phosphorus removal alternative scenario was considered. Therefore, two conceptual design scenarios were developed for Glencoe. The first scenario included the wastewater from the dairy operation. The second scenario which is summarized in Section 5.6.3.4 presents the results of the conceptual design analysis without the dairy wastewater.

5.6.3.1 Plant Description and Performance

A process flow diagram for the wastewater treatment facility is presented in Figure 5.6.3.1. The plant influent is pretreated by grit removal and screening before flowing to a 45-ft diameter, 20 ft deep plastic tower trickling filter. The lack of primary clarification results in frequent media fouling problems. Periodically, the plastic tower is taken out of service for cleaning and at that time the screened effluent is pumped to an existing 6 ft. deep rock trickling filter (61-ft diameter) for treatment.

The trickling filter effluent passes through two rectangular shallow (6.5 ft depth) intermediate clarifiers with an area of 1050 ft^2 each, which removes sloughed solids in the trickling filter effluent. The overflow rate of the intermediate clarifiers at the 2002 average flow rate was 380 gpd/ft^2. The clarified effluent passes into the activated sludge system which consists of two (2) parallel 15 ft-deep, 179,000 gallon tanks (57 ft by 28 ft) operated in a completely-mixed mode. Aeration is provided by fine bubble membrane Wyss diffusers. At the 0.80 MGD flow, the HRT of the activated sludge basins is 10.7 hours. The system has been operated with high and varying SRT values with MLSS concentrations ranging from 2,500 to 7,000 mg/L for different months. The process provides nitrification year-round and has on occasion experienced some floating sludge in the secondary clarifies due to denitrification. Four (4) 40 ft-diameter secondary clarifiers are installed and provide a conservative overflow rate of 160 gpd/ft^2, when all are in operation at the 0.80 MGD influent flow rate. Four (4) dual media (coal/sand) polishing filters provide further effluent solids removal. The effluent is disinfected in a chlorine contact tank and the dechlorinated prior to discharge into Buffalo Creek. Figure 5.6.3.2 shows a view of the trickling filter and aeration tanks at the Glencoe facility.

Anaerobic digestion is used for sludge processing prior to dewatering on drying beds. A sludge storage tank is used to hold digested sludge during the winter months. Polymers are added to the sludge before applying to the drying beds, which enhances the liquid solids separation. Water drains from below the drying beds for return to the plant influent flow. The plant reported that the drying bed sludge is thickened to about 4% solids. The sludge from the drying beds is land applied.



Source:
Glencoe WWTP

Figure 5.6.3.1 – Schematic Process Flow Diagram, Glencoe WWTF

Figure 5.6.3.2 - View of Plastic Media Trickling Filter and Aeration Tanks, Glencoe WWTF

The first scenario includes the milk producing company which accounted for about 50% of the plant influent BOD loading and 60% of the phosphorus loading. The flow and loadings appeared to be consistent from month to month. Influent and effluent plant data were reviewed to evaluate the plant performance and to establish the raw wastewater characteristics for the phosphorus removal analysis. Influent wastewater and final effluent characteristics are summarized on Tables 5.6.3.1 and 5.6.3.2 for the period of September 2002 through August 2003. These data represent the annual monthly average flow, $CBOD_5$, TSS, ammonia nitrogen (NH_4-N), and total phosphorus. The total plant influent characteristics are as follows:

Table 5.6.3.1 - Monthly Average Raw Wastewater Characteristics
Glencoe WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	TKN (mg/L)	TP (mg/L)	BOD/P
0.80	317	349	NA	15.1	21

NA – Not applicable

The average monthly values showed significant variation in the wastewater strength. The monthly average $cBOD_5$ concentration was 534 mg/L in January 2003 and 186 mg/L in May 2003; TSS averaged 349 mg/L and ranged between 207 and 596 mg/L. The average monthly influent phosphorus concentrations averaged 15.1 mg/L and ranged from 9.6 mg/L for August 2003 to 23.1 mg/L for March 2003. The influent BOD/P ratio also varied widely, from a value of 15 for April 2003 and 33 for August 2003. For BOD/P ratios below 20, phosphorus removal by EBPR processes is greatly limited and chemical treatment is required.

The plant effluent characteristics are summarized on Table 5.6.3.2 along with permit requirements and percent removals for $CBOD_5$, TSS, and phosphorus. The plant is operating within permit limits of 25 mg/L monthly averages for $CBOD_5$ and 30 mg/L for TSS. Good nitrification has been demonstrated and the effluent NH_4-N concentration has normally been well below the warm weather effluent limit of 1.0 mg/L as NH_4-N. Even in the colder months of January and February 2003 the monthly average effluent NH_4-N concentration was 0.55 and 0.08, respectively.

The plant achieved about 99% removal of $CBOD_5$ and TSS with average effluent concentrations of 2.9 mg/L and 4.6 mg/L, respectively. The low concentrations are a result of having polishing filters following secondary treatment. The monthly average phosphorus discharge concentration was 9.2 mg/L and the average removal efficiency was about 36%. This level of phosphorus removal is within the range expected for activated sludge treatment without EBPR or chemical addition.

Table 5.6.3.2 - Monthly Average Treatment Performance Summary
September 2002 – August 2003
Glencoe WWTF

	Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)
Average Performance	0.80	2.9	4.6	0.74	9.2
Permit Requirements	1.60	25	30	1.0	Monitor Only
% Removal	-	99.0%	98.5%	NR	35.8%

See Appendix 2.6.3 for detailed monthly plant data analysis
See Table 3.3 in Section 3 for summary of seasonal NH_4-N Limits
NR – Not required

5.6.3.2 Design Basis for Modifications for Phosphorus Removal

The influent wastewater characteristics used to evaluate phosphorus removal alternatives for the Glencoe WWTP were based on the annual average data and are summarized in Table 5.6.3.3. The influent BOD, TSS, and TP concentrations were taken from the 2002-2003 average monthly influent data summary. Without influent wastewater characterization, as would be done for a final design analysis for a given wastewater treatment system, the value for the percent soluble BOD, which is a key parameter that affects EBPR process efficiency, had to be assumed. A higher value than normal (50%) was assumed because of the significant input from the milk processing wastewater. There was limited influent nitrogen data available, but one set of data reported indicated an influent TKN concentration of 104 mg/L. Such a high value can be expected for a dairy wastewater. Since nitrification is required in this design, this is an important process parameter for the design evaluations.

Table 5.6.3.3 - Process Design Basis Used for Evaluation of Phosphorus Removal Alternatives
Glencoe WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	Percent sBOD	TSS (mg/L)	TKN (mg/L)	TP (mg/L)
1.6	317	50.0	349	104	15.1

Process Step	Dimensions	Design Loading	Comment
Plastic Media Trickling Filter	45 ft diameter Media depth = 20 ft	130 lb BOD/1000 ft^3-d	Significant BOD removal occurs at this loading leaving little BOD for EBPR.
Intermediate Clarifier	2-1050 ft^2	760 gpd/ft^2	Good solids capture possible. Can accept chemical addition.
Aeration Tanks	2-0.179 MG	HRT = 5.4 hrs	May have limited volume for nitrification.
Secondary Clarifiers	4 – 40 ft diameter	320 gpd/ft^2	Can accept chemical addition. Conservative loadings improves efficiency.
Dual Media Polishing Filters	4 – 80 ft^2	3.5 gpm/ft^2	Removes additional solids and improves phosphorus removal efficiency.

See Appendix 2.6.3 for summary of the design basis

A high average percent soluble BOD concentration of 50% was assumed based on the significant industrial wastewater contribution and its soluble nature as well as the high influent BOD/P ratio measured. Again it should be stressed that an actual engineering analysis and design would include a wastewater characterization study that would determine the influent rbCOD among other factors. The rbCOD content is also some fraction of the influent sBOD concentration. For the alternative analyses completed here, it was assumed that 70% of the influent sBOD was available to the bacteria as truly dissolved organic matter or rbCOD. The design temperature was 10°C.

Phosphorus loads from recycle streams must be considered when developing designs for phosphorus removal alternatives. The major source of phosphorus and recycle streams is from sludge processing. For plants with EBPR and anaerobic or aerobic digestion, a significant amount of the phosphorus removed in the biological process is released and recycle back. Phosphorus returns in the range of 30 to 50% have been reported. For plants with chemical treatment none or little of the phosphorus removal chemically is released and recycle. The Glencoe facility uses anaerobic digestion and sludge drying beds for solids processing. For this design, 40% of the phosphorus removed in the waste activated sludge was assumed to be released in the anaerobic digestion process. The actual amount of phosphorus returned is affected by the solids concentration in the solids taken off the sludge trying beds. The plant reported a solids concentration of 4% from the drying beds as it is pumped into sludge hauling trucks for land application. This solids concentration is lower than would be observed for solids dewatering by mechanical equipment (20-25%) and thus results in a lower amount of phosphorus recycle. A mass balance was done in the alternative design analysis to account for the recycled phosphorus. The mass balance also included the higher ammonia concentration that occurs in anaerobic digestion. For a final engineering analysis and design actual measurements would be needed to verify this design parameter.

Dimensions and loading rates for the existing liquid unit processes at the design flows and loadings are also summarized in Table 5.6.3.3. The table shows the units available for a retrofit to phosphorus removal and indicates important issues related to the retrofit design alternatives. The use of the trickling filter and an immediate clarifier at the loadings shown has a major impact on the feasibility of using an EBPR process for phosphorus removal after the trickling filter step. A large amount of the BOD would be removed by the trickling filter operation, and as the EBPR process efficiency is directly related to the amount of BOD taken up by the phosphorus accumulating organisms, this pretreatment step will greatly reduce the efficiency of an EBPR process.

Other aspects of the existing process design that are favorable for phosphorus removal are the conservative secondary clarifier hydraulic loading and the availability of polishing filters These two processes improve phosphorus removal by producing a low effluent TSS concentration. By removing more effluent TSS a greater amount of phosphorus that is in the particulate form as chemical precipitate or in biological solids for EBPR processes would be removed. This advantage is less apparent at the 1.6 MGD design loading, as the polishing filters would be operating at an abormally high hydraulic load, and thus would not produce as high a TSS removal efficiency as for the current 0.80 MGD flow condition.

For the existing flow schemes certain factors suggest that the use of an EBPR process would be less favorable. These are 1) a significant amount of the influent BOD would be removed by the trickling filter operation, 2) some phosphorus can be returned from the solids processing method, 3) nitrification is required, and 4) the plant has a very high influent TKN concentration. The high influent TKN concentration would result in a significant addition of nitrate to an EBPR anaerobic contact zones. The phosphorus removal efficiency in the EBPR process is decreased in direct proportion to the amount of nitrate added to the anaerobic contact zone.

5.6.3.3 Evaluation of Phosphorus Removal Alternatives with the Dairy Wastewater

In Section 4 process alternatives for retrofitting a trickling filter/activated sludge process for phosphorus removal were summarized. From this phosphorus removal alternatives for the Glencoe WWTF are chemical addition to the primary and secondary clarifiers (two-point addition) or chemical addition only to the secondary process, EBPR treatment after the trickling filter system, EBPR treatment after the trickling filter system with chemical addition, EBPR treatment with trickling filter bypass using the A^2O process (Figure 4.6e and 4.6f), with nitrification required) and the latter EBPR process scheme with chemical addition to the primary or secondary clarifiers. For the alternatives with trickling filter bypassing the intermediate clarifiers were operated as primary clarifiers. The evaluation of the Glencoe facility EBPR designs also required that the ability of the existing activated sludge basins to accommodate the anaerobic and anoxic zones for the A^2O process, in addition to the aeration volume needed for nitrification be determined.

The effluent P concentration goal in all cases was between 0.80 and 1.0 mg/L to meet the less than 1.0 mg/L effluent permit goal. For the alternative with chemical addition only, chemical was added to the intermediate clarifier at a dose that would provide phosphorus removal with an effluent P such that the chemical addition is at stoichiometric requirements (1.0 mole Al/mole P) for phosphorus precipitation.

The alternative evaluation process included developing conceptual designs followed by preliminary cost estimates for the viable alternatives. The conceptual designs included determining the activated sludge aeration volume requirements to meet the effluent treatment, the activated sludge tank volume needed for the anaerobic contact zone of the EBPR process, the amount of daily sludge production in both the primary and secondary processes, the amount chemical sludge produced, the amount of phosphorus removed by biomass growth and by the EBPR process, the phosphorus content of the waste sludge, and the fate of solids in solids processing and the characteristics of return flows.

None of the EBPR process alternatives were feasible. For the EBPR process alone following the trickling filter operation, it was not feasible because an insufficient amount of BOD remained after the trickling filter and intermediate clarifier treatment. The BOD from the intermediate clarifier was about 40 mg/L and the BOD/P ratio was about 4, much too low for a biological phosphorus removal process to work. Two conditions made the EBPR process unfeasible when it was applied in the flow schemes with trickling filter bypass. These were:

1. There was insufficient volume available in the existing aeration tank for a retrofit to an A^2O process. Without the trickling filter operation, there was less removal of BOD and suspended solids before the activated sludge process, and thus the BOD and solids loading to the activated sludge process required more volume to meet the nitrogen removal needs than was available. With the trickling filter and intermediate clarifier bypass there was not sufficient aeration volume for nitrification.

2. The high influent nitrogen concentration (104 mg/L) would result in the consumption of all the rbCOD by nitrate before it could be available for the biological phosphorus removal process.

The only feasible solutions from the alternative analyses would be with chemical treatment, and these results are summarized in Table 5.6.3.4 in terms of the effluent phosphorus concentration, chemical requirements (alum and alkalinity), and sludge production. For the alternatives with chemical treatment, an effluent phosphorus concentration of 0.50 to 1.0 mg/L can be normally expected under varying wastewater load conditions.

Results in Table 5.6.3.4 are similar to results for chemical addition for other retrofit examples in this project. The two-point chemical addition approach, with chemical addition in both the primary and secondary treatment steps in contrast to adding chemicals only for polishing in the secondary step, results in a lower chemical requirements, lower labor cost and less sludge production. As is shown in Table 5.6.3.5 the two-point chemical addition alternative reduces the operating costs by 31%, while both chemical feeding approaches have similar capital costs. Two-point chemical addition would be the most cost effective alternative.

Table 5.6.3.4 - Summary of Plant Modifications and Chemical Requirements and Plant Retrofit Needs for Phosphorus Removal Alternatives
Glencoe WWTF

Option	Units	Chemical Addition to Primary and Secondary Clarifiers	Chemical Addition to Secondary Clarifiers
Effluent P	mg/L	0.5 to 1.0	0.5 to 1.0
Chemical Addition	lb/d	5886	3859
Additional Sludge Production(1)	lb/d	1219	743
Alkalinity Used	mg/L	2649	1736
Increased Tank Volume	MG	0	0

(1)Alum Sludge

In summary, EBPR treatment would not be feasible with this pretreatment trickling filter operation, as the trickling filter would remove too much BOD before the EBPR process. The application of an EBPR process for this application was handicapped further by the fact that influent wastewater had a very high nitrogen concentration due to the industrial wastewater input. The high nitrogen level required BOD also, thus even without the trickling there was not sufficient BOD for the phosphorus removing organisms.

Table 5.6.3.5 - Preliminary Cost Estimates for Retrofit with the Dairy
Operation for Phosphorus Removal
with Different Process Options
Glencoe WWTF
June 2004 – January 2005

Parameter	Chemical Addition to Secondary Clarifiers	Chemical Addition to Primary and Secondary Clarifiers
Preliminary Capital Costs		
Chemical System	$137,000	$137,000
Total Capital Costs	$137,000	$137,000
Daily Operating Costs, $/d		
Alum	588	386
Alkalinity	802	586
Sludge disposal	110	67
Annual Labor Cost – Chemicals Only	$21,000	$17,000
Total annual operating costs	$576,000	$381,000
Present Worth Operating Costs, 5% @ 20 years	$7,178,000	$4,748,000
Total Present Worth	$7,315,000	$4,885,000

5.6.3.4 Evaluation of Phosphorus Removal Alternatives Without the Dairy Wastewater

Scenario two was an evaluation of phosphorus removal alternatives using the anticipated wastewater characteristics without the industrial wastewater input from the dairy operation. Recent influent wastewater characterization data without the dairy operations are summarized in Table 5.6.3.6. These data are for the period of June 2004 through January 2005. There has been a 30% reduction in $CBOD_5$, 50% reduction in TSS and 60% reduction in TP. For this condition, the wastewater flow is lower and the influent nitrogen and phosphorus concentrations are much less.

Table 5.6.3.6 - Influent Wastewater Characteristics Used for Evaluation of Phosphorus Removal Alternatives Without the Dairy Operation Wastewater
Glencoe WWTF
June 2004 – January 2005

Flow (MGD)	$CBOD_5$ (mg/L)	Percent sBOD	TSS (mg/L)	TKN (mg/L)	TP (mg/L)
0.691	254	40.0	217	30	6.2

The phosphorus alternatives evaluation considered plant treatment processes with and without the operation of the trickling filters. Because the trickling filter removed a significant amount of the influent soluble BOD, the use of an EBPR process with the trickling filter operation was not feasible. In this case, only chemical treatment was feasible and the design evaluation included two-point chemical addition (alum added to the intermediate and secondary clarifiers) and single-point chemical addition with alum added only at the secondary clarifier.

For the EBPR alternatives without the trickling filter pretreatment, the design alternatives also included nitrate removal as nitrification is required to meet the plant effluent permit. In this case the A^2O process was used for the EBPR alternative evaluation. The design evaluation showed that because of the reduce flow and loading on existing facility it was possible to convert the existing aeration basins to the A^2O process by adding baffles and mixers at the appropriate locations. An internal recycle pumping system was also required to feed nitrate from the aeration basin to the anoxic basin located between the anaerobic and aerobic zones. The evaluation included the effect of anaerobic digestion on the increased phosphorus concentration in the return flows for the alternative using an EBPR process. The assumed amount of phosphorus release in the anaerobic digestion process was 40% of the phosphorus removed by the phosphorus accumulating organisms.

Key impacts of the phosphorus removal alternatives, such as chemical addition, increased sludge production, alkalinity requirements, and possibly additional tankage are summarized in Table 5.6.3.7 for the four alternatives: EBPR with chemical addition to the secondary clarifiers, EBPR with chemical addition in the primary clarifiers, single point chemical addition to the secondary clarifiers with the trickling filter operation, and two-point chemical addition with the trickling filter operation. It is coincidental that the chemical addition is similar for the EBPR process, whether the chemicals are added to the intermediate or secondary clarifiers. In the first case, more phosphorus is removed by chemicals and less by biological oxidation.

Table 5.6.3.7 - Summary of Plant Modifications and Chemical Requirements and Plant Retrofit Needs for Phosphorus Removal Alternatives
Glencoe WWTF

Option	Units	EBPR with Chemical Addition to Secondary Clarifiers	EBPR with Chemical Addition to Primary Clarifiers	Trickling filter & Chemical Addition to Secondary Clarifiers	Trickling filter & Chemical Addition to Intermediate and Secondary Clarifiers
Effluent P	mg/L	0.5-1.0	0.7-1.0	0.5 to 1.0	0.5 to 1.0
Chemical Addition	lb/d	250	250	1120	850
Additional Sludge Production(1)	lb/d	50	45	230	170
Alkalinity Used	mg/L	19	19	87	66
Increased Tank Volume	MG	0	0	0	0

(1)Alum Sludge

The major cost trade-offs between these four phosphorus removal alternatives were the costs to convert the existing aeration basins to an A^2O process versus the higher operating costs for using chemical treatment only with the present treatment flow scheme. The preliminary cost analysis that reflects these issues, is summarized in Table 5.6.3.8. The preliminary cost analysis showed that the cost for the EBPR alternative was about 25% lower than the chemical treatment only alternative based on a present worth basis. Because these preliminary costs did not include final engineering, and many site considerations, it was possible that the actual costs for the tank conversions to an EBPR process would increase more than that shown for the actual costs for the chemical treatment alternative. On the other hand, the analysis may be less optimistic for the EBPR alternative as the actual wastewater characteristics were not fully determined. If wastewater sampling and characterization before any final engineering showed that there was a much higher fraction of readily biodegradable COD then the chemical addition requirements for the EBPR process would decrease and the cost savings for that alternative would be greater. Thus, this analysis showed that the cost differences between the EBPR and chemical treatment only alternatives were very close and more site specific information will determine the more preferred alternative.

For this analysis, the major factor favorable for an EBPR process for phosphorus removal is the aeration basin configuration and volume available to allow conversion to the A^2O process within the existing tank. On the other hand, phosphorus release in anaerobic digestion and in return flows, and the assumption of a moderate level of readily biodegradable COD and influent wastewater were less favorable for the EBPR process. The need and acceptability of bypassing the existing trickling filters, so that there is sufficient BOD available to make the EBPR process feasible is a site specific issue that must be considered by the municipality.

Table 5.6.3.8 - Preliminary Cost Estimates for Retrofit for Phosphorus Removal
with Different Process Options for Wastewater Characteristics Without the Dairy Operation
Glencoe WWTF

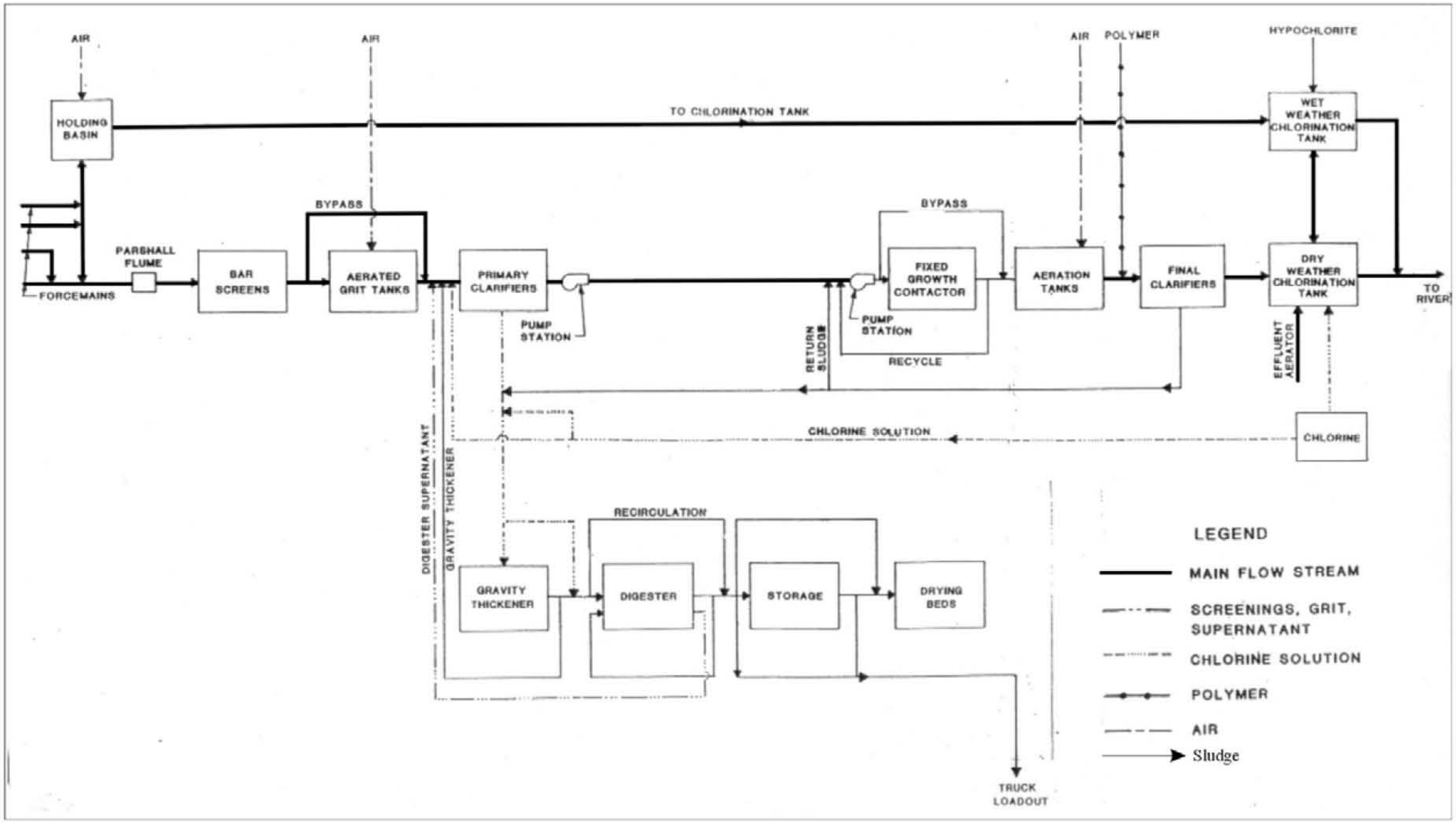
Parameter	EBPR with Chemical Addition to Secondary Clarifiers	EBPR with Chemical Addition to Primary Clarifiers	Trickling filter & Chemical Addition to Intermediate and Secondary Clarifiers	Trickling filter & Chemical Addition to Secondary Clarifiers
Preliminary Capital Costs				
Chemical System	$128,000	$128,000	$128,000	$128,000
EBPR Retrofit	$360,000	$360,000	-	-
Total Capital Costs	$488,000	$488,000	$128,000	$128,000
Daily Operating Costs, $/d				
Alum	25	25	85	112
Alkalinity	34	34	115	153
Sludge disposal	5	5	15	21
Annual Labor Cost – Chemicals Only	$11,000	$11,000	$12,000	$12,000
Total Annual Operating Costs, $/year	$35,000	$35,000	$91,000	$116,000
Present Worth Operating Costs, 5% @ 20 years	$436,000	$436,000	$1,134,000	$1,446,000
Total Present Worth	$924,000	$924,000	$1,262,000	$1,574,000

5.6.4 Little Falls WWTF

The Little Falls Wastewater Treatment Facility (Little Falls WWTF) is a combined trickling filter/suspended growth biological treatment system using an activated biological filter (ABF) and the activated sludge process. The plant has an average design flow of 2.4 MGD, a peak design flow of 3.0 MGD. The current plant flow is 1.5 MGD.

5.6.4.1 Plant Description and Performance

Figure 5.6.4.1 presents the process flow diagrams for the wastewater and sludge handling treatment processes. The influent wastewater enters the plant through a series of force mains and can either be diverted to an off line holding tank or flow by gravity to preliminary treatment. The



Source:
Little Falls WWTP

Figure 5.6.4.1 - Schematic Process Flow Diagram, Little Falls WWTF

254,000 gallon wet weather holding tank and chlorination facilities are provided for wastewater storage during storm events. The preliminary treatment steps include flow monitoring, screening and grit removal. Bypassing around the grit tanks is also provided. After primary clarification in the two-40 foot diameter clarifiers, the wastewater bypasses the old trickling filter and intermediate clarifiers and flows to the pump station. The wastewater is either pumped to the inlet of the 14 foot high ABF tower (fixed growth contactor) or bypassed around the tower to the aeration tanks. Effluent from the ABF can also be recycled back to the inlet of the tower. The 136,000 gallon aeration tanks provide additional biological treatment prior to the treated wastewater entering the two 50 foot diameter final clarifiers. Sludge collected in the final clarifiers is recycled back to the inlet to the ABF tower and also wasted to the gravity thickener. After clarification, the treated wastewater is chlorinated and dechlorinated prior to the discharge of the final effluent to the Mississippi River. Two photos of the treatment plants operation are presented on Figures 5.6.4.2 and 5.6.4.3. Photo 1 is a view of the two covered secondary clarifiers and part of the activated sludge system in the foreground. Photo 2 is a view of the gravity thickener.

The waste activated sludge (WAS) is mixed with the primary sludge prior to thickening in the 37,000 gallon gravity thickener. Prior to December 2003, sludge handling operations shown on Figure 5.6.4.1 included the gravity thickener, a 321,000 gallon anaerobic digester, an 84,500 gallon bio-solids storage tank and an 11,000 square foot sludge drying bed. A new sludge handling operation was implemented in December 2003 to produce stabilized sludge classified as Class A biosolids. The treatment process involves additional sludge thickening using centrifuge technology for dewatering, followed by lime stabilization and then heat treatment (pasteurization) prior to the storage of the bio-solids for land application.

Raw wastewater and final effluent characteristics are summarized on Tables 5.6.4.1 and 5.6.4.2. These data represent the annual average of the monthly averages. The influent wastewater characteristics are as follows:

Table 5.6.4.1 - Monthly Average Raw Wastewater Characteristics
Little Falls WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)	$CBOD_5$/P
1.5	133	170	19.2	3.5	38

There was a large variability in the monthly average for $CBOD_5$, TSS and ammonia nitrogen (NH_4-N) in the influent. The $CBOD_5$ averaged 133 mg/L and ranged between 70 mg/L and 243 mg/L; TSS averaged 170 mg/L and ranged between 107 mg/L and 351 mg/L; ammonia nitrogen

Figure 5.6.4.2 - Covered Secondary Clarifiers, Little Falls WWTF

Figure 5.6.4.3 - Gravity Thickener, Little Falls WWTF

(NH_4-N) concentration averaged 19.2 mg/L and ranged between 3.50 mg/L and 37 mg/L. Total phosphorus (TP) levels averaged 3.48 mg/L and ranged between 1.78 mg/L and 4.94 mg/L. A summary of the plant performance is presented on Table 5.6.4.2. The plant is meeting monthly permit requirements for $CBOD_5$ and TSS, achieving greater than 90% removal of $CBOD_5$ and TSS. Effluent monitoring is the only permit requirement for ammonia nitrogen and total phosphorus.

Table 5.6.4.2 - Monthly Average Treatment Performance Summary
October 2002 – September 2003
Little Falls WWTF

	Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)
Average Performance	1.5	10.5	15.7	11.4	2.2
Permit Requirements	2.4	25	30	Monitor Only	Monitor Only
Percent Removal	----	92%	90.4%	NR	NR

See Appendix 2.6.4 for detailed monthly plant data analysis.
NR – Not Required

5.6.4.2 Design Basis for Modification for Phosphorus Removal

The evaluation of phosphorus removal alternatives was based on the design parameters presented in Table 5.6.4.3. This design basis was used to look at the expected removals for the various phosphorus removal alternatives that could be employed at the plant. There are two return streams at the Little Falls plant including: thickener overflows which are returned to the head of the plant and centrate from the centrifuge operations prior to lime stabilization and heat treatment. There were no data available on the thickener overflows waste, however centrate operations have been characterized. Centrate flow averaged 24,000 gpd (4 to 5 days per week) with a phosphorus concentration of 220 mg/L. A flow of 20,000 gpd was assumed for the design analysis while $CBOD_5$, TSS and TKN concentrations were unknown and were assumed to 5,000 mg/L for $CBOD_5$ and TSS sludge centrate) and 600mg/L for TKN. Based on plant information, a design low temperature of 8^{O} C was selected for use in developing the biological nutrient kinetics.

Table 5.6.4.3 – Process Design Basis Used for Evaluation of Phosphorus Removal Alternatives
Little Falls WWTF

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH4- N (mg/L)	TP (mg/L)	rbCOD (mg/L)
2.4	184	170	26.5	3.5	124

Process Step	Dimensions	Design Loading	Comment
Primary Clarifiers	2-40 ft. diameter 11.0 ft. SWD	715 gpd/sf	Possible point of chemical addition
Activated Biological Filter	Media Depth = 14 ft. Surface Area = 768 sf Media Volume = 10,752 cf	Organic Loading Rate = 165 lbs/d/1000 cf Hydraulic Loading Rate = 3.7 gpm/sf	Consider bypassing flow around if $CBOD_5$ is insufficient for EBPR
Activated Sludge	2 trains; 36 ft.long x 18 ft. wide w/ 14.0 ft. SWD	HRT = 1.36 hrs F/M = 0.71 SRT = 4.5 days	Plant does not nitrify; consider EBPR retrofit; facilities in place to add polymer to AS effluent troughs
Secondary Clarifiers	2-50 ft. diameter 12.0 ft. SWD	611 gpd/sf	Possible point of chemical addition

See Appendix 2.6.4 for summary of the design basis

Certain wastewater characteristics, removal rates and treatment plant operating conditions were either assumed or based on plant operating data for this analysis. Biodegradable COD (discussed in Section 4) was assumed to be equal to 1.6 times the $CBOD_5$ leaving the ABF Tower (149 mg/L) and the readily biodegradable COD (rbCOD), that fraction of the COD that is easily converted to volatile fatty acids (VFA) which are used by EBPR bacteria, was assumed to be 42% of the biodegradable COD. Also baseline phosphorus removal by primary treatment (without chemical addition) was assumed to be 10% of the influent concentration.

5.6.4.3 Evaluation of Phosphorus Removal Alternatives

The evaluation of phosphorus removal alternatives included developing conceptual designs and preliminary cost estimates for the viable alternatives. The alternatives reviewed included EBPR with and without the ABF tower, alum addition in the secondary clarifiers, and two stage chemical addition at the primary and secondary clarifiers. The preliminary design analysis indicates that EBPR and two stage chemical addition or chemical addition to the secondary clarifiers would meet a target effluent phosphorus of 1 mg/L. The design analysis is summarized in Table 5.6.4.4. In many cases the EBPR process-alone cannot meet a 1 mg/L target level when the BOD/P is between 25 and 35, and must be used in conjunction with chemical precipitation to consistently meet 1 mg/L of phosphorus. In the case of the Little Falls plant, however, the conceptual design analysis indicated that EBPR alone would meet the 1 mg/L phosphorus target. The low influent phosphorus concentration and the high $CBOD_5$ to phosphorus ratio greater than 38 would allow EBPR to achieve the required phosphorus removal performance. The analysis indicated that new external tankage would be required to implement EBPR with a volume requirement of 165,000 gallons. The analysis also indicated that, in addition to a slight increase in sludge production, a slightly larger tank would be needed for EBPR if the ABF tower were bypassed.

Table 5.6.4.4 - Summary of Plant Modifications and Chemical Requirements and Retrofit Needs for Phosphorus Removal Alternatives
Little Falls WWTF

Operating Condition	Units	EBPR w/ ABF Tower	EBPR w/o ABF Tower	Chemical Addition to Primary and Secondary Clarifiers	Chemical Addition Secondary Clarifier
Effluent P	Mg/L	0.5 to1.0	0.5 to1.0	0.5 to1.0	0.5 to1.0
Alum Addition	Lb/d	0	0	1716	2862
Alkalinty Depleted	Mg/L	0	0	38	64
Equipment Requirements	NA	New Tankage (0.165 MG) & Mixers	New Tankage (0.167 MG) & mixers	Chem Feed Pumps & Chem Storage (6000 gallons)	Chem Feed Pumps & Chem Storage (6000 gallons)
Primary Sludge Production	Lb/d	2760	2760	3130	2760
Secondary Sludge Production	Lb/d	910	920	640	910
Chemical Sludge Production	Lb/d	0	0	430	910
Total Sludge Production	Lb/d	3670	3680	4200	4580

Chemical precipitation is a reliable means of phosphorus removal and can be effective at either the primary or secondary clarifier. In the case of the Little Falls plant, the conceptual design analysis for alum addition indicates that effluent goals could be met through a two-point addition in the primary and secondary clarifiers, or alum addition to the secondary clarifiers. The analysis indicated that two-point addition of alum to the primary and secondary clarifiers would require less chemicals and produce less sludge than chemical addition only to the secondary clarifier. For all chemical treatment alternatives, two point chemical addition is the most cost effective phosphorus removal alternative. Alum addition would also result in the destruction of alkalinity. The conceptual design analysis also indicated alkalinity consumption of 38 mg/L and 64 mg/L for two-point and secondary clarifier alum addition, respectively. Since the plant does not nitrify, the need for supplemental alkalinity would be unlikely. A review of influent wastewater alkalinity characteristics as well as bench scale testing of alum dosage requirements as part of a detailed design is recommended to determine the need for supplemental alkalinity addition for pH control.

Preliminary budgetary cost estimates were developed based on the information presented in Section 4 and are presented in Table 5.6.4.5. The capital costs are presented as September 2004 US dollars and the present worth costs are based on the annual O&M costs over a 20 year operating period at an interest rate of 5%. The costs were rounded to the nearest $1,000.

The EBPR alternatives would have the highest capital costs estimated at $1,090,000 (the slight difference in tank volume was considered insignificant) while the chemical feed facilities would incur a capital cost estimated to be $145,000 and was based on the ability to feed chemicals to one or both locations. The highest O&M costs are associated with the chemical phosphorus removal alternatives. The preliminary conceptual design indicated lower chemical use and chemical sludge production associated with two-point chemical addition. O&M costs based on chemical requirements, labor cost and sludge disposal costs were estimated to be $77,000 and $134,000, respectively, for two-point chemical addition and alum addition to the secondary clarifier only. These costs includes alum, chemical sludge disposal and labor. O&M costs for EBPR were substantially lower than those for the chemical addition alternatives. The present worth for the EBPR alternatives would be $1,264,000 (which includes a back-up chemical feed system) while the chemical addition alternatives would be $1,279,000 and $2,002,000 for two-point chemical addition and alum addition to the secondary clarifiers only, respectively. The present worth analysis indicated that the cost comparison between the cost for the EBPR system and two-point chemical addition was basically the same. The present worth analysis for Little Falls indicated that there would be a cost benefit of $15,000 after 20 years for the EBPR alternate. The estimated capital costs for retrofitting the plant with the EBPR process would be $1,090,000 compared to $145,000 for a two-point chemical addition treatment system.

It should be noted that the capital expenditure for implementation of EBPR would be 7.5 times higher than the estimated capital cost for chemical addition. While the EBPR annual O&M cost savings comparison with chemical addition would be significant, the payback period for electing EBPR over chemical addition would be approximately 12 years. Based on the cost comparison and

Table 5.6.4.5 - Preliminary Cost Estimates for Retrofit for Phosphorus Removal
with Different Process Options
Little Falls WWTF

Cost Factors	EBPR w/ ABF Tower	EBPR w/o ABF Tower	Chemical Addition to Primary and Secondary Clarifier	Chemical Addition Secondary Clarifier
Effluent P (mg/L)	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0
Preliminary Capital Costs	\$1,090,000(1)	\$1,090,000(1)	\$145,000	\$145,000
Preliminary O&M Costs (\$/year)	\$14,000	\$14,000	\$91,000	\$149,000
Present Worth	\$1,264,000	\$1,264,000	\$1,279,000	\$2,002,000

(1)Includes cost for back-up chemical feed system

present worth analysis, the two-point chemical addition treatment system is the most cost effective alternative. A more in depth review of the EBPR alternatives would be needed to determine benefits of continued use of the ABF tower.

Additional options that Little Falls might consider for addressing their phosphorus discharge limitations would be source control and phosphorus trading. Based on MPCA phosphorus strategy guidelines, source control is not an issue at Little Falls. The influent phosphorus level of 3.5 mg/L does not indicate a large industrial contribution of phosphorus and no industrial inputs of consequence were noted by plant personnel (ethanol plant with treatment contributes less than 5 mg/L P). However, a review of plant data indicated seasonal spikes in $CBOD_5$ greater than 200 and phosphorus greater than 4 during the winter months (January through March) of 2003 and two or three of their seven lift stations showing phosphorus levels above 10 mg/L. Therefore, a review of source control may be beneficial. Phosphorus trading would involve purchasing phosphorus removal capacity from another plant. If excess phosphorus capacity were available from a nearby wastewater treatment plant their excess capacity would be purchased like a commodity.

5.7 LAGOONS

The two lagoon systems evaluated for phosphorus removal were the 0.824 MGD Redwood Falls WWTP and 2.6 MGD Thief River Falls WWTP. The following summarizes the analysis of each plant.

5.7.1 Redwood Falls WWTP

The Redwood Falls Wastewater Treatment Plant (Redwood Falls WWTP) is a large lagoon system consisting of two sets of lagoons, the Redwood Falls Lagoons, which include a separate stage submerged media nitrification system, and the Regional Lagoons. Each lagoon system consists of three lagoons. Another set of lagoons treating wastewater from the single major industry, Central Bi-Products, also contributes their treated effluent to the Regional Lagoons. Figure 5.7.1.1a and 5.7.1.1b are schematic diagrams that show the configuration of the lagoons. Figure 5.7.1.1a shows the flow diagram of the Redwood Falls Lagoons. The Regional Lagoons are shown on Figure 5.7.1.1b. The first two Regional Lagoons are used as polishing lagoons for the Central Bi-Products lagoon system. The total flow from the Redwood Falls Lagoons and Central Bi-Products is combined in the last Regional Lagoon before discharge to the Minnesota River.

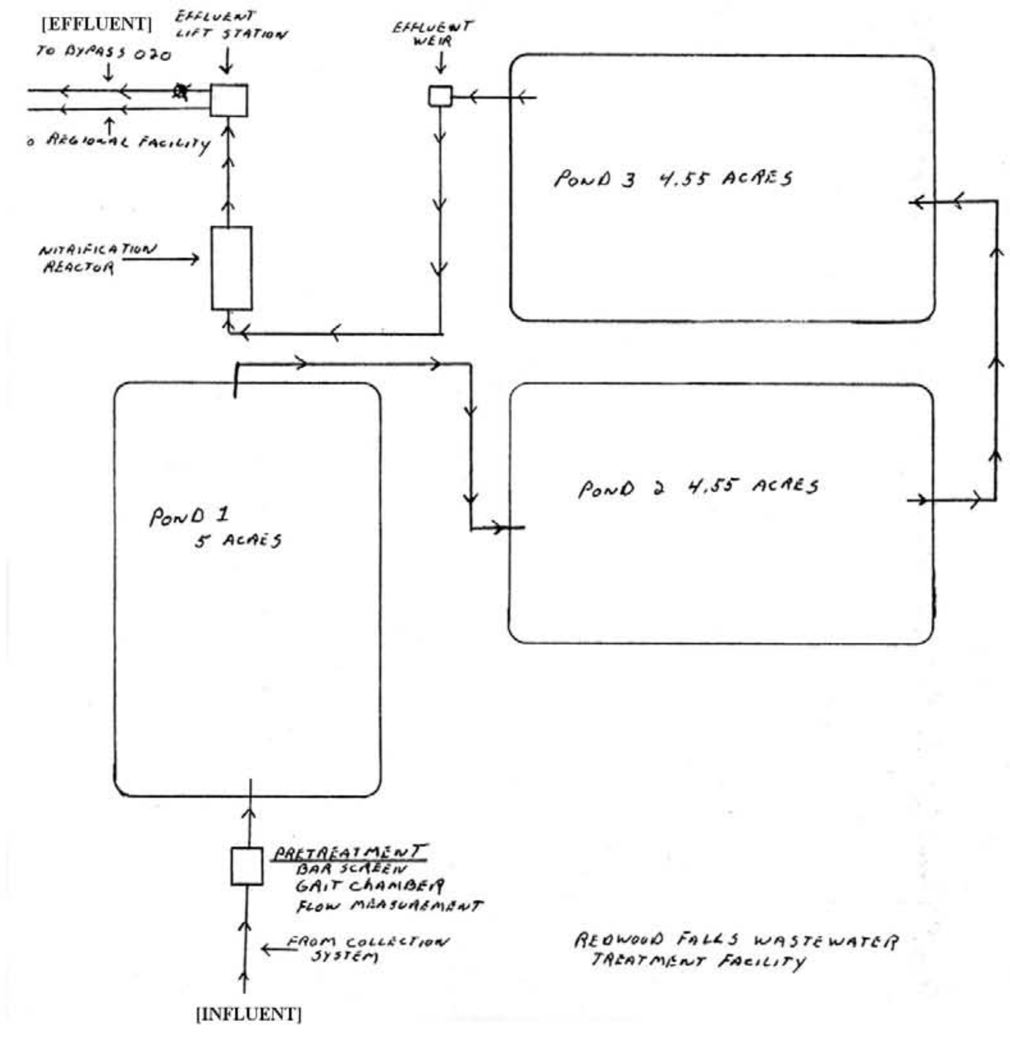
5.7.1.1 Plant Description and Performance

The Redwood Falls Lagoons are each approximately 11 to 12 million gallons (MG), 4.6 to 5 acres and 10 feet deep. The detention time of the Redwood Falls Lagoons at the design flow of 0.8 MGD is approximately 42 days. These lagoons use static tube aerators with the highest aerator density in the first lagoon, lower densities in the second and third lagoon. The Redwood Falls Lagoons discharge to a six cell submerged media nitrification process. This process is supplemented with EcoBac bacteria during the summer.

The Regional Lagoons, which are considered tertiary lagoons, are each approximately 5.75 MG, 1.9 acres and 13 feet deep. These lagoons are aerated with floating jet aerators. The first two Regional Lagoons receive flow from Central Bi-Product's lagoon system and are operated in parallel. The effluent from the first two Regional Lagoons is blended with the effluent from the Redwood Falls Lagoons in the third Regional Lagoon before discharge to the Minnesota River.

Although the design detention time of the Regional Lagoons is approximately 21 days, the actual detention time is less than this because of the current lagoon configuration. Using the first two lagoons to polish the Central Bi-Products wastewater provides approximately 140 days of detention time for this wastewater. Central Bi-Products is a large rendering operation. It discharges about 17 mg/L of phosphorus at 30 MG per year (4,253 lbs/yr).

The third Regional Lagoon provides an additional 7 days of detention time for the combined wastewater (Redwood Falls WWTP plus Central Bi-Products). In the current configuration both lagoon systems provide a detention time of approximately 49 days at the design flow of 0.824 MGD for the Redwood Falls WWTP wastewater. Figure 5.7.1.2 is a view of the first Redwood Falls Lagoon showing the degree of aeration and density of the static tube aerators. Figure 5.7.1.3 is a view of one of the Regional Lagoons showing the jet aerators.



Source:
Redwood Falls, WWF

Figure 5.7.1.1a - Schematic Process Flow Diagram, Redwood Falls WWTP

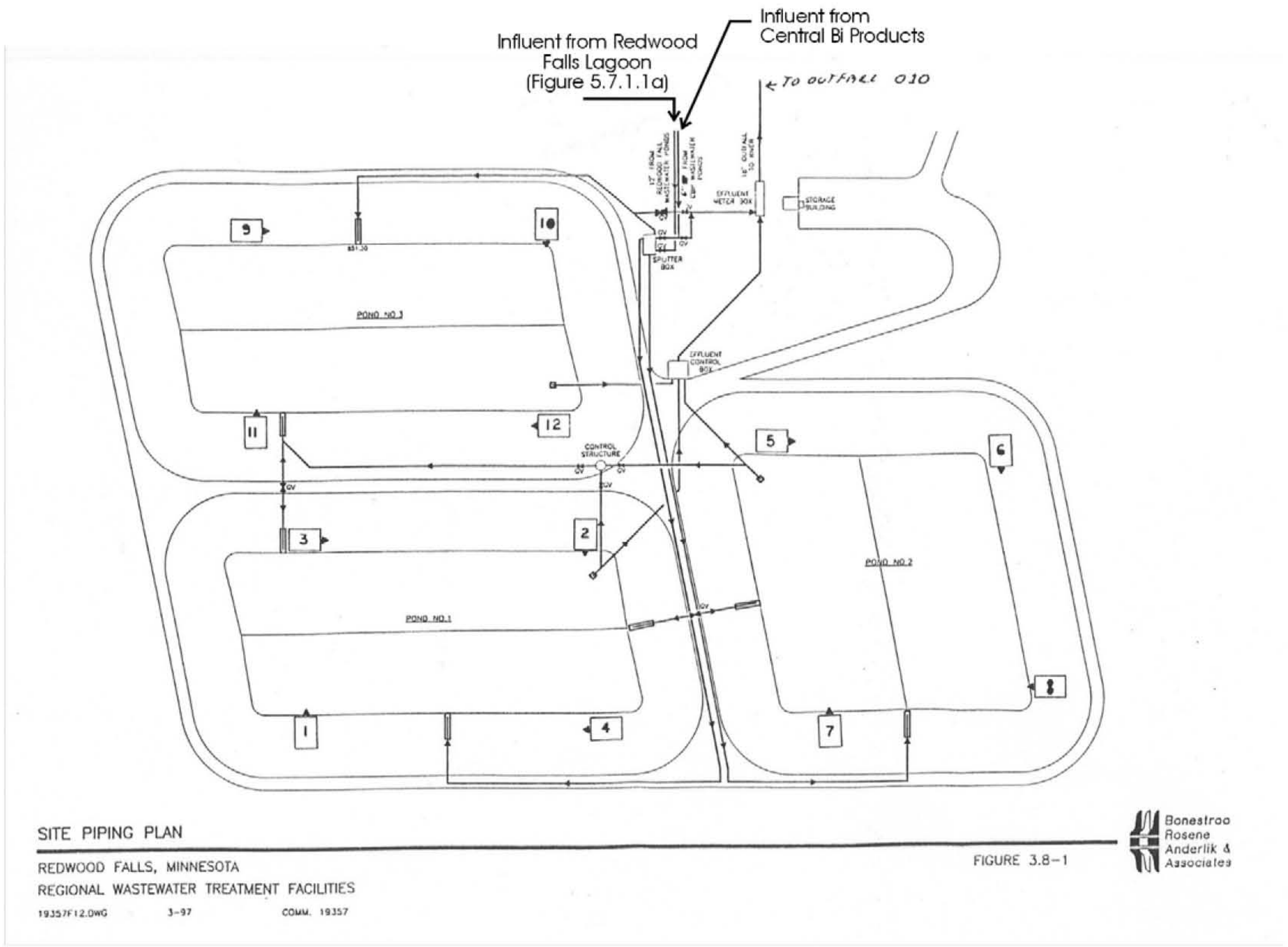


Figure 5.7.1.1b - Schematic Process Flow Diagram; Regional Ponds, Redwood Falls WWTP

Figure 5.7.1.2 - First Lagoon, Redwood Falls WWTP

Figure 5.7.1.3 - Regional Lagoon, Redwood Falls WWTP

Influent and effluent plant data were reviewed to develop the raw wastewater and final effluent characteristics to evaluate the plant performance, and for the phosphorus removal analysis. Plant influent is analyzed for $CBOD_5$ and TSS. Plant effluent is analyzed for these parameters plus ammonia nitrogen (NH_4-N) and total phosphorus. Influent wastewater and final effluent characteristics are summarized on Tables 5.7.1.1 and 5.7.1.2 for the period of October 2002 through September 2003. These data represent the monthly average results for the parameters analyzed plus plant flow. Appendix 2.7.1 presents summary tables on wastewater characteristics and plant performance. The total plant influent characteristics are as follows:

Table 5.7.1.1 - Monthly Average Raw Wastewater Characteristics
Redwood Falls WWTP

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)
0.70	200	297	NR	NR

NR – Not Required

Table 5.7.1.2 - Monthly Average Treatment Performance Summary
October 2002 – September 2003
Redwood Falls WWTP

	Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	Unionized Ammonia (mg/L)	TP (mg/L)
Average	0.76	8.3	33	7.24	0.23	2.85
Observed Removal	NR	99.6%	88.4%	NA	NA	NA
Permit Requirements	0.8003	25	45	7.5 (June to Sept) 9.7 (Oct to Nov) 94 (Dec to March) 64 (April to May)	1.0	Monitor Only
Removal Requirements	NR	85%	85%	NR	NR	NR

See Appendix 2.7.1 for detailed monthly average plant data analysis
NR – Not required
NA – Not Available

The variability of influent $CBOD_5$ was not very significant. It averaged 200 mg/L and ranged from 124 mg/L to 258 mg/L. Influent TSS did exhibit a significant degree of variability averaging 297 mg/L with a range of 194 to 549 mg/L.

As previously mentioned, there is only one major industrial contributor, Central Bi-Products. They operate a rendering and meat by-products processing facility that includes feather processing, hide curing and pet food production. Central Bi-Products pretreatment system consists of a covered anaerobic lagoon followed by two dissolved air flotation units and then three lagoons operated in series. Central Bi-Products discharges approximately 30 MG per year of wastewater to the Regional Lagoon system containing approximately 17 mg/L of phosphorus (4,253 pounds per year).

The plant effluent characteristics are summarized on Table 5.7.1.2 along with permit requirements and percent removals. The plant has effluent permit limits for $CBOD_5$, TSS, NH_4-N and unionized ammonia nitrogen. Monthly monitoring is the only requirement for total phosphorus (TP). Plant effluent flow is slightly higher than influent flow (0.76 MGD vs. 0.70 MGD) due to the discharge from Central Bi-Products. The plant is operating well within permit limits of 25 mg/L monthly averages for $CBOD_5$ and 45 mg/L for TSS. The plant achieved greater than 99% removal of $CBOD_5$ and 88% removal of TSS with an average effluent concentration of 8.3 mg/L and 33 mg/L, respectively. The 2002-2003 monthly average discharge concentration for ammonia nitrogen was 7.2 mg/L, which was less than the lowest limit for any season (7.5 mg/L). All seasonal effluent ammonia limits were met. The average monthly effluent concentration for unionized ammonia nitrogen was 0.23 mg/L which is also less than the limit of 1.0 mg/L. All monthly average effluent unionized ammonia results met the limit of 1.0 mg/L. The plant is meeting all permit requirements year-round.

The average phosphorus discharge level was 2.85 mg/L. The influent wastewater is not tested for phosphorus; therefore, current removals cannot be assessed. There is an apparent seasonal removal of phosphorus in the lagoons based on observed effluent concentrations. Effluent phosphorus ranged from 3.0 to 5.4 mg/L between December 2002 and May 2003. Between June and November effluent phosphorus ranged from 0.73 to 1.5 mg/L suggesting that some phosphorus removal occurs during summer and fall, probably due to algal uptake. During October and November of 2002, the effluent phosphorus concentration was <1 mg/L as shown in Table 5.7.1.2. Additional data provided for August and September 2002 also reaffirmed the removal with effluent concentrations of 0.83 and 0.73 mg/L respectively.

The Redwood Falls Lagoons also produce a significant population of minnows which supports a resident population of predatory birds. A few years ago the plant chemically treated the lagoons to reduce the minnow population. They removed seven 1-ton truck loads of dead minnows but many survived and the lagoons continue to have a significant minnow population.

5.7.1.2 Design Basis for Modifications for Phosphorus Removal

The evaluation of phosphorus removal alternatives was based on the design basis presented in Table 5.7.1.3. The table summarizes flow and wastewater characteristics used to assess the phosphorus removal alternatives. It also summarizes the facilities available to be retrofitted for phosphorus removal if it is determined that excess capacity exists. The only opportunity for phosphorus removal at Redwood Falls WWTP is to incorporate chemical addition to the lagoons. Some removal is already experienced seasonally; however, removal throughout the year can only be accomplished by chemical treatment.

The Redwood Falls WWTP plant does not analyze the influent wastewaters for phosphorus. An influent concentration of 4 mg/L was used in this analysis. It was based on an average of 4 mg/L present in the effluent between December and May. This concentration was the basis for developing chemical requirements and sludge production.

Table 5.7.1.3 – Process Design Basis Used for Evaluation of Phosphorus Alternatives
Redwood Falls WWTP

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	TP (mg/L)
0.824	200	297	4

Process Step	Dimensions	Design Loading	Comment
Redwood Falls Lagoons	3 – 4.6 to 5 ac, 10 ft deep	42 day HRT	Accomplishes seasonal removal, can accept chemical addition
Regional Lagoons	3 – 1.9 ac, 13 ft deep	21 day HRT (design) 7 day HRT (current operations)	Accomplishes seasonal removal, can accept chemical addition

See Appendix 2.7.1 for summary of the design basis.

5.7.1.3 Evaluation of Phosphorus Removal Alternatives

The evaluation of phosphorus removal alternatives included developing conceptual designs and preliminary cost estimates for the viable alternatives. The only viable phosphorus removal alternative for the Redwood Falls WWTP plant is chemical treatment. EBPR alternatives are not compatible with lagoon treatment systems because there is not enough control of the biological processes to promote the growth of EPBR bacteria.

Chemical addition is capable of meeting the effluent target of 1 mg/L; however it does produce sludge and consumes alkalinity. Chemical addition can be accomplished as single or two-point addition. For the process to be successful at Redwood Falls, chemicals should, at a minimum, be added to the influent to the last Regional Lagoon. This is the only point where all the wastewaters are blended. Alternatively, chemicals could also be added to one of the Redwood Falls Lagoons to accomplish partial phosphorus removal but chemical addition would still be required in the last Regional Lagoon to treat the phosphorus contributed by Central Bi-Products.

A summary of the chemical addition process is presented in Table 5.7.1.4. The table summarizes the calculated effluent phosphorus concentration, chemical requirements (alum and alkalinity), sludge production and facility requirements (chemical storage and piping) for each of the alternatives considered.

Table 5.7.1.4 - Summary of Plant Modifications and Chemical Requirements and Retrofit Needs for Phosphorus Removal Alternatives
Redwood Falls WWTP

Option	Units	Chemical Addition to Redwood Falls WWTP and Regional Lagoons	Chemical Addition Regional Lagoons
Effluent P	mg/L	0.5 to 1.0	0.5 to 1.0
Chemical Addition	lb/d	550	850
Additional Sludge Production	lb/d	700	425
Alkalinity added	lb/d	250	375
Chemical Storage	Yes/No	Yes	Yes
Pumps/Piping	Yes/No	Yes	Yes

Biological processes that occur in the lagoons will consume approximately 0.5 mg/L phosphorus leaving 2.5 to 3.5 mg/L for chemical removal. Single point addition applied to the last Regional Lagoon would require the addition of 836 pounds of alum per day, and will produce an additional 425 pounds per day of sludge. This is an increase of approximately 14% above the current calculated sludge production levels of 3000 pounds per day. Single point chemical addition would also consume 375 pounds of alkalinity.

Two-point addition could be practiced in the Redwood Falls WWTP and Regional Lagoons as described earlier. The best location for chemical addition to the Redwood Falls Lagoons would be the first lagoon which has a high degree of mixing due to aeration. The analysis targeted removal of approximately 2 mg/L of phosphorus in the lagoon. For the remaining 2 mg/L, approximately 0.5 mg/L was removed by biological uptake. Chemical addition to the last Regional Lagoon was based on an influent phosphorus of 1.5 mg/L. The two-point chemical addition process requires approximately 550 pounds per day of alum and will produce approximately an additional 700 pounds per day of sludge, an increase of 23%. The higher sludge production is related to enhanced removal of TSS in the Redwood Falls Lagoon receiving alum. The alkalinity requirement for two-point chemical addition would be approximately 250 pounds per day. In both the single and two-point chemical addition alternatives the alkalinity consumption translates to approximately 18 to 30 mg/L as $CaCO_3$. This is probably not high enough to depress effluent pH below the permit limit of 6.0.

Chemicals can be applied to the lagoons in a number of ways. For lagoons that operate with continuous flow, like the Redwood Falls WWTP, the best way to apply chemicals would be in the vicinity of the aerators which will provide mixing of the chemicals between lagoons, in which case some supplemental mixing might be required. Chemicals could also be injected near each of the static aerators at the front end of the first Redwood Falls Lagoon and/or at the jet aerators in the Regional Lagoons. Both locations would take advantage of the mixing produced by the aerators.

Preliminary budgetary cost estimates were developed based on the information presented in Section 4 and are presented in Table 5.7.1.5. The capital costs are presented as September 2004 US dollars and the present worth costs are based on the annual O&M costs over a 20 year operating period at an interest rate of 5%. The capital cost for two-point chemical addition would be approximately $90,000 with O&M costs of $46,000 per year which translates to a present worth cost of $663,000. Although the capital cost for single-point chemical addition would be the same, the present worth cost is higher at $726,000. This is related to the larger alum design requirement and higher chemical sludge production for single point chemical addition.

Table 5.7.1.5 – Preliminary Cost Estimates for Retrofit for Phosphorus Removal
with Different Process Options
Redwood Falls WWTP

Cost Factors	Chemical Addition to Redwood Falls WWTP and Regional Lagoons	Chemical Addition to Regional Lagoons
Effluent P (mg/L)	0.5 to 1.0	0.5 to 1.0
Preliminary Capital Cost	$90,000	$90,000
Daily Operating Costs $/d		
EBPR	0	0
Alum	76	84
Alkalinity	0	0
Sludge Disposal	16	24
Annual Labor Cost – Chemicals Only	$12,000	$12,000
Total Annual Operating Cost	$46,000	$51,000
Present Worth Operating Cost	$573,000	$636,000
Total Present Worth	$663,000	$726,000

The plant is considering phosphorus trading as a solution to any future phosphorus limit. They might be able to purchase excess phosphorus removal capacity from another municipal wastewater treatment plant at a cost of $1.70 per pound per year. At an average annual effluent phosphorus concentration of 2.85 mg/L and the design flow of 0.824 MGD, the annual cost for phosphorus effluent trading would be approximately $12,200 compared to an annual O&M cost for two-point chemical treatment of $34,000. The Redwood Falls WWTP should pursue phosphorus trading if it is a viable option.

5.7.2 Thief River Falls WWTP

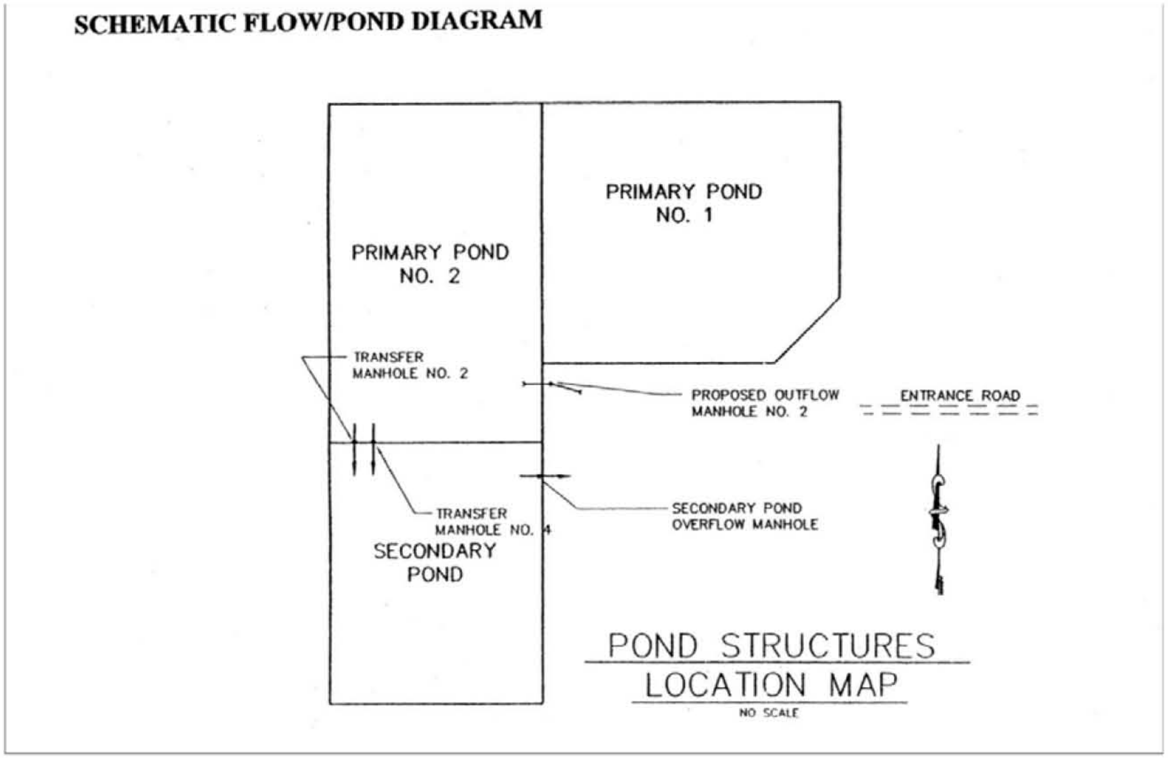
The Thief River Falls Wastewater Treatment Plant (Thief River Falls WWTP) is an aerobic-anaerobic stabilization pond system providing secondary biological treatment using three large ponds operating in series. The design flow is 2.57 MGD and the current flow is 1.24 MGD based on the data analyzed for the period of October 2002 to September 2003. The ponds store the wastewater for most of the year except for a period during late spring through the summer when the treated wastewater is discharged to the Red Lake River.

5.7.2.1 Plant Description and Performance

A schematic diagram of the pond wastewater treatment system is shown on Figure 5.7.2.1. The biological treatment system consists of two primary ponds (each 131 acres) followed by an 88 acre secondary pond for effluent polishing. The operating depth of the ponds ranges from 2 to 6 feet. The plant treats and stores the wastewaters in the ponds during most of the year with discharges to Red Lake River normally during the period of May through September. The discharge is based on water quality data (i.e. $CBOD_5$, TSS, pH) monitored in the secondary pond prior to discharge, and that the operating water level in the pond is greater than 2 feet. Figure 5.7.2.2 is a view of the two primary ponds with Primary Pond 1 in the center of the photo. Figure 5.7.2.3 is a view of the secondary pond at the outlet to the Red Lake River.

The plant receives three major industrial loads from Northern Pride poultry processing plant, Dean Foods dairy operations and the Arctic Cat off-road vehicle manufacturing facility. The largest industrial plant is Northern Pride which processes turkeys from May through November. During this period, Northern Pride wastewater flow averaged 0.303 MGD and ranged between 0.047 MGD to 0.408 MGD. The concentration of $CBOD_5$ and TSS average 493 mg/L and 448 mg/L, respectively and ranged from 200 mg/L to greater than 700 mg/L. The total phosphorus (TP) level averaged 11 mg/L with a range between 8 and 13 mg/L.

Dean Foods plant is a year round operation with high concentration of $CBOD_5$, TSS and total phosphorus in its wastewater. The $CBOD_5$ monthly average was 3,105 mg/L, TSS was 836



Source:
Thief River Falls WWTP

Figure 5.7.2.1 - Schematic Process Flow Diagram, Thief River Falls WWTP

Figure 5.7.2.2 - Two Primary Ponds, Thief River Falls WWTP

Figure 5.7.2.3 - Secondary Pond Outlet, Thief River Falls WWTP

mg/L and total phosphorus was 35 mg/L. The wastewater flow was consistent averaging 0.045 MGD and ranging between 0.039 and 0.056 MGD. Arctic Cat, a snowmobile and all terrain vehicle manufacturer, contributed a daily flow of 0.06 MGD with low levels of CBOD, TSS and total phosphorus.

Plant influent characteristics are summarized in Table 5.7.2.1. The influent characteristics are higher than $CBOD_5$ and total phosphorus found in domestic wastewaters and reflect the impact of the food processing plants discharge loadings.

Table 5.7.2.1 - Raw Wastewater Characteristics - Annual Monthly Averages
Thief River Falls WWTP

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	Total P (mg/L)	BOD:P
1.44	260	207	not sampled	15.8	16.5

The treatment ponds performance is summarized in Table 5.7.2.2. The plant is meeting permits limits for $CBOD_5$ and TSS.

Table 5.7.2.2 – Monthly Average Treatment Performance Summary
May, June, September 2003
Thief River Falls WWTP

	Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)
Average Performance (1)	1.37	6.0	24.0	4.1(1)	2.7(1)
Permit Requirements	2.51	15	45	Monitor only	Monitor only
Percent Removal	--	97.7%	85.2%	--	--

See Appendix 2.7.2 for detailed monthly plant data analysis.

(1) Discharge is intermittent during the year. For approximately 7 months, the wastewater is stored in the ponds for treatment. The plant normally discharges the treated effluent to Red Lake River during the period of May through September. For the study period of October 2003-September 2002, the plant discharged in the months of May, June and September. The plant is required only to monitor for ammonia nitrogen (NH_4-N) and total phosphorus (TP).

5.7.2.2 Design Basis for Modification for Phosphorus Removal

The evaluation of phosphorus removal was based on the design basis presented in Table 5.7.2.3. Certain wastewater characteristics were either assumed or based on plant operating data.

The plant design $CBOD_5$ influent concentration is 250 mg/L, however, the actual observed average $CBOD_5$ was 260 mg/L and therefore the higher concentration value was used for the design basis. There was no design basis information available for TSS and total phosphorus therefore the observed average concentrations were used. Pond sizes and design loadings are also presented and were used in the process design analysis on phosphorus removal.

5.7.2.3 Evaluation of Phosphorus Removal Alternatives

The evaluation of phosphorus removal alternatives included developing conceptual designs and preliminary cost estimates for the viable alternatives. The only viable phosphorus removal alternative for the Thief River Falls plant is chemical treatment. EBPR alternatives are not compatible with lagoon treatment systems because there is insufficient control of the biological processes to selectively favor the growth of EBPR bacteria. The preliminary design analysis indicates that chemical addition can meet a target goal of 1 mg/L total phosphorus in the final effluent. Two different application scenarios were reviewed, one with chemical addition in the initial primary lagoon cell followed by chemical addition in the secondary pond and the second being single point addition immediately following the second primary lagoon cell. In the case of chemical addition in the secondary pond only, two scenarios were evaluated. The first case was based on the influent phosphorus concentration of 9.90 mg/L which represented no biological uptake in the two upstream cells. This was a worst case scenario. The second scenario was selecting a phosphorus concentration of 2.70 mg/L which represented the average effluent phosphorus concentration when the plant was selectively discharging. The design analysis is summarized in Table 5.7.2.4.

Table 5.7.2.3 – Process Design Basis Used for Evaluation of Phosphorus Removal Alternatives
Thief River Falls WWTP

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	TP (mg/L)
2.57	260	207	11

Process Step	Dimensions	Design Loading	Comment
Primary Ponds	2 @ 131 acres 2-6 ft. operating depth	100 day HRT each @ max operating depth	No existing facilities for chemical addition or sludge removal
Secondary Pond	1 @ 88 acres 2-6 ft. operating depth	67 day HRT @ max operating depth	Plant discharges effluent when effluent meets permit limits; current operation removes ~ 70% of incoming phosphorus

See Appendix 2.7.2 for summary of design basis

Table 5.7.2.4 - Summary of Plant Modifications and Chemical Requirements and Retrofit Needs for Phosphorus Removal Alternatives
Thief River Falls WWTP

Operating Condition	Units	Chemical Addition to Plant Influent and Secondary Pond	Chemical Addition to Secondary Pond (w/o Bio Reduction)	Chemical Addition to Secondary Pond (using observed Effluent Data)
Effluent P	mg/L	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0
Alum Dosage	mg/L	367	375	88
Chemical Addition	lb/d	7861	8027	1893
Alum Sludge Produced	lb/d	1833	2562	604
Alkalinity Depleted	mg/L as $CaCO_3$	83	84	20

The design analysis showed that chemical addition to the secondary pond required the lowest alum dosage and chemical addition, 88 mg/L and 1,893 lbs/day respectively. This was based on using the observed effluent phosphorus data. These rates also indicated the lowest sludge production and alkalinity depletion rates of 604 lbs of sludge/day and 20 mg/L of alkalinity depletion. The impact of sludge production and alkalinity are considered negligible.

Preliminary budgetary cost estimates were developed based on the information presented in Section 4 and are presented in Table 5.7.2.5. The capital costs are presented as September 2004 US dollars and the present worth costs are based on the annual O&M costs over a 20 year operating period at an interest rate of 5%. The costs were rounded to the nearest $1,000.

Given the large variation in chemical application rates, the capital cost for each alternative was based on chemical application rates related to phosphorus levels at various points of application and not on plant flows. Since the plant does not process sludge, the annual O&M cost for this analysis was based on chemical and labor cost. The table shows that chemical addition to the secondary pond (using the current observed effluent data) would be the most cost effective alternative with the lowest present worth cost and the lowest capital and O&M costs.

Chemical precipitation is a reliable means of phosphorus removal across multiple points of application. However the point of application and the quantity of phosphorus removed significantly impacts the required chemical dosage, sludge production and the need for supplemental alkalinity. The lowest cost chemical precipitation option for the Thief River Falls Plant is to continue their practice of effluent storage and seasonal discharge with chemical addition to the secondary pond. This utilizes the maximum potential of the system to naturally remove phosphorus prior to chemical addition. Such an option would not be possible with a continuous flow system or if the plant flow increased such that discharge flexibility were impacted. The shorter detention times and discharge during cold winter months would result in reduced biological activity and diminished effluent quality including higher TP.

Table 5.7.2.5 – Preliminary Cost Estimates for Retrofit for Phosphorus Removal
with Different Process Options
Thief River Falls WWTP

Operating Condition	Chemical Addition to Plant Influent and Secondary Pond	Chemical Addition to Secondary Pond (w/o Bio Reduction)	Chemical Addition to Secondary Pond (using Observed Effluent Data)
Effluent P (mg/L)	0.5 to 1.0	0.5 o 1.0	0.5 to 1.0
Preliminary Capital Costs – Traditional Chemical Feed System (Alum Feed only)	$255,000	$260,000	$147,000
Preliminary O&M Costs ($/year)	$372,000	$402,000	$103,000
Present Worth	$4,891,000	$5,270,000	$1,431,000

Chemical injection in lagoons is more difficult to implement than in an existing clarifier or a dedicated reaction vessel and clarifier. Since lagoons are quiescent ponds, maximum chemical contact with the pond contents is critical. Available methods include: direct injection in a mixing chamber located between the last two cells of the treatment system or by adding a new flash mix, flocculation and settling process; batch treatment using liquid chemical applied by motor boat; and by automated circulating equipment. Direct injection is a common practice in the State of Michigan while batch treatment by motor boat is typical of treatment employed in the State of Minnesota. Batch application by automated circulation equipment was successfully piloted at two plants in Minnesota in 2003. Batch treatment would provide the lowest capital cost investment since the treatments could carried out using the tanker delivery trucks avoiding the high cost of a heated building to store and feed chemicals. Batch treatment by boat would likely have the lowest capital cost but the highest labor cost. An additional factor to consider would be the added safety concerns imposed by chemical application by motor boat. The best approach for chemical addition in lagoons was not evaluated or recommended in this report, as it is outside the scope of the project and highly site specific.

Additional options that Thief River Falls might consider for addressing the phosphorus discharge limitations include source reduction, phosphorus trading and alternate disposal methods. Based on MPCA phosphorus strategy guidelines, Thief River Falls should investigate source control as a means of reducing phosphorus levels in their discharge. At an influent total phosphorus level of 11 mg/L and two industries which may contribute more than a one-third of the daily phosphorus loading, an assessment of industrial contributions and pretreatment would reduce the plant influent phosphorus load and result in lower levels of phosphorus in the plant effluent. Phosphorus trading would involve purchasing phosphorus removal capacity from another plant. If excess phosphorus capacity was available from a nearby wastewater treatment plant, their excess capacity would be purchased like a commodity. Disposal via infiltration or spray irrigation, as evidenced in other Minnesota discharge permits, would provide an additional option for evaluating viable phosphorus reduction alternatives.

5.8 ROTATING BIOLOGICAL CONTACTORS (RBC)

The 3.613 MGD Brainerd and Baxter (Brainerd Area) Wastewater Treatment Plant (Brainerd Area WWTP) was the only RBC process evaluated for phosphorus removal. The following presents a summary of the analysis.

5.8.1 Brainerd Area WWTP

The Brainerd Area WWTP is an attached growth secondary treatment system using rotating biological contactors (RBC). The design flow is 3.13 MGD and peak design flow is 6.28 MGD. The existing flow is 2.61 MGD.

5.8.1.1 Plant Description and Performance

The process flow diagrams for the wastewater and sludge treatment are depicted on Figure 5.8.1.1. The influent entering the plant is initially treated for grit removal, followed by flow monitoring and screening. After preliminary treatment, the wastewater flows to the two parallel rectangular clarifiers prior to biological treatment in the RBCs. The RBC system is two parallel trains of 12 RBCs, and each train acts in series as the wastewater flows from contactor to contactor from the inlet to the outlet. The treated wastewater from each RBC train then flows to one of the two covered 65 foot diameter secondary clarifiers. The clarified effluent is then disinfected and dechlorinated prior to the discharge of the final effluent to the Mississippi River. Sludge handling involves primary anaerobic digestion of the sludges from the primary and secondary clarifiers followed by secondary digestion. The stabilized sludge is stored in the sludge storage tank. The biosolids are land applied in the spring and fall. The digester gas is used to heat the primary digester.

Figure 5.8.1.2 is an aerial view of the treatment plant. The photo shows the headworks building next to the rectangular primary clarifiers followed by the covered RBC system. In the background, the covered secondary clarifiers and the chlorination and dechlorination facilities can be seen. Figure 5.8.1.3 is a close up view of the primary clarifiers with the RBC treatment system and secondary clarifiers in the background.

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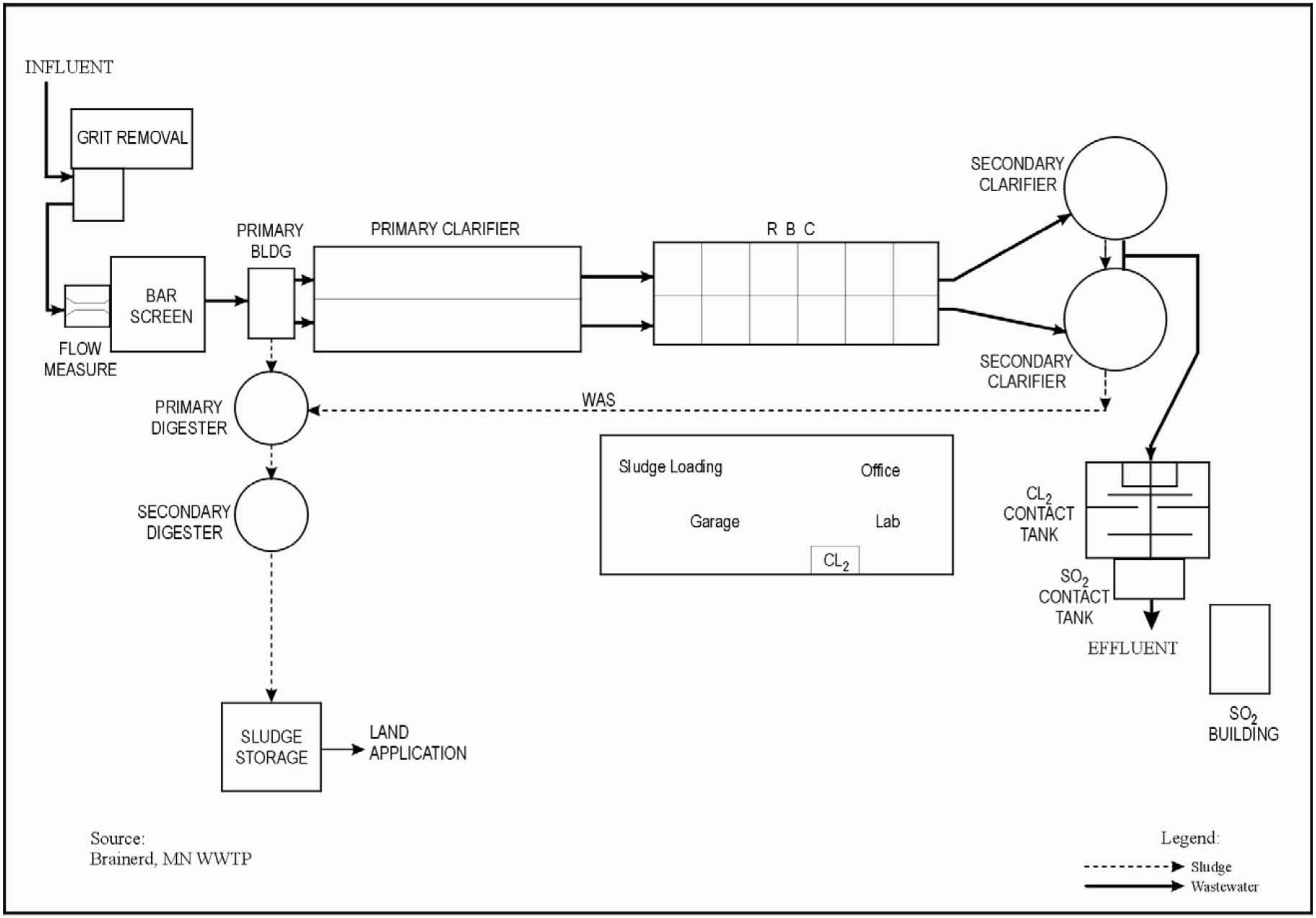

Source:
Brainerd, MN WWTP

Figure 5.8.1.1 - Schematic Process Flow Diagram, Brainerd Area WWTP

Figure 5.8.1.2 - Treatment Plant Aerial View, Brainerd Area WWTP

Figure 5.8.1.3 - Primary Clarifiers, Brainerd Area WWTP

Raw wastewater and final effluent characteristics are summarized in Tables 5.8.1.1 and 5.8.1.2. The data represent the average of the monthly averages for $CBOD_5$, TSS, and total phosphorus (TP). The average influent characteristics are as follows:

Table 5.8.1.1 – Monthly Average Raw Wastewater Characteristics
Brainerd Area WWTP

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	Ammonia Nitrogen (mg/L)	Total P(mg/L)
2.61	167	152	not sampled	5.6

Influent wastewater characteristics were relatively consistent. The $CBOD_5$ averaged 167 mg/L and ranged between 133 mg/L and 207 mg/L. TSS averaged 152 mg/L and ranged between 123 mg/L and 179 mg/L. Total P concentration averaged 5.6 mg/L and ranged from 3.2 mg/L to 7.6 mg/L.

The RBC performance during the October 2002 to September 2003 period is summarized in Table 5.8.1.2. The table presents the monthly average effluent concentrations for $CBOD_5$, TSS, NH_4-N, and total phosphorus, the permit requirements for these parameters, and the percent removals for $CBOD_5$ and TSS. The data show that the plant is meeting the permit requirements for $CBOD_5$ and TSS and had removal efficiency of 93.1% for $CBOD_5$, and 94.6% for TSS. The plant is required to monitor only for ammonia nitrogen (NH_4-N) and total phosphorus (TP) on a monthly basis

Table 5.8.1.2 - Monthly Average Treatment Performance Summary
October 2002 – September 2003
Brainerd Area WWTP

	Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	NH_4-N (mg/L)	TP (mg/L)
Average Performance	2.61	11.4	8.2	17.7	2.9
Permit Requirements	3.13	25	30	Monitor Only	Monitor Only
Percent Removal	--	93.1%	94.6%	--	--

See Appendix 2.8.1 for detailed monthly plant data analysis.

5.8.1.2 Design Basis for Modifications for Phosphorus Removal

Attached growth processes are poorly suited for EBPR retrofits and are rarely considered. This concept was discussed in Section 4 in the Fixed Film, Biological Treatment Processes Section. Establishing the required anoxic and anaerobic zones necessary for EBPR would involve the addition of new tankage and equipment. The high mixed liquor concentrations and sludge ages needed for EBPR are difficult to achieve with fixed film biological systems without causing operational problems that would preclude their use (ie. plugging and short-circuiting). In addition, establishing and maintaining a consistent biomass in the anaerobic and/or anoxic zones downstream of a RBC through the use of "sloughed" attached growth biomass is not feasible.

Since EBPR is not a practical option for an RBC plant, the acceptable process design modification available would be chemical addition at various points throughout the plant. Therefore, process design basis would include design flow, $CBOD_5$, TSS and total phosphorus which are presented in Table 5.8.1.3. The plant design flow, $CBOD_5$ and TSS were used for the phosphorus removal design basis. Table 5.8.1.3 also presents process design criteria for the clarifiers and the RBC. The observed average concentration was used for total phosphorus. Phosphorus removal achieved across the attached growth system was assumed to be 1.5 mg/L and is reasonable based on plant influent and effluent phosphorus concentrations.

5.8.1.3 Evaluation of Phosphorus Removal Alternatives

The conceptual design analysis indicated that chemical addition can meet a target goal of 1 mg/L effluent phosphorus. Both primary clarifier and secondary clarifier application points were considered as well as two point chemical addition. The design analysis is summarized in Table 5.8.1.4. As shown in the table, the range in operating parameters is narrow for the three alternatives, however, two point chemical addition indicated the most effective operating conditions in nearly all operating categories. Two point chemical addition will have the lowest overall alum dosage (149 mg/L), chemical addition (3,890 1b/day) and alkalinity depletion (34 mg/L). While it does not exhibit the lowest primary and/or secondary sludge production, it does have the lowest alum sludge production and lowest overall sludge production.

Table 5.8.1.3 – Process Design Basis Used for Evaluation of Phosphorus Removal Alternatives
Brainerd Area WWTP

Flow (MGD)	$CBOD_5$ (mg/L)	TSS (mg/L)	TP (mg/L)
3.13	210	230	5.6

Process Step	Dimensions	Design Loading	Comment
Primary Clarifiers	2-100 ft. x 20 ft. 10 ft. SWD	783 gpd/sf	Rectangular clarifiers, possible chemical addition point
Rotating Biological Contactors	12 units @ 12 ft. diameter x 25 ft long; 1.2 MSF of total surface area (min)	2.60 gpd/SF; HRT = 1.53 hrs	Plant does not nitrify
Secondary Clarifiers	2-65 ft. diameter 10.5 ft. SWD	472 gpd/sf	Preferred chemical addition point

See Appendix 2.8.1 for summary of the design basis

Table 5.8.1.4 - Summary of Plant Modifications and Chemical Requirements and Plant Retrofit Needs for Phosphorus Removal Alternatives
Brainerd Area WWTP

Operating Condition	Units	Chemical Addition at the Primary Clarifier	Chemical Addition at the Secondary Clarifier	Chemical Addition to Primary and Secondary Clarifiers
Effluent P	mg/L	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0
Alum Dosage				
Primary	mg/L	200	0	50
Secondary		0	190	100
Chemical Addition	lb/d	5300	5000	3900
Alkalinity Depleted	mg/L	45	43	34
Primary Clarifier Sludge Production	Lb/d	5550	3900	4280
Secondary Clarifier Sludge Production	Lb/d	850	2400	2050
Alum Sludge Production	Lb/d	1200	1600	1130
Total Sludge Production	Lb/d	7600	7900	7460

Chemical precipitation is a reliable means of phosphorus removal across multiple points of application. In the case of the Brainerd plant, the preliminary capital cost estimates for alum addition in either the primary or secondary clarifiers or two-point addition were similar. Table 5.8.1.5 presents preliminary budgetary cost estimates based on design and cost information presented in Section 4. The preliminary capital costs are presented as September 2004 US dollars and the present worth costs are based on the annual O&M costs over a 20 year operating period at an interest rate of 5%. The costs were rounded to the nearest $1,000.

The table includes effluent phosphorus concentration, preliminary capital costs, preliminary O&M costs and present worth. Chemical feed facilities would incur a capital cost estimated to be $152,200 and was based on the ability to feed chemicals to one or both locations. The O&M costs associated with the addition of chemical phosphorus removal for the single point options were very similar while two-point addition is roughly 32% cheaper to operate. The O&M costs include alum requirements, labor and chemical sludge disposal. The recommended alternative based on present worth analysis cost and operations considerations would be two point chemical addition.

Table 5.8.1.5 – Preliminary Cost Estimates for Retrofit for Phosphorus Removal
with Different Process Options
Brainerd Area WWTP

Cost Factors	Chemical Addition Primary Clarifier	Chemical Addition Secondary Clarifier	2 Point Chemical Addition Primary and Secondary
Effluent P (mg/L)	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0
Preliminary Capital Cost – Chemical Feed System (Alum Feed only)	$152,000	$152,000	$152,000
Preliminary O&M Costs ($/year)	$215,000	$219,000	$170,000
Present Worth	$2,831,000	$2,881,000	$2,271,000

Additional options that Brainerd might consider for addressing their phosphorus discharge concentration would include source reduction and phosphorus trading. Based on MPCA phosphorus strategy guidelines, Brainerd should investigate source control as a means of reducing phosphorus levels in their discharge. Although their influent phosphorus level of 5.6 mg/L does not indicate a large industrial contribution of phosphorus and no industrial inputs of consequence were noted by plant personnel, a review and confirmation of their possible industrial sources of phosphorus is prescribed by the MPCA phosphorus strategy guidelines. Phosphorus trading would involve purchasing phosphorus removal capacity from another plant. If excess phosphorus capacity were available from a nearby wastewater treatment plant their excess capacity would be purchased like a commodity.

It should also be noted that the Brainerd plant has reached 90% of its design capacity. Any planned expansion of plant capacity should consider phosphorus removal objectives in its design. If a new or expanded plant includes a suspended growth (activated sludge) process, consideration should be given to the incorporation of EBPR system.

SECTION 6

SUMMARY OF PHOSPHORUS REMOVAL ANALYSIS

This section discusses the results of the phosphorus removal alternatives analysis conducted on the 17 treatment plants. In Section 5, conceptual designs were developed for each plant for the different phosphorus removal options involving either enhanced biological phosphorus removal (EBPR) and/or chemical treatment. The process designs were based on retrofitting the existing wastewater treatment plants with a phosphorus removal treatment system to meet a monthly average discharge phosphorus target concentration of 1 mg/L. Preliminary capital and O&M costs were developed for each plant and a present worth cost comparison was made to select the most cost effective phosphorus removal system. The cost analysis provided a framework to allow comparisons of relative costs at a specific site and to assist individual plants to further investigate viable phosphorus removal options.

Based on the findings presented in Section 5, process selection factors and process design criteria were developed and are discussed in this section for the phosphorus removal alternatives. These process guidelines provide conceptual design information for retrofitting an existing wastewater treatment for phosphorus removal for a wide range of wastewater treatment plants in Minnesota. This section includes a summary of the plant evaluations findings presented in Section 5, a review and comparison of the preferred treatment alternatives, a summary of the process factors affecting the selection of a phosphorus removal alternative, and a discussion on the basic process design guidelines for the phosphorus removal processes.

6.1 PLANT EVALUATIONS SUMMARY

Table 6.1 summarizes the results of the evaluation of phosphorus removal alternatives. The table lists the 17 plants grouped into their specific biological treatment process, the various phosphorus removal treatment systems available and the preferred alternatives evaluated for each plant in a matrix format. The table lists the plants which are nitrifying and/or providing phosphorus removal. There are eight (8) treatment plants that are nitrifying and four (4) plants required to meet a phosphorus limit of 1 mg/L. A summary of the discharge permit requirements for all plants is presented in Table 3.3 in Section 3. The phosphorus removal options considered four EBPR scenarios: EBPR with modifications to the existing aeration system for an internal anaerobic tank (EBPR with internal A_NT); EBPR with an external anaerobic tank (EBPR with external A_NT); EBPR with chemical additions; and EBPR with an anoxic zone for those plants that are nitrifying. The evaluation of chemical treatment included single point addition to either the primary or secondary

Table 6.1 - Summary of the Phosphorus Reduction/Removal Evaluation

		Available Phosphorus Removal Treatment Alternatives								
			Phosphorus	EBPR						
Biological Treatment Process (BTP) Plant Name	Report Section	Nitrification Required	Removal Required	With Internal AnT(1)	With External AnT(2)	With Chemical Addition(3)	With Anoxic Zone(4)	Chemical Addition(5)	No Action	Source Control
Activated Sludge	***5.1***			▲	▲	▲	▲	▲	▲	▲
Alexandria Lakes Area WWTF	5.1.1		●		X		X	▨ X √	▨ √	X
Grand Rapids WWTF	5.1.2	●							▨ √	▨ X √
New Ulm WWTF	5.1.3			▨ X		▨ X √		X		X
Biological Nutrient Removal (BNR)	***5.2***			▲	▲	▲	▲	▲	▲	▲
St. Cloud WWTF	5.2.1			▨ X		▨ X √		X		X
Fergus Falls WWTP	5.2.2	●	●	▨ X			▨ X √		▨ √	X
Oxidation Ditch	***5.3***			▲	▲	▲	▲	▲	▲	▲
Wadena WWTF	5.3.1	●			X			▨ X √		X
Whitewater River PCF	5.3.2	●			▨ X	▨ X √	▨ X √	X		X
High Purity Oxygen (HPO)	***5.4***			▲	▲	▲	▲	▲	▲	▲
Moorhead WWTF	5.4.1				▨ X √			X		X
Rochester WRP	5.4.2	●	●		X	X	X	▨ X √	▨ √	X
Trickling Filter	***5.5***							▲	▲	▲
Detroit LakesWWTF	5.5.1		●					▨ X √	▨ √	X
Trickling Filter/Activated Sludge	***5.6***			▲	▲	▲	▲	▲	▲	▲
Faribault WWTF	5.6.1							▨ X√		X
Marshall WWTF	5.6.2	●			▨ X	▨ X √	▨ X √	X		X
Glencoe WWTF(6)	5.6.3	●		▨ X		▨ X√		▨ X √		X
Little Falls WWTF	5.6.4				X	X		▨ X √		X
Lagoons	***5.7***							▲	▲	▲
Redwood Falls WWTP	5.7.1	●						▨ X √		X
Thief River Falls WWTP	5.7.2							▨ X √	X	X
Rotating Biological Contactors (RBC)	***5.8***							▲	▲	▲
Brainerd Area WWTP	5.8.1							▨ X √	X	X

● = Ammonia and/or Phosphorus limit; See Section 3, Table 3.3, for a summary of the discharge permit limits
▲ = Applicable phosphorus reduction/removal option
X = Plant Specific Option reviewed
√ = Recommended alternative based on cost effective analysis
▨ **Shaded area shows recommended**

Notes:
(1) EBPR with internal anaerobic tank
(2) EBPR with external anaerobic tank
(3) EBPR with chemical addition to primary or secondary clarifiers
(4) EBPR with anoxic tank for denitrification
(5) Chemical Addition in the primary and secondary clarifiers
(6) Two scenarios were evaluated for Glencoe with and without dairy operation. See Section 5 for details on the evaluation

See Section 4 for detailed descriptions of available phosphorus treatment processes
See Section 5 for conceptual design details of Plant Evaluation and Recommendations of Phosphorus Reduction/Removal Methods

clarifiers and two-point chemical precipitation at the primary and secondary clarifiers. Two-point chemical addition treatment was determined to be the more cost effective alternative than a single point chemical addition, to either the primary or secondary clarifiers. The column with the heading "No Action" indicates that no modification would be made to the existing facility. It should be noted that the Glencoe plant was reviewed for two scenarios, one with the major dairy in operation and the second case for the present situation where the dairy operation has moved. These scenarios are discussed in detail in Section 5.

Both the EPPR process and chemical treatment (chemical precipitation) were evaluated for each plant. The recommended alternatives were based on a cost effectiveness analysis including process reliability, preliminary estimates of capital and operating cost and present worth. These parameters provided the necessary criteria to select the most cost effective phosphorus removal system. The selected alternatives are shown on the table in the shaded box or boxes. The shaded boxes indicate the specific process selected for each plant. For example, the recommended phosphorus removal alternative for the Whitewater River PCF is EBPR with an external anaerobic tank, chemical addition and an anoxic zone.

A comparison of EBPR and chemical treatment processes was conducted on 10 treatment plants. The results of the analysis summarized in Table 6.1 indicate that EBPR was the more cost effective phosphorus removal system for 7 of the 11 treatment systems evaluated. The treatment plants not selected for EBPR were Alexandria Lake WWTF, Wadena WWTF, Rochester WRP and Little Falls WWTF. Alexandria and Rochester are currently meeting a phosphorus limit of 1 mg/L using chemical treatment, and the conceptual design analyses for Wadena and Little Falls indicated that chemical treatment would be the most cost effective phosphorus treatment system.

The EBPR process was selected for the following seven (7) plants: Moorhead with EBPR and an external anaerobic tank; Glencoe (without the dairy operation), New Ulm and St. Cloud with EPBR and an internal modification to the aeration system for an anaerobic zone and chemical addition; Whitewater River and Marshall with EBPR with an external anaerobic tank, chemical addition and provisions for an anoxic zone or tank; and Fergus Falls with an ongoing BNR process (internal EBPR process and anoxic zone). Fergus Falls was not included in the cost comparison since it was considered a no action alternative. It is currently meeting a phosphorus discharge limit of 1 mg/L. Except for Moorhead and Fergus Falls, the other five EBPR plants would require chemical addition to the secondary clarifiers. Stand-by chemical equipment would be recommended for the Moorhead and Fergus Falls facilities.

Chemical treatment was the most appropriate phosphorus removal alternative for 10 of the 15 treatment plants evaluated. Grand Rapids and Fergus Falls were not included in the analysis.

The evaluation of chemical treatment, as a stand alone phosphorus removal alternative, considered both single and two-point chemical addition. In all cases, the conceptual design analysis demonstrated that two-point chemical addition at the primary and secondary clarifiers would be the most cost effective chemical precipitation system. Two-point chemical treatment would result in lower alum requirements and smaller chemical sludge production. Chemical treatment was the recommended phosphorus removal alternative for the following ten (10) plants, Alexandria, Wadena, Rochester, Detroit Lakes, Faribault, Glencoe (with the dairy operation), Little Falls, Redwood Falls, Thief River Falls, and Brainerd.

Five (5) plants listed in Table 6.1 (Alexandria Lake Area WWTF, Grand Rapids WWTF, Fergus Falls WWTP, Rochester WRP and Detroit Lakes WWTF) were designated as no action alternatives. These treatment plants are meeting the monthly average phosphorus permit limit of 1 mg/L using current phosphorus control measures. Alexandria and Rochester were previously discussed. Grand Rapids provides nutrient addition on site at the industrial pretreatment area for the nitrogen and phosphorus deficient paper mill wastewater and has the on-site controls required to regulate the concentration of phosphorus entering and leaving the treatment plant. Fergus Falls has an ongoing biological nutrient removal (BNR) treatment system that is meeting its ammonia nitrogen and phosphorus discharge limits without chemical addition. Detroit Lakes has a combined storage, spray irrigation, and ground water infiltration system with a winter surface discharge after chemical addition for phosphorus removal.

The preliminary cost estimate analysis discussed in Section 5 is summarized in Table 6.2. The table lists the capital, O&M and present worth cost for both the chemical treatment and EBPR processes, the estimated pay back periods to off set the higher capital cost for EBPR, and the recommended phosphorus removal alternatives for each treatment plant. For the 10 plants where the EBPR process and chemical treatment were compared, the cost comparison analysis showed that EBPR was the more cost effective alternative. The present worth cost analysis showed that EBPR process was the most cost effective phosphorus removal alternative for the following six plants: New Ulm WWTF, St. Cloud WWTF, Whitewater River PCF, Moorhead WWTF, Glencoe WWTF (without the dairy operation), and Marshall WWTF. For two plants, Wadena and Little Falls, chemical treatment was more cost effective. Alexandria and Rochester were designated as No Action sites. As shown on Table 6.2, the EBPR systems had higher capital costs and lower O&M cost, and chemical treatment systems had lower capital cost and higher O&M costs.

The annual capital and O&M costs for each plant and for each phosphorus removal alternative are summarized in Table 6.3. The table lists for each plant, the treatment plants grouped into each biological wastewater treatment process category, the design flow, estimated annual phosphorus removal, total and annual capital costs, annual O&M costs, total annual costs and an

Table 6.2 - Summary of Preliminary Cost Estimates

Biological Treatment Process (BTP) Plant Name	Design Flow (MGD)	Chemical Treatment			EBPR			Payback Period (years) (1)	Recommended Phosphorus Removal Alternative
		Capital Cost	Annual O&M Cost	Total Present Worth	Capital Cost	Annual O&M Cost	Total Present Worth		
Activated Sludge									
Alexandria Lake WWTF	3.25	$15	$181,000	$2,410,000	$924,000	$92,000	$2,071,000	10.3	No Action - Continue with chemical treatment
Grand Rapids WWTF	14.3	-	-	-	-	-	-	-	No Action - Implement source control
New Ulm WWTF	6.77	$190,000	$654,000	$8,340,000	$390,000	$137,000	$2,097,000	0.8	EBPR with chemical addition to the secondary clarifiers
Biological Nutrient Removal (BNR)									
St. Cloud WWTF	13.0	$250,000	$472,000	$6,132,000	$426,000	$130,000	$2,046,000	0.5	EBPR with chemical addition to the secondary clarifiers
Fergus Falls WWTP	2.81	-	-	-	-	-	-	-	No Action - Continue to operate under present conditions of BNR/EBPR with standby chemical treatment
Oxidation Ditch									
Wadena WWTF	0.50	$103,000	$40,000	$601,000	-	-	-	-	Two point chemical addition to primary and secondary clarifiers would be the most cost effective alternative.
Whitewater River PCF	0.80	$129,000	$69,000	$989,000	$389,000	$12,500	$545,000	4.6	EBPR with chemical addition to the secondary clarifiers
High Purity Oxygen (HPO)									
Moorhead WWTF	6.0	$180,000	$232,000	$3,072,000	$1,176,000	$30,000	$1,550,000	5.1	EBPR only. High BOD/P ratio eliminates need for chemical treatment. A standby chemical feed system is also recommended to ensure satisfactory phosphorus removal.
Rochester WRP	19.1	$320,000	$1,586,000	$20,085,000	$4,070,000	$734,000	$13,217,000	4.8	No Action - Continue with chemical treatment.
Trickling Filter									
Detroit Lakes WWTF	1.64	$140,000	$204,000	$2,682,000	-	-	-	-	No Action - Continue to operate under present conditions of effluent storage, spray irrigation and chemical precipitation during winter.
Trickling Filter/Activated Sludge									
Faribault WWTF	7.0	$191,000	$460,000	$5,924,000	-	-	-	-	Chemical treatment to primary and secondary clarifiers
Marshall WWTF	3.3	$160,000	$526,000	$6,715,000	$1,370,000	$278,000	$4,824,000	4.9	EBPR with chemical addition to the secondary clarifiers and bypassing the trickling filters.
Glencoe WWTF	1.6	$137,000	$381,000	$4,885,000	-	-	-	-	EBPR not feasible, chemical treatment to the primary and secondary clarifiers (w/dairy operations). EBPR, (w/o dairy operation)
w/o dairy	0.69	$128,000	$91,000	$1,262,000	$488,000	$35,000	$924,000	8.7	
Little Falls WWTF	2.4	$145,000	$91,000	$1,279,000	$1,090,000	$14,000	$126	12.3	Two-point chemical addition to the primary and secondary clarifiers would be the most cost effective alternative.
Lagoons									
Redwood Falls WWTP	0.824	$90,000	$46,000	$663,000	-	-	-	-	Chemical treatment to a number of possible locations in the two sets of ponds
Thief River Falls WWTP	2.6	$147,000	$103,000	$1,431,000	-	-	-	-	Chemical treatment to the secondary pond based on phosphorus level in the secondary pond
Rotating Biological Contactors (RBC)									
Brainerd Area WWTP	3.13	$152,000	$170,000	$2,271,000	-	-	-	-	Chemical treatment to primary and secondary clarifiers

(1) Estimated payback period to offset the initial capital costs for the EBPR process is based on the capital and O&M cost differentials between EBPR and Chemical Treatment alternatives.

Table 6.3 - Summary of Annual Preliminary Capital and O&M Cost

			Chemical Treatment					EBPR				
Biological Treatment Process (BTP) Plant Name	Design Flow (MGD)	Phosphorus Removal (Pr) (lbs/year)	Preliminary Capital Cost	Annual Capital Costs	Preliminary Annual O&M Cost	Total Annual Cost	Annual Cost/Pr ($/lb Pr)	Preliminary Capital Cost	Annual Capital Costs	Preliminary Annual O&M Cost	Total Annual Cost	Annual Cost/Pr ($/lb Pr)
Activated Sludge												
Alexandria Lake WWTF	3.25	36,000	$154,000	$12,000	$181,000	$193,000	5.0	$924,000	$74,000	$92,000	$166,000	4.6
New Ulm WWTF	6.77	120,000	$190,000	$15,000	$654,000	$669,000	5.5	$390,000	$31,000	$137,000	$168,000	1.4
Biological Nutrient Removal (BNR)												
St. Cloud WWTF	13.0	105,000	$250,000	$20,000	$472,000	$492,000	4.5	$426,000	$34,000	$130,000	$164,000	1.6
Oxidation Ditch												
Wadena WWTF	0.50	8,000	$103,000	$8,000	$40,000	$48,000	6.0	-	-	-	-	-
Whitewater River PCF	0.80	17,000	$129,000	$10,000	$69,000	$79,000	4.6	$389,000	$31,000	$13,000	$44,000	2.6
High Purity Oxygen (HPO)												
Moorhead WWTF	6.0	93,000	$180,000	$14,000	$232,000	$246,000	2.6	$1,176,000	$94,000	$30,000	$124,000	1.3
Rochester WRP	19.1	256,000	$320,000	$26,000	$1,586,000	$1,612,000	6.3	$4,070,000	$327,000	$734,000	$1,061,000	4.1
Trickling Filter												
Detroit Lakes WWTF	1.64	18,000	$140,000	$11,000	$204,000	$215,000	11.9	-	-	-	-	-
Trickling Filter/Activated Sludge												
Faribault WWTF	7.0	120,000	$191,000	$15,000	$460,000	$475,000	4.0	-	-	-	-	-
Marshall WWTF	3.3	102,000	$160,000	$13,000	$526,000	$539,000	5.3	$1,370,000	$110,000	$278,000	$389,000	3.8
Glencoe WWTF w/o dairy	1.6 0.69	68,000/ 10,000	$137,000 $128,000	$11,000	$381,000 $91,000	$392,000	5.8	- $488,000	$39,000	- $35,000	- $74,000	- 7.4
Little Falls WWTF	2.4	23,000	$145,000	$12,000	$91,000	$103,000	4.5	$1,090,000	$87,000	$14,000	$101,000	4.4
Lagoons												
Redwood Falls WWTP	0.824	7,000	$90,000	$7,000	$46,000	$53,000	7.6	-	-	-	-	-
Thief River Falls WWTP	2.6	15,000	$147,000	$12,000	$103,000	$115,000	7.7	-	-	-	-	-
Rotating Biological Contactors (RBC)												
Brainerd Area WWTP	3.13	34,000	$152,000	$12,000	$170,000	$182,000	5.4	-	-	-	-	-

unit cost for phosphorus removal ($/pound of phosphorus removal). The annual capital costs were based on an interest rate of 5 percent over a 20 year period at a payment schedule of once per year. The annual costs show that the annual cost for a combined EBPR and chemical addition treatment system would be less expensive than for the chemical treatment only alternative.

6.2 REVIEW OF TREATMENT ALTERNATIVES SELECTED

The ability to retrofit a number of different types of wastewater treatment systems for phosphorus removal to meet an effluent target of less than 1.0 mg/L was evaluated, and the results of these evaluations were summarized in Section 5, along with a description of the facilities and their wastewater characteristics. The two main pathways for phosphorus removal, chemical treatment and enhanced biological phosphorus removal (EBPR) were evaluated for all of the facilities to determine which process designs would be feasible to retrofit a specific existing facility and which process designs appeared to be more cost effective. Chemical treatment is more easily implemented than EBPR treatment which is very much dependant on the plant layout and tankage available.

The phosphorus removal efficiency of the two processes depends on several factors with those associated with chemical treatment more easily controlled. While chemical treatment requires feeding metal salts to the primary and/or secondary treatment processes, the EBPR process requires soluble BOD in the influent wastewater to support the growth of phosphorus-storing organisms. The EBPR alternative also requires additional process tankage within the facility above that needed for BOD removal or nitrification. In contrast, chemical treatment could reduce the tankage volume required in the secondary treatment process by improving BOD removal efficiency in the primary clarifier if chemicals are added there. However, additional sludge is produced and must be processed and disposed. The plant evaluation analyses accounted for the cost of disposal of additional sludge, but did not conduct specific site investigations to determine if the existing facilities needed additional sludge processing equipment.

Where there was a sufficient amount of soluble BOD available in the influent wastewater, the EBPR alternative was, in most cases, more attractive than the chemical treatment alternative for facilities that involved suspended growth activated sludge. For treatment processes without suspended growth activated sludge, such as trickling filters, rotating biological contactors and lagoon facilities, chemical treatment was the main viable alternative for upgrading existing systems for phosphorus removal without major changes in the treatment system design or treatment concepts.

The EBPR process alternative could be used for the various types of activated sludge processes examined, provided that there was sufficient influent soluble BOD available to support biomass growth of the microorganisms accomplishing the phosphorus removal by biological uptake and cell storage. A successful EBPR alternative also required that tank modifications could be done within the existing activated sludge system, which depended on the location and the availability of excess tank volume within the existing aeration basins. For systems with plug flow aeration tanks, the EBPR process could be more easily accommodated. The ability to have some excess capacity within the existing aeration basin is affected by the EBPR process and the type of mixed liquor biomass that is developed. The solids settling characteristics are significantly improved with biological phosphorus removal, which allows the system to maintain a higher mixed liquor suspended solids concentration resulting in increased existing aeration tank capacity.

The impact of the influent wastewater strength relative to the phosphorus concentration was one of the major factors that determined the potential for using an EBPR alternative to achieve phosphorus target concentrations of less than 1.0 mg/L. This impact is illustrated in Table 6.4 which shows a comparison of the alternative evaluation process selection and the influent BOD/P ratio for the 13 plants with suspended growth biological treatment process. The Grand Rapids facility is unique and is not included for this analysis as it had a phosphorus limited wastewater. Neither chemical treatment, nor EBPR treatment was necessary as sufficient phosphorus uptake occurred by biomass synthesis and the treatment plant has the capability of phosphorus control when adding nitrogen and phosphorus to the wastewater. Of the remaining 12 suspended growth facilities, the evaluation showed that two (2) facilities, Fergus Falls and Moorhead, could achieve an effluent phosphorus concentration of less than 1.0 mg/L with an EBPR process without continuous chemical addition. (It should be noted that these EBPR processes were recommended with stand-by chemical feed equipment available on-site as backup during periods with low EBPR performance). For Fergus Falls and Moorhead with EBPR treatment only, the estimated BOD/P ratio in the feed to the initial anaerobic contact zone of the activated sludge process as shown on Table 6.4 was 26 and 32, respectively. These estimated BOD/P ratios accounted for variations in the influent soluble BOD fraction. The data was normalized to an influent soluble BOD fraction of 30%. Thus for facilities where the apparent influent soluble BOD fraction was estimated at 40%, the BOD/P ratio in the table is higher by a factor of 1.33 compared to its influent BOD/P ratio based on the total BOD concentration value. A total BOD with a higher percentage of soluble BOD would provide more substrate to the phosphorus-removing organisms and thus more phosphorus removal. This was accounted for in the process design evaluations.

The effect of the plant type can be observed by comparing the recommended alternatives for New Ulm, St. Cloud, and Wadena. The influent BOD/P ratio was similar for these three plants (22-23). The recommended alternative was EBPR plus chemicals for the conventional activated sludge system (New Ulm) and the existing biological nutrient removal facility (St. Cloud), but for the Wadena oxidation ditch facility the recommendation was chemical treatment. The reason for this is

Table 6.4 - Comparison of Selected Phosphorus Removal Alternative to Approximate Influent BOD/P Ratio to Activated Sludge Process

Biological Treatment Process Plant Name	Selected Alternative	Activated Sludge Feed ~BOD/P Ratio	Comments
Activated Sludge			
Alexandria Lake WWTF	(Chemical)	27	
New Ulm WWTF	EBPR + Chemical	23	
Grand Rapids WWTF	(Biomass Synthesis)	>100	*Phosphorus limited, Source control*
Biological Nutrient Removal			
St. Cloud WWTF	EBPR + Chemical	23	*Demonstrating P removal*
Fergus Falls WWTP	(EBPR)	26	*Demonstrating P removal*
Oxidation Ditch			
Wadena WWTF	Chemical	22	*Nitrification and denitrification in ditch increases nitrate to EBPR process*
Whitewater River PCF	EBPR + Chemical	46	
High Purity Oxygen			
Moorhead WWTF	EBPR	32	
Rochester WRP	(Chemical)	30	
Trickling Filter/Activated Sludge			
Faribault WWTF	Chemical	12	*Highly loaded trickling filters/BOD ≈ 100 mg/L in trickling filter effluent*
Marshall WWTF	EBPR	28	*By-Passed Trickling Filter*
Glencoe WWTF 1) with dairy operation 2) w/o dairy operation	 EBPR Chemical	 40 10	 *Includes bypassing the trickling filter.* *Excess nitrogen and insufficient tankage for BNR*
Little Falls WWTF	Chemical	36	*Highly loaded trickling filters*

(….) indicates process already in use

that an oxidation ditch system process results in a less efficient EBPR performance compared to that for conventional activated sludge treatment due to its longer operating solids retention time (SRT). At a longer SRT there is less total biomass production of phosphorus storing organisms (PAOs) due to more loss of biomass from endogenous decay. With less biomass production less phosphorus is removed via sludge wasting.

Another possible disadvantage for EBPR processes with oxidation ditch systems, and one that also had an impact on the retrofit process selection in the Wadena plant analysis, is that nitrification occurs in oxidation ditch operations. Nitrification was not required for the New Ulm and St. Cloud plants, and thus those plants were not impacted by nitrate as was the oxidation ditch system for this comparison. For the oxidation ditch system, some of the nitrate produced enters the anaerobic contact zone of the EBPR process, which reduces the EBPR treatment efficiency because bacteria using nitrate consume influent soluble BOD that would otherwise be available to grow more PAOs. In contrast to Wadena for which chemical treatment was the selected alternative, the selected alternative for the Whitewater oxidation ditch facility was the EBPR process with chemicals. The Whitewater influent wastewater had a much higher influent BOD/P ratio than for Wadena, and thus sufficient phosphorus removal would occur with the EBPR process in spite of the long SRT and nitrate production. Where the EBPR process could accomplish most of the phosphorus removal without excessive tank installation costs, it was more cost effective than chemical treatment only.

More variable results were obtained from the alternative evaluations for the trickling filter/activated sludge (TF/AS) processes. For the four plants evaluated, the alternatives selected were either EBPR plus chemicals or chemical treatment. EBPR was not feasible for the Glencoe facility, which had a very low influent BOD/P to the activated sludge system after the trickling filter treatment with the dairy operation. The system also had a very high influent nitrogen concentration, and there was only enough BOD present for partial removal of the nitrate and thus all of the available BOD could be consumed by the nitrate alone, leaving none for the EBPR process. Without the dairy operation and bypassing the trickling filter, the EBPR process would be the most cost effective alternative for Glencoe. The EBPR and chemical treatment process was the preferred alternative for the Marshall TF/AS facility. For the Marshall facility, a cost-effective EBPR alternative involved bypassing the trickling filters, as the existing basins had sufficient capacity for a biological nutrient facility including anaerobic anoxic and aerobic treatment zones. Bypassing the trickling filter provided sufficient BOD for the EBPR process. If a TF/AS process was used to treat a typical domestic wastewater, there would not be sufficient BOD to support a downstream EBPR process. This was the case for the Faribault facility. Recent plant data indicated low BOD concentration in the effluent of the trickling filter suggesting chemical treatment as the most appropriate treatment system.

The fact that chemical treatment was selected as the most cost-effective phosphorus removal system for the Little Falls plant, even though the facility had a high influent BOD/P ratio (36), illustrates another aspect of retrofit considerations that impact the alternative selection. The Little Falls facility also had a highly loaded trickling filter with a high influent BOD concentration so that sufficient BOD appeared to be available for good biological phosphorus removal. However, the aeration tank had a limited volume which significantly increased the capital cost for a retrofit to an EBPR process which indicated that the payback due to savings in O&M costs would be about 12 years. A final design analysis for EBPR for these facilities would require more extensive sampling and review of the influent wastewater characteristics and its variability.

It is reasonable to expect that for a given type of activated sludge process a single retrofit method might be applicable in all cases, but the results from these alternative evaluations showed that this is not the case. More than one type of phosphorus removal alternative was selected for retrofitting a given type of activated sludge treatment process. For example, a conventional activated sludge system with a lower SRT should be more compatible with EBPR treatment then an oxidation ditch system with a much longer SRT and with more nitrate. However, for the conventional activated sludge system at Alexandria Lake the selected alternative was chemical treatment, but for the Whitewater oxidation ditch system it was EBPR plus chemicals. The reason that the selected alternative was different than the expected alternative based on the treatment process alone, was that the influent wastewater characteristics was also a major factor that can compound or offset the effects of the treatment process parameters. For the TF/AS processes the wastewater characteristics, trickling filter loading rate, BOD removal efficiency, and downstream aeration basin capacity had a greater affect on the potential for EBPR then the fact that a TF/AS process was being used. Thus, the wastewater characteristics and specific process design conditions had a major effect on the retrofit process alternatives costs in addition to the type of process evaluated for phosphorus removal.

6.3 FACTORS AFFECTING THE SELECTION OF A PHOSPHORUS REMOVAL ALTERNATIVE

In this study, a procedure for evaluating phosphorus removal alternatives for representative wastewater treatment facilities was developed and applied in a consistent manner. The process involved defining the facility wastewater characteristics, design loads, and site conditions and preparing preliminary designs leading to a cost evaluation. A result of this approach was the recognition that certain conditions could be identified that favored the selected phosphorus removal alternative and could meet the treatment goal at the lowest present worth cost.

Table 6.5 presents a summary of the process selection factors for retrofitting wastewater treatment plants (WWTP) for phosphorus removal. The table lists four specific wastewater treatment technology/type, the eight different biological treatment processes, the three basic phosphorus removal alternatives (EBPR, EBPR with chemicals, and chemical treatment only) and the process selection factors associated with each biological treatment process and wastewater treatment technology. The eight biological treatment processes were divided into the following four

Table 6.5 - Process Selection Factors for Phosphorus Removal Options for Treatment Plant Retrofits

Wastewater Treatment Technology/Type	Biological Treatment Process	Phosphorus Removal Alternatives (1)	Process Selection Factors
Suspended Growth	1. Conventional Activated Sludge 2. Biological Nutrient Removal (BNR)	EBPR	● Wastewater has a high influent BOD/P ratio (BOD/P> 40) or at a moderate BOD/P ratio has a high soluble BOD content (> 40%) ● May be able to increase MLSS concentration to ~3500 mg/L with conventional sized secondary clarifiers to gain aeration tank capacity ● Excess aeration tank volume is available in existing tanks and can be converted to provide an anaerobic contact zone with a detention time of 1 hour or the site layout is compatible with the addition of a new anaerobic tank before the existing aeration tank ● If effluent standard requires NH_3 removal an anoxic zone and internal recycle can be incorporated within existing aeration tank ● Minimal phosphorus load from recycle streams -chemically treating centrate or filtrate from dewatering digester sludge -using alternative to gravity thickening of waste activated sludge -digested sludge is not dewatered before land application -sludge is stored in lagoon before land application ● System can be operated at lower SRT, which allows for a lower influent BOD/P ratio for same effluent P concentration
		EBPR with chemical addition	● Wastewater has a moderate influent BOD/P ratio (25-35) and some variability in wastewater BOD concentration ● May be able to increase MLSS concentration to ~3500 mg/L with conventional sized secondary clarifiers ● Excess aeration tank volume is available in existing tanks and can be converted to provide an anaerobic contact zone with a detention time of 1 hour or the site layout is compatible with the addition of a new anaerobic tank before the existing aeration tank ● If effluent standard requires NH_3 removal an anoxic zone and internal recycle can be incorporated within existing aeration tank ● Aluminum or iron salts can be added to primary and/or secondary clarifiers for phosphorus precipitation to remove phosphorus from concentration possible with EBPR only to less than 1.0 mg/L ● Chemical addition also enhances removal of TSS and particulate BOD in primary treatment which results in excess aeration tank volume ● Nitrification is not required and pH can decrease so that alkalinity addition is not needed offset the alkalinity reduction caused by chemical addition ● System has excess solids handling capacity to handle increased waste solids due to chemical addition

(1) Source control and phosphorus trading are options that should be considered by all plants. Protocols for evaluating the effectiveness of source control are discussed in detail in the MPCA PMP Guidelines Document. Phosphorus trading or nutrient trading can be developed through participation with MESERB's Minnesota River Nutrient Trading Committee.

Table 6.5 - Process Selection Factors for Phosphorus Removal Options for Treatment Plant Retrofits (Continued)

Wastewater Treatment Technology/Type	Biological Treatment Process	Phosphorus Removal Alternatives (1)	Process Selection Factors
	3. Oxidation Ditch	EBPR and External Anaerobic Tank	● Wastewater has a high influent BOD/P ratio (> 40) ● Space available for construction of external anaerobic tank with a detention time of 1 hour. ● Oxidation ditch has control system, sufficient volume, and aeration control to provide for significant nitrate removal in ditch ● Minimal phosphorus load from recycle streams -chemically treating centrate or filtrate from dewatering digester sludge -using alternative to gravity thickening of waste activated sludge -digested sludge is not dewatered before land application -sludge is stored in lagoon before land application
		EBPR and External Anaerobic Tank with chemical addition	● Wastewater has a moderate to high influent BOD/P ratio (30-40) and some variability in wastewater BOD concentration and periods of low soluble BOD in influent ● Space available for construction of external anaerobic tank with a detention time of 1 hour. ● Oxidation ditch has control system, sufficient volume, and aeration control to provide for significant nitrate removal in ditch ● Aluminum and iron salts can be added to the ditch influent and/or secondary clarifiers for phosphorus precipitation ● Wastewater has high alkalinity to help maintain pH after alkalinity depletion due to chemical addition
		Chemical Treatment	● Wastewater has low influent BOD/P ratio (< 25) ● Wastewater has a variable influent BOD with low soluble BOD at times ● Insufficient space available to construct an external anaerobic tank ● Aluminum or iron salts can be added to the ditch influent and/or secondary clarifier for phosphorus precipitation ● Chemical feed system can be easily and rapidly implemented ● Wastewater has high alkalinity to help maintain pH after alkalinity depletion due to chemical addition ● System has excess solids handling capacity to handle increased waste solids due to chemical addition

(1) Source control and phosphorus trading are options that should be considered by all plants. Protocols for evaluating the effectiveness of source control are discussed in detail in the MPCA PMP Guidelines Document. Phosphorus trading or nutrient trading can be developed through participation with MESERB's Minnesota River Nutrient Trading Committee.

Table 6.5 - Process Selection Factors for Phosphorus Removal Options for Treatment Plant Retrofits (Continued)

Wastewater Treatment Technology/Type	Biological Treatment Process	Phosphorus Removal Alternatives (1)	Process Selection Factors
	4. High Purity Oxygen (HPO)	EBPR and External Anaerobic Tank	● Wastewater has a moderate to high influent BOD/P ratio (30-40) ● Space available for construction of an external anaerobic tank with a detention time of 1 hour ● Minimal phosphorus load from recycle streams -chemically treating centrate or filtrate from dewatering digester sludge -using alternative to gravity thickening of waste activated sludge -digested sludge is not dewatered before land application -sludge is stored in lagoon before land application
		EBPR and External Anaerobic Tank with chemical addition	● Wastewater has a moderate influent BOD/P ratio (25-35) ● Space available for construction of an external anaerobic tank with a detention time of 1 hour ● Aluminum or Iron salts can be added to the primary and/or secondary clarifiers for phosphorus precipitation ● System has excess solids handling capacity to handle increased waste solids due to chemical addition
		Chemical Treatment	● Wastewater has a low influent BOD/P ratio (< 25) ● Wastewater has a variable influent BOD with low soluble BOD at times ● Aluminum or Iron salts can be added to the primary and/or secondary clarifiers for phosphorus precipitation ● Chemical feed system can be easily and rapidly implemented ● Influent has high alkalinity to minimize pH drop due to alkalinity depletion from chemical addition ● System has excess solids handling capacity to handle increased waste solids due to chemical addition
Combined Biological Wastewater Treatment	5. Trickling Filter and Activated Sludge	EBPR	● Wastewater has a high influent BOD/P ratio (> 40) and a high soluble BOD content (> 40%) ● Trickling filter has a high organic loading (> 150 lb BOD/$1000ft^3$-d) so that less than 40% BOD removal occurs ●Trickling filter can be bypassed to direct more BOD to EBPR anaerobic contact tank ● Excess aeration capacity exist for handling higher BOD load if trickling filter is bypassed

(1) Source control and phosphorus trading are options that should be considered by all plants. Protocols for evaluating the effectiveness of source control are discussed in detail in the MPCA PMP Guidelines Document. Phosphorus trading or nutrient trading can be developed through participation with MESERB's Minnesota River Nutrient Trading Committee.

Table 6.5 - Process Selection Factors for Phosphorus Removal Options for Treatment Plant Retrofits (Continued)

Wastewater Treatment Technology/Type	Biological Treatment Process	Phosphorus Removal Alternatives [(1)]	Process Selection Factors
			● May be able to increase MLSS concentration to ~3500 mg/L with conventional sized secondary clarifiers to gain aeration tank capacity ● Excess aeration tank capacity available so that it can be sectioned to provide anaerobic contact zone with 1 hr. detention time ● Minimal phosphorus load from recycle streams -chemically treating centrate or filtrate from dewatering digester sludge -using alternative to gravity thickening of waste activated sludge -digested sludge is not dewatered before land application -sludge is stored in lagoon before land application ● If effluent standard requires NH3 removal an anoxic zone and internal recycle can be incorporated within existing aeration tank
		EBPR with chemical addition	● Wastewater has a high influent BOD/P ratio (BOD/P> 40) and a high soluble BOD content (> 40%) ● Trickling filter has a high organic loading (> 150 lb BOD/1000ft^3-d) so that less than 40% BOD removal occurs ● May be able to increase MLSS concentration to ~3500 mg/L with conventional sized secondary clarifiers to gain aeration tank capacity ● Excess aeration tank capacity available so that it can be sectioned to provide anaerobic contact zone with 1 hr. detention time ● Aluminum or iron salts can be added to the primary and/or secondary clarifiers for phosphorus precipitation ● System has excess solids handling capacity to handle increased waste solids due to chemical addition
		Chemical Treatment	● Wastewater has a low influent BOD/P ratio (< 25) ● Trickling filter has conventional or low organic loading (< 80 lb BOD/1000 ft^3-d) ● Wastewater has a variable influent BOD with low soluble BOD at times ● Aluminum or iron salts can be added to primary and/or secondary clarifiers ● Chemical feed system can be easily and rapidly implemented ● System has excess solids handling capacity to handle increased waste solids due to chemical addition

[(1)] Source control and phosphorus trading are options that should be considered by all plants. Protocols for evaluating the effectiveness of source control are discussed in detail in the MPCA PMP Guidelines Document. Phosphorus trading or nutrient trading can be developed through participation with MESERB's Minnesota River Nutrient Trading Committee.

Table 6.5 - Process Selection Factors for Phosphorus Removal Options for Treatment Plant Retrofits (Continued)			
Wastewater Treatment Technology/Type	Biological Treatment Process	Phosphorus Removal Alternatives [1]	Process Selection Factors
Attached Growth	6 & 7. Trickling Filter, Rotating Biological Contactor (RBC)	Chemical Treatment	● Aluminum or iron salts can be added to primary and/or secondary clarifiers. ● Chemical feed system can be easily and rapidly implemented ● System has excess solids handling capacity to handle increased waste solids due to chemical addition ● Influent has high alkalinity to minimize pH drop due to alkalinity depletion from chemical addition
Lagoons	8. Facultative Ponds, Aerated Lagoons, Stabilization Ponds	Chemical Treatment	● Chemicals can be applied upstream clarifiers (primary or secondary) if available ● Chemicals can be added to ponds at inlet structure, or near aerators for continuous discharge lagoon systems ● Chemicals can be batch fed with motor boat or other acceptable feed and mixing systems for lagoons/ponds with seasonal discharge ● Alum is the chemical of choice as it will provide a more stable aluminum phosphate precipitate with potential pH variation in lagoons

(1) Source control and phosphorus trading are options that should be considered by all plants. Protocols for evaluating the effectiveness of source control are discussed in detail in the MPCA PMP Guidelines Document. Phosphorus trading or nutrient trading can be developed through participation with MESERB's Minnesota River Nutrient Trading Committee.

wastewater treatment technologies: suspended growth, combined biological wastewater treatment, attached growth and lagoons. For each type of biological treatment process, process selection factors are presented for the three basic phosphorus removal alternatives. These factors and the process design parameters discussed in Section 6.4 were developed to provide broad based process design guidelines that could be used to evaluate and select cost effective phosphorus removal alternative for a wide range of wastewater treatment plants in Minnesota.

Factors that favored one type of phosphorus removal technology over another and the conditions that were most advantageous for each phosphorus removal technology option for each type of secondary wastewater treatment process are summarized in Table 6.5. Several of the process selection factors presented on the table for wastewater treatment plants retrofits are discussed for the three major phosphorus removal technologies: EBPR, EBPR with chemical addition, and chemical treatment only.

The most important factor affecting the EBPR option is the amount of readily degradable organic material in the influent wastewater that is available to the PAOs relative to the amount of phosphorus. The influent BOD/P ratio was used as a general characterization parameter for different wastewater facilities. Higher influent BOD/P ratios were required to make EBPR a favored alternative for wastewater treatment processes that were operated with a longer SRT, had more nitrate recycled to the anaerobic contact zone, or had pretreatment processes (e.g. trickling filters) that removed influent soluble BOD. The influent BOD/P ratio can be affected by recycle flows, which can reduce it in some cases to make it more difficult for the EBPR process to meet the effluent phosphorus concentration goal. Facilities with anaerobic or aerobic digestion and sludge dewatering equipment can produce recycle streams with the highest phosphorus concentration and with minimal BOD to essentially decrease the influent BOD/P ratio and increase the amount of phosphorus that the EBPR system has to remove. Some Minnesota facilities stored waste sludge without solids dewatering prior to land application of the biosolids. These practices minimize recycle phosphorus loads and provide a more favorable condition for an EBPR process.

Retrofitting existing plants for an EBPR process required a means to provide an anaerobic contact tank with about a 1.0 hour detention time prior to the aeration basin. The aeration basin layout and configuration and capacity at some facilities provided favorable conditions for installing an anaerobic contact basin at less costs. Because the EBPR process generally improves sludge settling characteristics, existing aeration basins could be designed at higher MLSS concentrations, which then led to excess capacity in the aeration basin that could be used for the EBPR anaerobic contact tank. When nitrification was required, additional tank volume was needed to provide an anoxic zone for nitrate removal. Systems with excess aeration tank capacity to accommodate anoxic tanks also were more favorable for an EBPR process. For some applications, because of the process configuration, the installation of an external tank for the EBPR anaerobic contact zone was unavoidable. This was the case for facilities with oxidation ditch and high purity oxygen processes.

The option of an EBPR process with chemical addition appeared to be most favored when the EBPR process could provide substantial phosphorus removal, but not enough to meet the effluent phosphorus concentration goal of 1 mg/L based on a monthly average. In these cases, chemical addition for polishing, usually in the secondary treatment process, added a nominal cost to the overall phosphorus removal treatment technology and resulted in a favorable combination. Conditions that favored the EBPR process with chemical addition were a moderate influent BOD/P (25-35) ratio, a higher variability in the wastewater strength, and additional phosphorus from return flows.

For systems with low wastewater strength, as indicated by a low influent BOD/P ratio (< 25), an EBPR process was less effective and chemical treatment alone became the more cost-effective and more reliable alternative. Systems with highly variable influent wastewater BOD/P ratios would also have poor or unreliable EBPR performance and thus would favor chemical treatment. Wastewaters with higher alkalinity were more favorable for chemical addition, as there would be less cost for pH control by purchasing alkalinity to offset the alkalinity consumed by the chemical addition. Though not evaluated specifically in this study, systems with excess capacity for handling increased sludge, especially in the primary treatment step, would provide a more favorable condition for the chemical treatment option. Site layout conditions could also increase the cost of constructing necessary facilities for the EBPR process to thus make chemical treatment more favorable. Most systems had convenient locations for chemical addition, either to the primary and/or secondary treatment steps. Chemical treatment was the only viable option for systems that did not have a suspended growth activated sludge process (necessary for EBPR). Secondary treatment facilities that fit this category were trickling filters, rotating biological contactors, and lagoons.

6.4 PROCESS DESIGN GUIDELINES FOR PHOSPHORUS REMOVAL PROCESSES

This section presents a summary of the basic process design parameters that should be considered in the evaluation, design and selection of a phosphorus removal treatment system. Process design factors and the effect of these factors on the effectiveness of the treatment process are presented for the EBPR processes and chemical treatment processes.

Important process design guidelines critical to the final design and evaluation of EBPR processes are summarized in Table 6.6. The table lists specific process design parameters, key

Table 6.6 – Process Design Guidelines for EBPR Processes for Phosphorus Removal Retrofit Designs

Design Parameter	Key Factors	Effect
Wastewater Characterization	1. BOD	Sludge production, tank volumes, oxygen supply
	2. rbCOD	Amount of EBPR
	3. Total Phosphorus	Higher values require more rbCOD for low effluent Phosphorus (P) concentration
	4. TKN	For nitrification designs – NO_3 concentration, oxygen demand
	5. Alkalinity	pH
	6. TSS	Sludge production, tank volumes
	7. Variability	Stability of EBPR
Waste Activated Sludge Recycle Streams	1. (WAS) Thickening	Gravity thickeners have anaerobic conditions with Phosphorus (P) release
	2. Aerobic Digestion and dewatering	P is released – 20 to 40% returned
	3. Anaerobic Digestion and dewatering	P released – 40 to 50% returned
	4. Sludge storage and land application	Minimal P returned to EBPR process
Aeration Tank Volume	1. MLSS concentration	Higher MLSS concentration possible with EBPR and conventional secondary clarifier loadings
	2. Sludge production	Function of WWT characteristics and pretreatment
	3. Sludge retention time (SRT)	Need > than 4-5 days for EBPR
		Longer SRTs such as for nitrification or oxidation ditches decrease EBPR efficiency
Oxygen Supply	Aeration design	Need sufficient DO for phosphorus uptake by PAOs
Activated Sludge pH	Alkalinity	Need pH above 7.2 for more efficient EBPR
EBPR Anaerobic Tank Detention Time	MLSS concentration and influent rbCOD	For 3000 – 4000 mg/L MLSS and 30-60 mg/L rbCOD, 1.0 hour detention time is typical
EBPR Phosphorus Removal Efficiency	1. rbCOD in influent to anaerobic zone	Wastewater characteristics
		Upstream biological treatment such as trickling filters deplete rbCOD
		12 – 15 mg rbCOD/mg P removed
	2. NO_3/NO_2 to anaerobic zone	Nitrification systems need anoxic zones for 80-90% NO_3 removal
Nitrate Removal	1. Anoxic zone detention time	Higher influent BOD and rbCOD and higher MLSS concentrations allows shorter detention times
		Colder temperature requires longer detention time
	2. Sufficient BOD	Need influent BOD/N ratio of > 4.0
	3. Oxidation ditch design/operation	Need effective DO control
Secondary Clarification	1. Overflow rate, gpd/ft^2	Excessive levels lead to higher effluent TSS and lower P removal efficiency
	2. Solids loading rate, lb/d-ft^2	EBPR provide better settling sludge and higher solids loading rates
Polishing Filtration	Media and hydraulic application rate, gpm/ft^2	Filtration improves P removal efficiency

process factors, and the effect of a specific parameter on the effectiveness of the EBPR process. The process design parameters listed include wastewater characterization, recycle stream, aeration tank volume, oxygen supply, activated sludge pH, EBPR anaerobic tank detention time, EBPR phosphorus removal efficiency, nitrate removal, secondary clarification, and polishing filtration. These design parameters were discussed in detail in Sections 4 and 5.

For example, an important aspect of any EBPR process design is the influent wastewater characterization. Included in the characterization data is the readily biodegradable COD concentration (rbCOD), which is the main substrate consumed by the phosphorus-storing bacteria in the anaerobic contact zone. This wastewater characterization parameter was not available for the facilities evaluated in this study, and thus estimates of the rbCOD were made based on the information on the industrial wastewater inputs. A plant design evaluation would include a wastewater characterization plan, as well as a sampling plan for characterizing recycle streams that could add a significant phosphorus load to the EBPR facility. The design guidelines table, Table 6.6, also includes typical design considerations for aeration tank volume, oxygen supply, secondary clarifiers, and polishing filtration. EBPR performance is also affected by liquid solids separation steps as indicated in Table 6.6. Low effluent suspended solids concentrations from the secondary clarifier, or possibly a polishing filter, remove solids that contain phosphorus and thus provide a lower and more reliable effluent phosphorus concentration. Another factor critical to an EBPR process identified in the table is the nitrate influence on the EBPR phosphorus removal efficiency. Factors related to nitrate removal designs must be considered where EBPR systems have nitrification requirements.

Similar process design guidelines are provided in Table 6.7 for chemical treatment processes for phosphorus removal retrofit designs. The chemical dose and dosing points are major factors affecting the process performance and economics. The plant evaluations showed that, for chemical treatment, two-point chemical addition with chemical addition in the secondary clarifier for polishing was the most cost-effective approach. When alum or ferric is added where high phosphorus concentrations exist, such as in the primary treatment step, the chemical dose is close to the stoichiometric condition for metal-phosphate precipitation at about one mole of metal per mole of phosphorus. Other important factors included as design guidelines are sludge production associated with the chemical addition and the alkalinity concentration of the wastewater which may have to be replenished due consumption by the chemical dose.

Table 6.7 – Process Design Guidelines for Chemical Treatment Processes for Phosphorus Removal Retrofit Designs

Design Parameter	Key Factors	Effect
Wastewater Characterization	1. Total Phosphorus	Higher values require more chemical addition
	2. Alkalinity	Higher alkalinity helps buffer effect on pH of alkalinity depletion by chemical addition
	3. TKN	For nitrification designs – higher N concentration depletes more alkalinity
Chemical Dose	Effluent P and stoichiometry	For lower effluent Total P concentration of < 1.0 mg/L, need 1.5-2.0 mole metal/mole P
		For effluent Total P of 2-5 mg/L, need 1.0-1.2 mole metal/mole P
Chemical Dose Points	1. Dose both primary and secondary clarifier influent	For two-point dosing less chemical is used
	2. Dose secondary clarifier influent	For low dose requirements for polishing
Clarifier Sludge Settling	Clarifier hydraulic application rates	Normally clarifier operation improves. No need to use lower application rates. Polymer may be used in secondary clarifiers with alum
Sludge Production	Thickening, digesting, and disposal	Sludge quantity will increase with chemical addition
Chemical Addition to Primary Clarifier	1. Sludge production	Sludge production increases due to chemical sludge and improved primary settling performance
	2. BOD load to secondary treatment process	Reduces load to secondary treatment process, which may provide more aeration basin capacity
Secondary Clarifier	1. Overflow rate, gpd/ft^2	Excessive levels lead to higher effluent TSS and lower P removal efficiency
	2. Solids loading rate, lb/d-ft^2	Chemical treatment will not reduce normal loading rates
Polishing Filtration	Media and hydraulic application rate, gpm/ft^2	Filtration improves P removal efficiency, can reduce chemical dose

SECTION 7

CONCLUSIONS

The following is a list of conclusions developed from the findings of this report. Conclusions are presented for the following biological treatment processes; activated sludge and biological nutrient removal (BNR), oxidation ditch, high purity oxygen (HPO) and trickling filters, lagoons, and rotating biological contactors (RBC). In addition general conclusions are provided on important aspects of retrofitting existing plants for phosphorus removal.

7.1 TREATMENT PROCESSES SPECIFIC CONCLUSIONS

1. ACTIVATED SLUDGE AND BIOLOGICAL NUTRIENT REMOVAL (BNR)

- Enhanced biological phosphorus removal (EBPR) is a viable phosphorus removal alternative that requires an anaerobic contact tank that can be incorporated into existing tanks if there is sufficient capacity. EBPR processes can be operated at higher MLSS concentrations to help increase the aeration tank capacity. Plug flow aeration tanks facilitate retrofit conversions to EBPR by the use of baffles and mixers.
- Cost comparisons between EBPR and chemical treatment indicate that the EBPR, in most cases, is the most cost effective phosphorus removal alternative.
- Alkalinity consumption by BNR or chemical phosphorus removal must be evaluated during detailed evaluation of phosphorus removal options to determine if alkalinity supplementation is necessary. Where nitrification is required and the pH must be maintained, alkalinity addition may be necessary to compensate for alkalinity consumption due to chemical addition.

2. OXIDATION DITCH

- An EBPR process will require construction of external tanks for an anaerobic contact zone.
- High levels of nitrate reduction are necessary in the oxidation ditch channels to assure that an EBPR process can be operated successfully. Sufficient tank volume and a control system must be available. The control system is used to assure nitrate removal and can be ones that control aeration to provide anoxic zones within the ditch channels or provide on/off aeration operations with mixing for nitrate removal.

- Because of their relatively longer SRTs, oxidation ditch systems are less efficient for EBPR removal and require a higher influent BOD/P ratio compared to conventional activated sludge processes.

3. HIGH PURITY OXYGEN (HPO)

- An EBPR process will require construction of external tanks for an anaerobic contact zone.
- HPO systems are generally operated at lower solids retention time (SRTs) than conventional activated sludge systems, which should improve the efficiency of EBPR performance.
- A minimal SRT is required for EBPR and should be greater than 5 days and 3 days at 10^0C and 20^0C, respectively.

4. COMBINED BIOLOGICAL WASTEWATER TREATMENT (TRICKLING FILTER AND ACTIVATED SLUDGE)

- For weaker wastewaters or low trickling filter loadings, bypassing the trickling filter to provide BOD for EBPR may be necessary. This approach requires that sufficient aeration tank volume is available downstream for treatment and to accommodate the EBPR anaerobic contact zone.
- For high strength wastewaters and high trickling filter loadings there may be sufficient BOD remaining after the trickling filter to support a successful EBPR operation.
- EBPR treatment with chemical addition is more likely than EBPR alone.
- Some trickling filter/activated sludge processes may not have sufficient aeration volume for an EBPR retrofit and chemical treatment would be the likely alternative.

5. TRICKLING FILTERS, LAGOONS AND ROTATING BIOLOGICAL CONTACTORS (RBCS)

- Chemical treatment is the only viable alternative for these processes.
- Two-point chemical treatment is the most cost effective chemical treatment alternative for trickling filters and RBC plants (attached growth systems).
- Lagoons (as the primary means of biological treatment) with seasonal discharge can consider batch chemical treatment.
- Lagoons with a continuous discharge should consider continuous two-stage chemical treatment.

- Alkalinity consumption by chemical phosphorus removal must be evaluated during the engineering evaluation of phosphorus removal alternatives to determine if alkalinity supplementation is necessary.

7.2 GENERAL RETROFIT CONCLUSIONS

- EBPR and chemical treatment are the most common phosphorus removal technologies.
- EBPR has the higher capital cost and lower O&M cost. Chemical treatment has the lower capital cost and higher O&M cost.
- For a given type of activated sludge system, the EBPR retrofit design and the choice of EBPR, EBPR with chemical treatment, or chemical treatment can vary depending on other site-specific factors.
- Wastewater characteristics must be determined to establish process requirements and effectiveness of EBPR.
- Wastewater characteristics have a major impact on the feasibility and economics of an EBPR retrofit for phosphorus removal. The influent BOD/P ratio has been used as a rough parameter to provide a general indication of the effect of the influent wastewater characteristics on EBPR performance. However, the influent soluble readily biodegradable COD, which is not commonly measured, is more directly related to EBPR performance. General guidelines for BOD/P ratio are as follows:

    - Wastewaters exhibiting BOD/P ratios of greater than 40 may be able to consistently achieve an effluent phosphorus of less than 1 mg/L.
    - Wastewaters with ratios between 25 and 35 will need chemical treatment for effluent polishing.
    - If the BOD/P ratio is less than 25, chemical treatment is typically the most cost effective phosphorus removal alternative

- The pH of EBPR processes should be maintained at 7.2 or greater.
- Stand-by chemical treatment should always be provided with EBPR treatment systems.
- The cost analysis for the wastewater facilities requiring supplemental soluble BOD indicated that sugar is more expensive than adding alum or ferric metal salts for phosphorus removal, and that the construction and operation of a fermenter to process primary sludge to produce volatile fatty acids for EBPR is not cost effective unless the plant size is significantly greater than 10 MGD.

- The cost analysis indicated significant cost savings for phosphorus removal with effluent phosphorus levels greater than 1 mg/L. The present worth cost for the EBPR process was compared for each of five treatment plants for discharge phosphorus concentrations of 1 mg/L or 2 mg/L. For each plant, the present worth analysis indicated that the cost for phosphorus removal was less expensive for a phosphorus discharge of 2 mg/L. Similar cost savings would be recognized for seasonal phosphorus discharge requirements or for more stringent phosphorus removal only during the algal growing season.
- For treatment systems requiring chemical treatment only, two-point chemical addition at the primary and secondary clarifiers is the most cost effective system.
- Chemical addition to primary clarifiers should consider the nutrient requirements of the activated sludge process.
- For chemical treatment, the capacity of the sludge processing and handling operations should be evaluated during the design of the phosphorus treatment system.
- Sludge processing residuals and other plant returns must be characterized to assess their impact on phosphorus loads when evaluating phosphorus removal systems especially EBPR.
- Source control should follow the MPCA PMP guidelines for defining influent phosphorus loads and developing a management plan to control phosphorus.

SECTION 8

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Appendix 1.1

Blank Screening Form

HydroQual

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Engineers & Scientists

Wastewater Facility Screening Form
Preliminary Information

1. Plant Information

Plant Name:

Contact Name:

Phone: ( ) -

Fax: ( ) -

E-mail:

Design Capacity: MGD

Present Flow: MGD

2. Discharge Permit Concentration (mg/L)

(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency(1)
BOD_5				
COD				
TSS				
Settleable Solids				
NH_4-N				
NO_3-N				
TKN				
Total Nitrogen				
Total Phosphorous				
Soluble Phosphorus				
Fecal Coliform				
pH				
Others(?) List				

Receiving Water body:

(1)type - composite, grab
(1)frequency - # samples/week or month

3. Liquid Process Description

Pre-treatment (check)

Barscreen ______ Comminutor ______

Self Cleaning Screens ______

Aerated Grit Removal ______

Other Grit Removal ______

Number of Treatment Trains ______

Primary treatment (please check) Yes ______ No ______

# of clarifiers ______ Diameter ______

Chemical addition Yes ______ No ______

If yes, chemical(s) used ______

Secondary Treatment (please check)

Trickling Filter ______ Rotating Biological Contactor ______

Activated Sludge ______ Oxidation Ditch ______

Lagoon ______ Biological Nutrient Removal ______
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes ______ No ______

If yes, chemical(s) used ______

Secondary Clarifiers

# of clarifiers ______ Diameter ______

Chemical addition Yes ______ No ______

If yes, chemical(s) used ______

Tertiary Treatment

Polishing Filters Yes ______ No ______

Type of Filter ______ # of Filters ______

Media/depth ______ Area/Filter ______

Disinfection (please check)

Chlorine ______ Ultraviolot ______

Dechlorination Yes ______ No ______

Please provide a copy of the most recent monthly plant performance reporting form.

4. Sludge Processing/Ultimate Reuse or Disposal

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

____

____

Primary Sludge Thickening (please check)

Primary Tanks ________ Gravity ________ Belt Thickeners ________

Secondary Sludge Thickening (please check)

Gravity ________ Belt Thickeners ________

Centrifuge ________ Dissolved Air Flotation ________

Combined Sludge Thickening (please check)

Yes ________ No ________

Please Name Thickening Process ____

Sludge Digestion (please check)

Aerobic ________ Anaerobic ________

Other (name) ____

Sludge Dewatering (please check)

Brying Beds ________ Centrifuge ________

Belt Filter Press Other (name) ________

Storage/Disposal	Quantity (cy or lbs)	Cost
• Summer		
Storage	________	________
Disposal	________	________
• Winter		
Storage	________	________
Disposal	________	________

5. Additional Information

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant:

____

____

____

Estimated percent of plant BOD load: ____________

Collection System (check)

Separate sanitary sewers: ____________

Combined domestic/storm sewers: ____________

Plant Sampling and Analyses

Influent

24 hr composite ____________ Grab ____________ Other ____________

Frequency (days/week) ____________

Effluent

24 hr composite ____________ Grab ____________

Other ____________ Location ____________

Frequency (days/week) ____________

Does plant have a lab? ____________

Analyses done by plant lab (check)

BOD	____	TSS	____	PH	____	TKN	____
NH_4-N	____	NO_3-N	____	$NO2_3$-N	____	Total P	____
Soluble Ortho P	____	Coliform	____	COD	____		

Others (List) ____

Appendix 1.2

Plant Screening Forms

HydroQual

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Engineers & Scientists

Plant Screening Forms

Activated Sludge Treatment Plants

Wastewater Facility Screening Form
Preliminary Information

(ALASD)

1. **Plant Information**

Plant Name: ALEXANDRIA LAKE AREA SANITARY DISTRICT

Contact Name: BRUCE NELSON or SCOT SPRANGER

Phone: 320 762-1135 ( ) - Fax: 320-762-1108 ( ) -

E-mail: alasd at REA-ALP.COM

Design Capacity: 2.980 MGD wet weather Present Flow: 2.6 MGD

↳ can double flow have WWap Plan and will typically handle

2. **Discharge Permit Concentration (mg/L)**
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency(1)
BOD_5	25	< 5	Same	INF EFF 3/WK
D				
TSS	30	< 5	Same	Inf EFF 5/WK
Settleable Solids				
NH_3-N				
NO_3-N				
TKN				
Total Nitrogen				
Total Phosphorous	1	0.33	Same	Inf Eff 7/WK
Soluble Phosphorus				
Fecal Coliform	200 Geo Mean	< 20	Same	Eff 3/WK
pH	9.0 to 6.0	7.0 to 7.5	Same	Inf Eff 1/Day
Others(?) List				

ceiving Water body: Lake Winona

(1)type - composite, grab
(1)frequency - # samples/week or month

4. Sludge Processing/Ultimate Reuse or Disposal

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

Agricultural

Primary Sludge Thickening (please check)

Primary Tanks X Gravity ______ Belt Thickeners ______

Secondary Sludge Thickening (please check)

Gravity ______ Belt Thickeners ______

Centrifuge ~~X~~ NA Dissolved Air Flotation ______ None

ombined Sludge Thickening (please check)

Yes ______ No ______

Please Name Thickening Process ______

Sludge Digestion (please check)

Aerobic X Anaerobic ______

Other (name) Wasting from primaries only

Sludge Dewatering (please check)

Brying Beds ______ Centrifuge X

Belt Filter Press ______ Other (name) ______

Additional Information

Industrial Wastewater 0

List name/type of any significant industrial wastewater load to the plant:

NORTHERN Food & DAIRY –
NORDIC ASCEPTIC –
3 M – ABRASIVES
DMF – metal finishing

Estimated percent of plant BOD load: 35%

Collection System (check)

Separate sanitary sewers: X

Combined domestic/storm sewers: ______

Plant Sampling and Analyses

Influent

hr composite	X	Grab		Other	
Frequency (days/week)	7 0				

Effluent

24 hr composite	X	Grab	
Other		Location	
Frequency (days/week)	7 0		
Does plant have a lab?	YES		

Analyses done by plant lab (check)

CBOD^5	X	TSS	X	PH	X	TKN	
NH_4-N		NO_3-N		$NO2_3$-N		Total P	X
Soluble Ortho P		Coliform	X	COD	X		

Others (List) ______

3. Liquid Process Description

-treatment (check)

Barscreen X Comminutor X

Self Cleaning Screens X

Aerated Grit Removal X ?

Other Grit Removal X

Number of Treatment Trains 1

Primary treatment (please check) Yes X No ____

\# of clarifiers 2 Diameter ____

Chemical addition Yes ____ No X

If yes, chemical(s) used ____

Secondary Treatment (please check)

Trickling Filter ____ Rotating Biological Contactor ____

Activated Sludge X Oxidation Ditch ____

Lagoon ____ Biological Nutrient Removal ____
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes X No ____

If yes, chemical(s) used Ferric sulfate dosed to aeration effluent

Secondary Clarifiers

\# of clarifiers 2 Diameter ____

Chemical addition Yes ____ No X

If yes, chemical(s) used ____

Tertiary Treatment

Polishing Filters Yes X No ____

Type of Filter SAND/ANTRACITE # of Filters 6

Media/depth ____ Area/Filter ____

Disinfection (please check)

Chlorine X Ultraviolet ____

Dechlorination Yes X No ____

Please provide a copy of the most recent monthly plant performance reporting form.

PUBLIC UTILITIES COMMISSION

Fax

To: Mellisa Morrone
From: Jim Ackerman
Fax: 201 529 5728
Pages: 5
Phone:
Date: 8-25-03
Re:
CC:

☐ **Urgent** ☐ **For Review** ☐ **Please Comment** ☐ **Please Reply** ☐ **Please Recycle**

- **Comments:**

500 SE 4th Street
Grand Rapids, MN 55744
WWTP Fax (218) 326-7199 Service Center Fax (218) 326-7489
Phone (218) 326-7024

Wastewater Facility Screening Form
Preliminary Information

1. **Plant Information**

Plant Name: Grand Rapids Wastewater Treatment Facility

Contact Name: Jim Ackerman

Phone: 218() 326-7195 Fax: 218() 326-7199

E-mail: jcackerman@grpuc.org

Design Capacity: 15.2 MGD Present Flow: 9.0 MGD

2. **Discharge Permit Concentration (mg/L)**
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency[1]
BOD_5	25	3.0	3.0	24 Hr Comp.
	None			
TSS	30	10	10	24 Hr Comp
Settleable Solids	—			
NH_4-N	8	2	2	24 Hr Comp
NO_3-N	—			
TKN	—			
Total Nitrogen	—			
Total Phosphorous	Monitor only			
Soluble Phosphorus	None			
Fecal Coliform	200 #/100 ml			grab 3/wk
pH	9.0/6.0			grab 3/wk
Others(?) List				

Receiving Water body: Mississippi River

[1] type - composite, grab

[1] frequency - # samples/week or month

Liquid Process Description

e-treatment (check)

arscreen ✓

Comminutor O

elf Cleaning Screens ✓

erated Grit Removal

Other Grit Removal

Number of Treatment Trains

Primary treatment (please check) Yes ✓ No

\# of clarifiers ✓ Diameter 100

Chemical addition Yes No ✓

If yes, chemical(s) used

Secondary Treatment (please check)

Trickling Filter

Rotating Biological Contactor

ivated Sludge ✓

Oxidation Ditch

Lagoon

Biological Nutrient Removal
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes No ✓

If yes, chemical(s) used

Secondary Clarifiers

\# of clarifiers 3 Diameter 2@100, 1@180

Chemical addition Yes No ✓

If yes, chemical(s) used

Tertiary Treatment

Polishing Filters Yes No ✓ polishing ponds (4)

Type of Filter # of Filters

Media/depth Area/Filter

Disinfection (please check)

Chlorine ✓ Ultraviolet

Dechlorination Yes No ✓

Please provide a copy of the most recent monthly plant performance reporting form.

Sludge Processing/Ultimate Reuse or Disposal

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

Landfill

Primary Sludge Thickening (please check)

Primary Tanks ✓ Gravity ____ Belt Thickeners ____

Secondary Sludge Thickening (please check)

Gravity ✓ Belt Thickeners ____

Centrifuge ____ Dissolved Air Flotation ____

Combined Sludge Thickening (please check)

Yes ____ No ✓

ease Name Thickening Process ____

Sludge Digestion (please check)

Aerobic ____ Anaerobic ____

Other (name) NONE

Sludge Dewatering (please check)

Drying Beds ____ Centrifuge ____

Belt Filter Press ✓ Other (name) ____

Storage/Disposal	Quantity (cy or lbs)	Cost
• Summer		
Storage		
Disposal		
• Winter		
Storage		
Disposal		

Additional Information

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant: Paper Mill - nutrient deficient influent. 90% of flow and load. Plant feeds liquid N/P fertilizer to support Biological Activated Process.

Estimated percent of plant BOD load: 90%

Collection System (check)

Separate sanitary sewers: ✓

Combined domestic/storm sewers: ____

Plant Sampling and Analyses

Influent

r composite ✓ Grab ____ Other ____

Frequency (days/week) 7/wk

Effluent

24 hr composite ✓ Grab ____

Other ____ Location ____

Frequency (days/week) 7/wk

Does plant have a lab? yes

Analyses done by plant lab (check)

BOD	✓	TSS	✓	PH	✓	TKN	
NH_4-N	✓	NO_3-N		$NO2_3$-N		Total P	
Soluble Ortho P		Coliform	✓	COD			

Others (List) ____

MINNESOTA ENVIRONMENTAL SCIENCE AND ECONOMIC REVIEW BOARD

Wastewater Phosphorus Control and Reduction Initiative

c/o 444 Cedar Street, Suite 1200
St. Paul, MN 55101
(651) 225-8840
(651) 225-9088 (Fax)

Please deliver the following 6 pages *(includes cover page)*

TO: George J. Kehrberger, HydroQual, Inc.

FAX: 201-529-5728

DATE: August 8, 2003

FROM: Steven W. Nyhus SM

Attached please find the City of New Ulm's facility screening form.

If you have problems receiving this fax, please call (651) 225-8840.

New Ulm Wastewater Facility
Public Utilities Commission
3 Tower Road
New Ulm, Minnesota 56073
Telephone: (507) 359-8360
Fax: (507) 354-7293

FAX COVER SHEET

DATE: 8/8/03 **TIME:** **# OF PAGES** 5
(Including this page)

TO: ~~George Kehrberger~~ Steve

COMPANY: ~~HydroQual~~ Flaherty + Hood

FAX NUMBER: ~~201-529-5782~~ 651-225-9088

FROM: Del Senst

WASTEWATER DEPARTMENT, NEW ULM PUBLIC UTILITIES

COMMENTS: Thank you Steve for forwarding this for me.

Wastewater Facility Screening Form
Preliminary Information

1. **Plant Information**

Plant Name: New Ulm Wastewater Treatment Facility

Contact Name: Del Senst

Phone: 507-359 8360

Fax: 507-354-7293

E-mail: del.senst@ci.new-ulm.mn.us

Design Capacity: 6.77 MGD

Present Flow: 2.6 MGD

2. **Discharge Permit Concentration (mg/L)**
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency(1)
BOD_5	25/40 mg/l	3 mg/l	Same	24 hr comp 3/7
COD				
TSS	30/45 mg/l	5 mg/l	Same	24 hr comp 7/7
Settleable Solids		0.1		24 hr comp 7/7
NH_3-N				
NO_3-N		<0.08		Grab 1/7
TKN				
Total Nitrogen				
Total Phosphorous		4-5		Grab 1/mo.
Soluble Phosphorus				
Fecal Coliform	200/400	<50		Grab 3/7
pH	6 min 9. Max	7		Grab 7/7
Others(?) List	Eff Turbid 25			

Receiving Water body: Minnesota River

(1)type - composite, grab
(1)frequency - # samples/week or month

3. Liquid Process Description

Pre-treatment (check)

Barscreen yes Comminutor yes

Self Cleaning Screens ______

Aerated Grit Removal yes

Other Grit Removal ______

Number of Treatment Trains 2

Primary treatment (please check) Yes ✓ No ______

# of clarifiers 2 Diameter 65 ft

Chemical addition Yes ______ No ✓

If yes, chemical(s) used ______

Secondary Treatment (please check)

Trickling Filter ______ Rotating Biological Contactor ______

Activated Sludge ✓ Oxidation Ditch ______

Lagoon ______ Biological Nutrient Removal i.e. (Anaerobic and/or anoxic compartments ______

Chemical addition Yes ______ No ✓

If yes, chemical(s) used ______

Secondary Clarifiers

# of clarifiers 3 Diameter 65 ft

Chemical addition Yes ______ No ✓

If yes, chemical(s) used ______

Tertiary Treatment

Polishing Filters Yes ______ No ✓

Type of Filter ______ # of Filters ______

Media/depth ______ Area/Filter ______

Disinfection (please check)

Chlorine ✓ Ultraviolet ______

Dechlorination Yes ✓ No ______

Please provide a copy of the most recent monthly plant performance reporting form.

4. Sludge Processing/Ultimate Reuse or Disposal

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

Agricultural application

Primary Sludge Thickening (please check)

Primary Tanks ______ Gravity ✓ Belt Thickeners ______

Secondary Sludge Thickening (please check)

Gravity ✓ Belt Thickeners ______

Centrifuge ______ Dissolved Air Flotation ______

Combined Sludge Thickening (please check)

Yes ______ No ______

Please Name Thickening Process ______

Sludge Digestion (please check)

Aerobic ______ Anaerobic ______

Other (name) ATAD Autothermal Thermophilic Aerobic Digestion

Sludge Dewatering (please check)

Drying Beds ______ Centrifuge ______

Belt Filter Press ______ Other (name) decant

5. Additional Information

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant

Kraft Foods, cheese waste – AMPI, Butter waste – Schell Brewing Co.,

Estimated percent of plant BOD load: 80%

Collection System (check)

Separate sanitary sewers: ✓

Combined domestic/storm sewers: ______

Plant Sampling and Analyses

Influent

24 hr composite ✓ Grab ______ Other ______

Frequency (days/week) 7/7

Effluent

24 hr composite ✓ Grab ______

Other ______ Location ______

Frequency (days/week) 7/7

Does plant have a lab? yes

Analyses done by plant lab (check)

BOD	✓	TSS	✓	PH	✓	TKN	
NH_3-N		NO_3-N		$NO2_3$-N		Total P	
Soluble Ortho P		Coliform	✓	COD			

Others (List) ______

Wastewater Facility Screening Form
Preliminary Information

Present Plant

1. **Plant Information**

Plant Name: FAIRMONT Wastewater Treatment

Contact Name: Butch Hybbert

Phone: ( ) 507-235-6502 Fax: ( ) 507-235-6391

E-mail: www.wwtf@bevcomm.net

Design Capacity: 2.34 MGD Present Flow: 1.25 MGD

2. **Discharge Permit Concentration (mg/L)**
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency(1)
BOD$_5$	10 mg/L	8		24hr C 2X
COD				
TSS	30mg/L	9		24hrc 2X
Settleable Solids				
NH$_4$-N		8.6		
NO$_3$-N				
TKN				
Total Nitrogen				
Total Phosphorous		2.8		
Soluble Phosphorus				
Fecal Coliform	200/100ml	140		Grab 2X
pH	6.0 to 9.0	7.2		Grab Daily
Others(?) List	D.O. 5mg/L	6.4		Grab Daily

Receiving Water body: Center Creek

(1)type - composite, grab
(1)frequency - # samples/week or month

Present Plant

Fairmont

3. Liquid Process Description

Pre-treatment (check)

Barscreen ✓ Comminutor

Self Cleaning Screens

Aerated Grit Removal

Other Grit Removal ✓

Number of Treatment Trains 1

Primary treatment (please check) Yes No ✓

\# of clarifiers Diameter

Chemical addition Yes No

If yes, chemical(s) used

Secondary Treatment (please check)

Trickling Filter Rotating Biological Contactor

Activated Sludge ✓ Oxidation Ditch

Lagoon Biological Nutrient Removal
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes No ✓

If yes, chemical(s) used

Secondary Clarifiers

\# of clarifiers 2 Diameter 57 ft

Chemical addition Yes No ✓

If yes, chemical(s) used

Tertiary Treatment

Polishing Filters Yes No ✓

Type of Filter # of Filters

Media/depth Area/Filter

Disinfection (please check)

Chlorine ✓ Ultraviolet

Dechlorination Yes ✓ No

Please provide a copy of the most recent monthly plant performance reporting form.

Present Plant.
FAIRMONT

5. **Additional Information**

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant: No Wet INdustrial Waste

Estimated percent of plant BOD load: ______

Collection System (check)

Separate sanitary sewers: ✓

Combined domestic/storm sewers: ______

Plant Sampling and Analyses

Influent

24-hr composite 4/Wk Grab ______ Other ______

Frequency (days/week) ______

Effluent

24 hr composite Yes Grab ______

Other ______ Location ______

Frequency (days/week) 4/wk

Does plant have a lab? Yes

Analyses done by plant lab (check)

BOD	✓	TSS	✓	PH	✓	TKN	
NH_4-N	✓	NO_3-N		$NO2_3$-N		Total P	✓
Soluble Ortho P		Coliform	✓	COD			

Others (List) ______

Present Plant
Fairmont

4. **Sludge Processing/Ultimate Reuse or Disposal**

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

Land Application

Primary Sludge Thickening (please check) NA

Primary Tanks ____ Gravity ____ Belt Thickeners ____

Secondary Sludge Thickening (please check)

Gravity ✓ Belt Thickeners ____

Centrifuge ____ Dissolved Air Flotation ____

Combined Sludge Thickening (please check)

Yes ____ [✓ No]

Please Name Thickening Process ____

Sludge Digestion (please check)

Aerobic ✓ Anaerobic ____

Other (name) ____

Sludge Dewatering (please check)

Drying Beds ✓ Centrifuge ____

Belt Filter Press ____ Other (name) ____

Wastewater Facility Screening Form
Preliminary Information

Future Plant Construction Starts Spring 2004

1. **Plant Information**

Plant Name: FAIRMONT Wastewater

Contact Name: Butch Hubbert

Phone: ( ) 507-235-6502 Fax: ( ) 507-235-6391

E-mail: www.wwtf@bevcomm.net

Design Capacity: 3.9 MGD Present Flow: 1.25 MGD

2. **Discharge Permit Concentration (mg/L)**
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency(1)
BOD_5	15mg/L			24hr C/3/wk
COD				
TSS	30			24hr C/3/wk
Settleable Solids				
NH_4-N	1.0 to 5.3			24hr 3/wk
NO_3-N				
TKN				
Total Nitrogen				
Total Phosphorous	1.0			24hr-C 3/wk
Soluble Phosphorus				
Fecal Coliform	200			
pH	6.0 to 9.0			G-Daily
Others(?) List	D.O 5mg/L			G-Daily
	Mercury monitor only			1-Q

Receiving Water body: Center Creek

(1)type - composite, grab
(1)frequency - # samples/week or month

Future Plant Fairmont

3. Liquid Process Description

Pre-treatment (check)

Barscreen ✓ Comminutor

Self Cleaning Screens

Aerated Grit Removal

Other Grit Removal ✓

Number of Treatment Trains 2

Primary treatment (please check) Yes ✓ No

\# of clarifiers 2 Diameter 72 ft

Chemical addition Yes ✓ No

If yes, chemical(s) used Ferric Chloride

Secondary Treatment (please check)

Trickling Filter Rotating Biological Contactor

Activated Sludge ✓ Oxidation Ditch

Lagoon Biological Nutrient Removal i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes ✓ No

If yes, chemical(s) used Ferric Chloride

Secondary Clarifiers

\# of clarifiers 4 Diameter (2) 72 & 2 at 50

Chemical addition Yes ✓ No

If yes, chemical(s) used Ferric Chloride

Tertiary Treatment

Polishing Filters Yes No ✓

Type of Filter # of Filters

Media/depth Area/Filter

Disinfection (please check)

Chlorine Ultraviolot ✓

Dechlorination Yes No ✓

Please provide a copy of the most recent monthly plant performance reporting form.

Future Plant
Fairmont

4. **Sludge Processing/Ultimate Reuse or Disposal**

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

ag land, city Parks - new plant will have Class A sludge

Primary Sludge Thickening (please check)

Primary Tanks ____ Gravity ✓ Belt Thickeners ____

Secondary Sludge Thickening (please check)

Gravity ✓ Belt Thickeners ____

Centrifuge ____ Dissolved Air Flotation ____

Rotary Drum thickener

Combined Sludge Thickening (please check)

Yes ____ No ____

Please Name Thickening Process ____

Sludge Digestion (please check)

Aerobic ____ Anaerobic ✓

Other (name) ____

Sludge Dewatering (please check)

Drying Beds ____ Centrifuge ____

Belt Filter Press ✓ Other (name) ____

Future plant
Fairmont

5. **Additional Information**

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant: Harvest States Soy bean plant will come on line Oct, 2003 estimated load of 1000 to 1300 lbs/day BOD & TSS

Estimated percent of plant BOD load: ~~1/3~~ 30% to 50%

Collection System (check)

Separate sanitary sewers: ✓

Combined domestic/storm sewers: ______

Plant Sampling and Analyses

Influent

24 hr composite ______ Grab ______ Other ______

Frequency (days/week) ______

Effluent

24 hr composite ______ Grab ______

Other ______ Location ______

Frequency (days/week) ______

Does plant have a lab? ______

Analyses done by plant lab (check)

BOD ______ TSS ______ PH ______ TKN ______

NH_3-N ______ NO_3-N ______ $NO2_3$-N ______ Total P ______

Soluble Ortho P ______ Coliform ______ COD ______

Others (List) ______

CITY OF Winona MINNESOTA

Box 378
City Hall
Winona, MN 55987-0378

FAX TRANSMITTAL COVER SHEET

City of Winona FAX Number: [507] 457-8212

Transmittal Date 8-11-03 Transmittal Time

Please Deliver The Following Pages To:

Name: Dr. David Stensel

Phone Number: Fax Number: 206-685-9185

Company:

From: Jack Lipinski / Superintendent / Winona WWTP

Total Pages 9 Including Cover Sheet

INSTRUCTIONS:

Dr. Stensel,

Here is the information requested for the Phosphorus Initiative.

If you have any questions, call me at 507/457/8207.

Jack Lipinski

IF YOU DO NOT RECIEVE ALL THE PAGES, PLEASE CALL AS SOON AS POSSIBLE (507) 457-8231

[illegible] Form
Preliminary Information

1. **Plant Information**

Plant Name: Winona Wastewater Treatment Plant

Contact Name: Jack Lipinski

Phone: 507/457/8207 Fax: ( ) -

E-mail: JHerbert@Cityhall.luminet.net

Design Capacity: 6.5 MGD Present Flow: 3.4 MGD

2. **Discharge Permit Concentration (mg/L)**
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency[1]
BOD_5	25	8		comp/3x week
COD				
TSS	30	11		comp/3x week
Settleable Solids	monitor	0.1		comp/1x day
NH_3-N	monitor	0.1		comp/1 month
NO_3-N				
TKN				
Total Nitrogen				
Total Phosphorous	monitor	3		comp/1x week
Soluble Phosphorus				
Fecal Coliform	200 mpn/100ml	5.5 mpn/100ml		grab/3x week
pH	between 6+9 s.u.	7.2 s.u.		grab/1x day
Others(?) List	See attached list			

Receiving Water body: Mississippi River

---

[1] type - composite, grab
[1] frequency - # samples/week or month

4. **Sludge Processing/Ultimate Reuse or Disposal**

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

Agricultural application.

Primary Sludge Thickening (please check)

Primary Tanks X Gravity ______ Belt Thickeners ______

Secondary Sludge Thickening (please check)

Gravity ______ Belt Thickeners ______

Centrifuge ______ Dissolved Air Flotation ______

Combined Sludge Thickening (please check)

Yes ______ No ______

Please Name Thickening Process ______

Sludge Digestion (please check)

Aerobic ______ Anaerobic X

Other (name) ______

Sludge Dewatering (please check)

Drying Beds ______ Centrifuge ______

Belt Filter Press X Other (name) ______

Wastewater Facility Screening Form

Additional parameters tested for.

Parameter	Permit Limit	Actual Discharge	Sample type/Frequency.
Copper	monitor	0.018	Comp/1x month
Zinc	monitor	0.007	Comp/1x quarter
Mercury	monitor	0.000003	Grab/1x quarter
Dissolved oxygen	monitor	4.7	Grab/1x day

FACILITY NAME/ADDRESS:
Winona WWTP
650 Winona St
Winona, MN 55987

WASTEWATER TREATMENT
DISCHARGE MONITORING REPORT

PERMITTEE NAME/ADDRESS:
Winona city of
PO Box 378
Winona, MN 559870378

PERMIT #	LIMIT STATUS	FORMER #
MN0030147	FINAL	010MG

ATION INFORMATION:
S-001 (Influent Waste Stream)
Waste Stream, Influent Waste
ention: Jack Lipinski

	MONITORING PERIOD		
	YEAR MO. DAY		YEAR MO. DAY
FROM	2003/06/01	TO	2003/06/30

☐ No Flow

MPCA:MK

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Precipitation 00193	SAMPLE VALUE	******	3,1	in	******	******	******	****	X	X
	PERMIT REQ	******	REPORT CalMoTot		******	******	******		1 x Day	Measur
Flow 50050	SAMPLE VALUE	******	100,169	MG	******	3,339	4,139	mgd	X	X
	PERMIT REQ	******	REPORT CalMoTot		******	REPORT CalMoAvg	REPORT CalMoMax		1 x Day	MeaCon
CBOD 05 Day 20 Deg C) 082	SAMPLE VALUE	******	******	****	******	127	204	mg/L	X	X
	PERMIT REQ	******	******		******	REPORT CalMoAvg	REPORT CalMoMax		3 x Week	Comp24
S 530	SAMPLE VALUE	******	******	****	******	115	188	mg/L	X	X
	PERMIT REQ	******	******		******	REPORT CalMoAvg	REPORT CalMoMax		3 x Week	Comp24
100	SAMPLE VALUE	******	******	****	7,0	******	7,3	SU	X	X
	PERMIT REQ	******	******		REPORT CalMoMin	******	REPORT CalMoMax		1 x Day	Grab
osphorus otal (as P) 00665	SAMPLE VALUE	******	******	****	******	3,6	******	mg/L	X	X
	PERMIT REQ	******	******		******	REPORT CalMoAvg	******		1 x Week	Comp24

nd original with supplemental DMR (if
plicable) by the 21st day of month following
porting period to:
INNESOTA POLLUTION CONTROL AGENCY
20 LAFAYETTE RD
ST. PAUL, MN 55155-4194
ATTN: Discharge Monitoring Report

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT — DATE: 7-8-03

Jack Lipinski — SIGNATURE OF CHIEF OPERATOR
PHONE: 507/457-8207
DATE: 7-8-03
CERTIFICATION#: A-5638

COMMENTS:

FACILITY NAME/ADDRESS:
Winona WWTP
650 Winona St
Winona, MN 55987

WASTEWATER TREATMENT DISCHARGE MONITORING REPORT

PERMITTEE NAME/ADDRESS:
Winona city of
PO Box 378
Winona, MN 559870378

PERMIT #	LIMIT STATUS	FORMER #
MN0030147	FINAL	010MG

ATION INFORMATION:
-001 (Total Facility Discharge)
Surface Discharge, Effluent To Surface Water
ention: Jack Lipinski

MONITORING PERIOD
FROM YEAR/MO./DAY 2003/06/01 TO YEAR/MO./DAY 2003/06/30

☐ No Discharge

MPCA:MK

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
CBOD 05 Day (20 Deg C) 80082	SAMPLE VALUE	102	120	kg/day	******	8	9	mg/L	X	X
	PERMIT REQ	907 CalMoAvg	1452 MxCalWkAvg		******	25 CalMoAvg	40 MxCalWkAvg		3 x Week	Comp24
CBOD 05 Day % Removal 80091	SAMPLE VALUE	******	******	****	93	******	******	%	X	X
	PERMIT REQ	******	******		85 MnCalMoAvg	******	******		3 x Week	Calcul
TSS 30	SAMPLE VALUE	142	192	kg/day	******	11	15	mg/L	X	X
	PERMIT REQ	1089 CalMoAvg	1633 MxCalWkAvg		******	30 CalMoAvg	45 MxCalWkAvg		3 x Week	Comp24
S Removal 11	SAMPLE VALUE	******	******	****	89	******	******	%	X	X
	PERMIT REQ	******	******		85 MnCalMoAvg	******	******		3 x Week	Calcul
00	SAMPLE VALUE.	******	******	****	7.0	******	7.2	SU	X	X
	PERMIT REQ	******	******		6.0 CalMoMin	******	9.0 CalMoMax		1 x Day	Grab
sphorus Total (as P) 00665	SAMPLE VALUE	******	******	****	******	3	******	mg/L	X	X
	PERMIT REQ	******	******		******	REPORT CalMoAvg	******		1 x Week	Comp24
al Coliform, MPN/ mbrane Fltr 44.5C 48201	SAMPLE VALUE	******	******	****	******	5.49	******	#100ml	X	X
	PERMIT REQ	******	******		******	200 CalMoGeoMn	******		3 x Week	Grab

nd original with supplemental DMR (if
plicable) by the 21st day of month following
orting period to:
INNESOTA POLLUTION CONTROL AGENCY
0 LAFAYETTE RD
ST. PAUL, MN 55155-4194
ATTN: Discharge Monitoring Report

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT — DATE 7-8-03

Jack Lipinski — 507/457-8207 — 7-8-03 — A-5638
SIGNATURE OF CHIEF OPERATOR — PHONE — DATE — CERTIFICATION

COMMENTS:

FACILITY NAME/ADDRESS:
Winona WWTP
550 Winona St
Winona, MN 55987

WASTEWATER TREATMENT DISCHARGE MONITORING REPORT

PERMITTEE NAME/ADDRESS:
Winona city of
PO Box 378
Winona, MN 559870378

PERMIT #	LIMIT STATUS	FORMER #
MN0030147	FINAL	010MG

ITION INFORMATION:
SD-001 (Total Facility Discharge)
Surface Discharge, Effluent To Surface Water
ntion: Jack Lipinski

	MONITORING PERIOD		
FROM	YEAR/ MO. / DAY 2003/06/01	TO	YEAR/ MO. / DAY 2003/06/30

☐ No Discharge

MPCA:MK

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Chlorine Total Residual 50060	SAMPLE VALUE	******	******	****	******	******	<0.1	mg/L	X	X
	PERMIT REQ	******	******		******	******	0.038 DailyMax		1 x Day	Grab
Copper Total (as Cu) 01042	SAMPLE VALUE	******	******	****	******	******	18.2	ug/L	X	X
	PERMIT REQ	******	******		******	******	REPORT DailyMax		1 x Month	Comp24
Mercury al (as Hg) 00	SAMPLE VALUE	******	******	****	******	******	2.9	ng/L	X	X
	PERMIT REQ	******	******		******	******	REPORT SingleVal		1 x Quarter	Grab
ogen, Ammonia al (as N) 10	SAMPLE VALUE	******	******	****	******	******	0.1	mg/L	X	X
	PERMIT REQ	******	******		******	******	REPORT SingleVal		1 x Month	Comp24
gen, Dissolved 00	SAMPLE VALUE	******	******	****	4.7	******	******	mg/L	X	X
	PERMIT REQ	******	******		REPORT CalMoMin	******	******		1 x Day	Grab
c Total (as Zn) 01092	SAMPLE VALUE	******	******	****	******	******	118	ug/L	X	X
	PERMIT REQ	******	******		******	******	REPORT SingleVal		1 x Quarter	Comp24

nd original with supplemental DMR (if plicable) by the 21st day of month following porting period to:
INNESOTA POLLUTION CONTROL AGENCY
520 LAFAYETTE RD
ST. PAUL, MN 55155-4194
ATTN: Discharge Monitoring Report

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT — DATE: 7-8-03

Jack Lipinski — 507/457-8207 — 7-8-03 — A-5638
SIGNATURE OF CHIEF OPERATOR — PHONE — DATE — CERTIFICATION#

COMMENTS:

Month June , 20 03 Outfall Number 001

DATE	DAY OF WEEK	PRECIPITATION (INCHES)	INFLUENT FLOW (MGD)	EFFLUENT FLOW (MGD)	INFLUENT CBOD₅ (mg/L)	EFFLUENT CBOD₅ (mg/L)	PERCENT REMOVAL CBOD₅	EFFLUENT CBOD₅ (kg/day)	INFLUENT TSS (mg/L)	EFFLUENT TSS (mg/L)	PERCENT REMOVAL TSS	EFFLUENT TSS (kg/day)	INFLUENT pH	EFFLUENT pH	EFFLUENT PHOSPHORUS (mg/L)	EFFLUENT PHOSPHORUS (kg/day)	EFFLUENT D.O (mg/L)	FECAL COLIFORM (number/100 ml)	EFFLUENT CHLORINE RESIDUAL (mg/L)	CHLORINE USED (lbs)	DECHLORINATION AGENT USED (lbs)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Sun.	0.0	3,696										7.0	7.0			5.2		<0.1	120	140
2	Mon.	0.0	4,139										7.2	7.1			4.8		<0.1	160	120
3	Tue.	0.0	4,087		134	6	96.0	93	122	4	97.0	62	7.2	7.1			5.2	1	<0.1	160	130
4	Wed.	0.0	3,976		118	7	94.0	105	130	8	94.0	120	7.2	7.0			5.3	3	<0.1	200	130
5	Thur	0.0	4,026		136	9	93.0	137	116	13	89.0	198	7.2	7.1	2.9	44	5.3	6	<0.1	140	120
6	Fri.	0.5	4,091										7.1	7.1			5.5		<0.1	140	120
7	Sat.	0.0	3,661										7.1	7.1			5.5		<0.1	200	130
8	Sun.	0.5	3,253										7.1	7.1			5.4		<0.1	160	110
9	Mon.	0.6	3,887										7.2	7.1			5.6		<0.1	200	160
10	Tue.	0.4	3,513		113	10	96.0	133	116	9	92.0	120	7.2	7.2			5.1	2	<0.1	180	130
11	Wed.	0.1	3,317		123	7	94.0	88	82	16	80.0	201	7.2	7.1			5.6	43	<0.1	200	130
12	Thur	0.0	3,365		96	11	89.0	140	89	20	78.0	254	7.3	7.1	3.6	46	4.8	9	<0.1	200	130
13	Fri.	0.0	3,485										7.2	7.1			5.1		<0.1	180	120
14	Sat.	0.0	3,142										7.2	7.1			4.8		<0.1	240	120
15	Sun.	0.0	2,826										7.2	7.2			5.5		<0.1	220	130
16	Mon.	0.0	3,376										7.3	7.2			5.6		<0.1	160	120
17	Tue.	0.0	3,306		95	6	94.0	75	67	12	82.0	150	7.3	7.1			5.4	2	<0.1	160	120
18	Wed.	0.0	3,149		130	11	92.0	131	116	14	88.0	167	7.2	7.1			5.4	7	<0.1	200	140
19	Thur	0.0	3,193		134	6	96.0	72	188	10	95.0	121	7.3	7.1	2.9	35	5.4	1	<0.1	180	130
20	Fri.	0.0	3,240										7.2	7.1			4.7		<0.1	180	130
21	Sat.	0.0	2,864										7.1	7.2			4.9		<0.1	200	130
22	Sun.	0.0	2,570										7.1	7.1			5.2		<0.1	200	150
23	Mon.	0.0	3,112										7.2	7.1			5.5		<0.1	180	140
24	Tue.	0.5	3,170		204	8	94.0	96	154	13	92.0	156	7.3	7.1			6.8	6	<0.1	180	140
25	Wed.	0.0	3,053		128	6	95.0	69	116	8	93.0	92	7.2	7.1			5.4	54	<0.1	200	130
26	Thur.	0.3	3,020		116	7	94.0	80	86	6	93.0	68	7.3	7.1	2.6	30	5.6	13	<0.1	200	140
27	Fri.	0.0	3,134										7.2	7.1			5.4		<0.1	200	130
28	Sat.	0.2	2,822										7.1	7.2			5.3		<0.1	200	140
29	Sun.	0.0	2,591										7.1	7.2			5.4		<0.1	180	140
30	Mon.	0.0	3,105										7.3	7.2			5.8		<0.1	180	130
31																					
Total		3.1	100,169		1,527	94	1122.0	1,219	1,382	133	1073.0	1,709	215.8	213.5	12.0	155	160.5	5.49	3.0	5,500	3930

This form replaces the 703 and 704 forms, and should be submitted with your preprinted Discharge Monitoring Report (DMR) forms.

ADDITIONAL PARAMETERS

June Date 2003											Day of week	Inf Temp oF	Eff Temp oF	Digested Sludge % Volatile	Eff copper ug/L	NH3-N Eff ug/L	Inf Phosphorus ug/L	Eff Zinc ug/L			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1											Sun.	58	58								
2											Mon.	59	59								
3											Tue.	59	59								
4											Wed.	59	61								
5											Thur.	59	61	73,2	18,2		3,8				
6											Fri.	58	61								
7											Sat.	58	61								
8											Sun.	59	61								
9											Mon.	61	61								
10											Tue.	61	61								
11											Wed.	61	63								
12											Thur.	61	61				3,2				
13											Fri.	61	61								
14											Sat.	61	61								
15											Sun.	61	61					Zinc			
16											Mon.	61	63					Test	Run on	4/17/03	
17											Tue.	61	63					118			
18											Wed.	63	64								
19											Thur.	63	64	73,5	15,1	0,1	4,0				
20											Fri.	63	63								
21											Sat.	63	63								
22											Sun.	63	63								
23											Mon.	63	64								
24											Tue.	64	66				3,2				
25											Wed.	64	66								
26											Thur.	64	66								
27											Fri.	64	64								
28											Sat.	64	64								
29											Sun.	64	66								
30											Mon.	64	64								
31																					
TOTAL												1844	1873	146.7	33,3	0,1	14,2				

Send with preprinted DMRs to:
Minnesota Pollution Control Agency
Division of Water Quality
520 Lafayette Road
St. Paul, MN 55155
Attn: Training Info. Management

Facility Name: Winona Municipal Wastewater Treatment Plant

Permit Number: MN0030147

Plant Screening Forms

Biological Nutrient Removal (BNR) Treatment Plants

PUBLIC UTILITIES

WASTEWATER	(320) 255-7226	FAX (320) 255-7223
WATER	(320) 255-7225	FAX (320) 650-2833
HYDROELECTRIC	(320) 255-7229	

FACSIMILE TRANSMITTAL

WASTEWATER TREATMENT FACILITY
525 60TH STREET SOUTH
ST CLOUD MN 56301
(320) 255-7226

DATE: 8-12-03

TO: Dr. George Kehrberger @ HydroQual 201-529-5728

FROM: Ken Robinson – St. Cloud WWTF
via WW Lab

NUMBER OF PAGES (Including this page): 5

Please phone to verify receiving document: _____

Please review and phone/FAX comments, etc: _____

For your information only: _____

MESSAGE:

Survey – MESERB

Please deliver to the above addressee(s). Call number above to report any problems.

400 2nd Street South • St. Cloud, MN 56301-3699
http://ci.stcloud.mn.us

Wastewater Facility Screening Form
Preliminary Information

1. Plant Information

Plant Name: St. Cloud Wastewater Treatment Facility

Contact Name: Patrick Shea

Phone: ( )(320) 255-7226 Fax: ( )(320) 255-7221

E-mail: pshea@ci.stcloud.mn.us

Design Capacity: 13.00 MGD Present Flow: 9.74 MGD

2. Discharge Permit Concentration (mg/L)
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency[1]
BOD$_5$	25 MoMaxAvg 40 WkMaxAvg	6.0		Comp/3xWeek
COD				
TSS	30 MoMaxAvg 45 WkMaxAvg	7.5		Comp/3xWeek
Settleable Solids				
NH_3-N				
NO_3-N				
TKN				
Total Nitrogen				
Total Phosphorous	NA	0.97	less than 1.00	Comp/7xWeek
Soluble Phosphorus				
Fecal Coliform	200 CFU/100mL MoGeomeanMax	37 MaxMoGeomean		Grab/3xWeek
pH	6.0 MoMin 9.0 MoMax	6.7 MoMin 7.7 MoMax		Grab/7xWeek
Others(?) List				
Total Chlorine Residual	0.038 MoMax	0.027 MoMax		Grab/7xWeek

Receiving Water body: Mississippi River

[1]type - composite, grab
[1]frequency - # samples/week or month

3. Liquid Process Description

Pre-treatment (check)

Barscreen X — Comminutor ____

Self Cleaning Screens X

Aerated Grit Removal ____

Other Grit Removal X

Number of Treatment Trains ____

Primary treatment (please check) Yes X No ____

\# of clarifiers 4 — Diameter 41.5' W X 100' L X 8' D

Chemical addition Yes ____ No X

If yes, chemical(s) used ____

Secondary Treatment (please check)

Trickling Filter ____ — Rotating Biological Contactor ____

Activated Sludge X — Oxidation Ditch ____

Lagoon ____ — Biological Nutrient Removal X
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes ____ No X

If yes, chemical(s) used ____

Secondary Clarifiers

\# of clarifiers 3 — Diameter 96' D (12'D)

Chemical addition Yes ____ No X

If yes, chemical(s) used ____

Tertiary Treatment

Polishing Filters Yes ____ No X

Type of Filter ____ — # of Filters ____

Media/depth ____ — Area/Filter ____

Disinfection (please check)

Chlorine X — Ultraviolet ____

Dechlorination Yes X No ____

Please provide a copy of the most recent monthly plant performance reporting form.

4. Sludge Processing/Ultimate Reuse or Disposal

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

Agricultural application

Primary Sludge Thickening (please check)

Primary Tanks X Gravity ____ Belt Thickeners ____

Secondary Sludge Thickening (please check)

Gravity X Belt Thickeners X

Centrifuge ____ Dissolved Air Flotation X

Combined Sludge Thickening (please check)

Yes ____ No X

Please Name Thickening Process ____

Sludge Digestion (please check)

Aerobic ____ Anaerobic X

Other (name) ____

Sludge Dewatering (please check)

Drying Beds ____ Centrifuge ____

Belt Filter Press ____ Other (name) Biosolids Storage Tank w/ Gravity Settling

5. Additional Information

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant:

Electrolux Home Products / Northern Wire; Metal finishers

AmeriPride Linen Apparel Services / G&K Services; Commercial laundry

Estimated percent of plant BOD load: 7%

Collection System (check)

Separate sanitary sewers: X

Combined domestic/storm sewers: ____

Plant Sampling and Analyses

Influent

24 hr composite X Grab ____ Other ____

Frequency (days/week) 7 x Week

Effluent

24 hr composite X Grab ____

Other ____ Location Taken prior to discharge, after dechlorination

Frequency (days/week) 7 x Week

Does plant have a lab? Yes

Analyses done by plant lab (check)

BOD	X	TSS	X	PH	X	TKN	X
NH_3-N	X	NO_3-N	X	$NO2_3$-N		Total P	X
Soluble Ortho P	X	Coliform	X	COD	X		

Others (List) Total Chlorine Residual, Volatile Acids, Alkalinity

Wastewater Facility Screening Form
Preliminary Information

1. **Plant Information**

Plant Name: Fergus Falls WWTP

Contact Name: DAVID REIN

Phone: 218-849-8707   Fax: 218 233 8463

E-mail: rein@cableone.net

Design Capacity: 2.81 MGD   Present Flow: 1.9 MGD

2. **Discharge Permit Concentration (mg/L)**
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency(1)
BOD$_5$	25	3.3		
COD				
TSS	30	8.2		
Settleable Solids				
NH$_3$-N	4.3	1.0		
NO$_3$-N				
TKN				
Total Nitrogen				
Total Phosphorous	1.0	0.66		
Soluble Phosphorus				
Fecal Coliform	200	43		
pH	6-9	7.7		
Others(?) List				

eceiving Water body: Otter Tail River

(1)type - composite, grab
(1)frequency - # samples/week or month

5. **Additional Information**

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant:

Estimated percent of plant BOD load: ______

Collection System (check)

Separate sanitary sewers: ✓

Combined domestic/storm sewers: ______

Plant Sampling and Analyses

Influent

24 hr composite ✓ Grab ______ Other ______

Frequency (days/week) 3

Effluent

24 hr composite ✓ Grab ______

Other ______ Location Discharge

Frequency (days/week) 3

Does plant have a lab? Yes

Analyses done by plant lab (check)

BOD	✓	TSS	✓	PH	✓	TKN	
NH_3-N	✓	NO_3-N	✓	$NO2_3$-N		Total P	✓
Soluble Ortho P		Coliform	✓	COD			

Others (List) ~~[illegible]~~ Conductivity, MLSS, MLVSS, SV

3. Liquid Process Description

-treatment (check)

Barscreen ____ Comminutor ____

Self Cleaning Screens ✓

Aerated Grit Removal ✓

Other Grit Removal ____

Number of Treatment Trains 1

Primary treatment (please check). Yes ✓ No ____

# of clarifiers 2 Diameter ____

Chemical addition Yes ✓ No ____

If yes, chemical(s) used None

Secondary Treatment (please check)

Trickling Filter ____ Rotating Biological Contactor ____

Activated Sludge ✓ Oxidation Ditch ____

oon ____ Biological Nutrient Removal ✓
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes ____ No ✓

If yes, chemical(s) used ____

Secondary Clarifiers

# of clarifiers 2 Diameter 50

Chemical addition Yes ✓ No ____

If yes, chemical(s) used Designed for alum or ferric

Tertiary Treatment

Polishing Filters Yes ____ No ✓

Type of Filter ____ # of Filters ____

Media/depth ____ Area/Filter ____

Disinfection (please check)

lorine ✓ Ultraviolet ____

Dechlorination Yes ✓ No ____

Please provide a copy of the most recent monthly plant performance reporting form.

4. Sludge Processing/Ultimate Reuse or Disposal

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

Agricultural Application

Primary Sludge Thickening (please check)

Primary Tanks ✓ Gravity ____ Belt Thickeners ____

Secondary Sludge Thickening (please check)

Gravity ✓ Belt Thickeners ____

Centrifuge ____ Dissolved Air Flotation ____

Combined Sludge Thickening (please check)

Yes ____ No ____

Please Name Thickening Process ____

Sludge Digestion (please check)

Aerobic ____ Anaerobic ✓

Other (name) ____

Sludge Dewatering (please check)

Drying Beds ____ Centrifuge ____

Belt Filter Press ✓ Other (name) ____

Plant Screening Forms

Oxidation Ditch Treatment Plants

Wastewater Facility Screening Form
Preliminary Information

1. **Plant Information**

Plant Name: Wadena Wastewater Treatment Facility

Contact Name: Dave Pesola Foreman/operator

Phone: ( ) - 218-631-7715 Fax: ( ) - 218-631-7709

E-mail: wwtp@wcta.net

Design Capacity: wet weather .750 Dry weather .500 MGD Present Flow: .350 MGD

2. **Discharge Permit Concentration (mg/L)**
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency(1)
BOD_5	15 mg/L max. cal. wk avg.	2 mg/L	No changes	composite 1x/week
D			expected	
TSS	45 mg/L max. cal. wk. avg.	2 mg/L		composite 1x/week
Settleable Solids				
NH_4-N				
NO_3-N				
TKN	2 mg/L June-Sept. cal mo. avg			
Total Nitrogen	15 mg/L Dec.-march cal. mo. avg 8 mg/L april-may " " "	.70 mg/L		composite 1x/week
Total Phosphorous	monitor only cal. mo. avg	6.2 mg/L		composite 1x/week
Soluble Phosphorus				
Fecal Coliform	200/100mL april-oct.	2 mg/L		grab 1x/week
pH	6.0 min 9.0 max.	8.2 8.4		grab/composite 1x/week

Others(?) List chlorine Residual april-oct. .038 mg/L max. Daily grab Daily

Dissolved Oxygen - cannot be less than 7.0 mg/L grab/Daily

Receiving Water body: union creek

---

(1)type - composite, grab

(1)frequency - # samples/week or month

3. Liquid Process Description

reatment (check)

Barscreen ________ Comminutor ✓ Macerator/grinder

Self Cleaning Screens ________

Aerated Grit Removal ✓

Other Grit Removal Hydro gritter

Number of Treatment Trains ________

Primary treatment (please check) Yes ✓ No ________

\# of clarifiers 1 Diameter 40 ft

Chemical addition Yes ________ No ✓

If yes, chemical(s) used ________

Secondary Treatment (please check)

Trickling Filter un-used Rotating Biological Contactor ________

vated Sludge ✓ Oxidation Ditch ✓

Lagoon ________ Biological Nutrient Removal ________
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes ________ No ✓

If yes, chemical(s) used ________

Secondary Clarifiers

\# of clarifiers 2 Diameter 40 ft

Chemical addition Yes ________ No ✓

If yes, chemical(s) used ________

Tertiary Treatment

Polishing Filters Yes ✓ No ________

Type of Filter automatic backwash Traveling carriage # of Filters 2

Media/depth Sand 16" Area/Filter ≈ 150 cu ft of filter media/filter

isinfection (please check)

Chlorine ✓ Ultraviolot ________

Dechlorination Yes ✓ No ________

Please provide a copy of the most recent monthly plant performance reporting form.

4. Sludge Processing/Ultimate Reuse or Disposal

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

agricultural application with Field Gymmy

Primary Sludge Thickening (please check)

Primary Tanks ________ Gravity ________ Belt Thickeners ________

Secondary Sludge Thickening (please check)

Gravity ________ Belt Thickeners ________

Centrifuge ________ Dissolved Air Flotation ________

mbined Sludge Thickening (please check)

Yes ________ No ________

Please Name Thickening Process ________

Sludge Digestion (please check)

Aerobic ________ Anaerobic X

Other (name) primary digester (anerobic) 189,000 gallons, Sec. digester gas holder cover (Floating) 140,000 gallons
Two 250,000 gallon concrete storage Tanks

Sludge Dewatering (please check)

Brying Beds ________ Centrifuge ________

Belt Filter Press ________ Other (name) we decant clear supernatant From Sec. digester and Storage Tanks
Typically apply 2-3% biosolids

5. Additional Information

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant:

Homecrest Industries - Metal Finishing

Car washes

Laundromat/dry cleaners, Hospital, Nursing home

Estimated percent of plant BOD load: ________

Collection System (check)

Separate sanitary sewers: ✓

Combined domestic/storm sewers: ________

Plant Sampling and Analyses

Influent

hr composite	✓	Grab		Other	
Frequency (days/week)	7 days/week				

Effluent

24 hr composite	✓	Grab	
Other		Location	
Frequency (days/week)	7 days/week		
Does plant have a lab?	yes		

Analyses done by plant lab (check)

BOD	✓	TSS	✓	PH	✓	TKN	
NH_4-N	✓	NO_3-N		$NO2_3$-N		*Total P	* we do it but are not certified yet
Soluble Ortho P		Coliform	✓	COD			

Others (List) ________

DOVER
EYOTA
ST CHARLES

Wastewater Facility Screening Form
Preliminary Information

Dover Eyota study

1. Plant Information

Plant Name: Whitewater River Pollution Control Facility

Contact Name: Bob Wiskow

Phone: (507) -932-4171 Fax: (507)-932-4217

E-mail: descasd@venturecs.net

Design Capacity: 0.8 MGD Present Flow: 0.683 MGD

2. Discharge Permit Concentration (mg/L)
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency[1]
BOD_5	5.0	2.74	5.0	24C 1/7
COD	NA	NA	—	
TSS	30	3.53	30	24C 1/7
Settleable Solids	NA	—	—	—
NH_3-N	NA	0.24	1.3 to 10.8	24c 1/7
NO_3-N	NA	—	—	—
TKN	NA	—	—	—
Total Nitrogen	NA	—	—	—
Total Phosphorous	NA	6.9	1.0	24C 1/7
Soluble Phosphorus	NA	—	—	—
Fecal Coliform	200	113	200	grab 1/7
pH	6.0 to 9.0	7.07	6.0 to 9.0	7/7
Others(?) List				

Receiving Water body: South Fork, Whitewater River

---

(1) type - composite, grab
(1) frequency - # samples/week or month

5. Additional Information

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant:

North Star Foods, Inc., BOD and TSS.

Estimated percent of plant BOD load: 38 %

Collection System (check)

Separate sanitary sewers: X

Combined domestic/storm sewers: ______

Plant Sampling and Analyses

Influent

24 hr composite X   Grab ______   Other ______

Frequency (days/week) 1/7days

Effluent

24 hr composite X   Grab ______

Other ______   Location Chlorine Contact Tank effluent.

Frequency (days/week) 1/7 days

Does plant have a lab? yes

Analyses done by plant lab (check)

BOD		TSS	X	PH	X	TKN	
NH_3-N		NO_3-N		$NO2_3$-N		Total P	
Soluble Ortho P		Coliform	X	COD	X		

Others (List) ______

3. Liquid Process Description

Pre-treatment (check)

Barscreen ______ Comminutor ______

Self Cleaning Screens 1-Rotimat 1-Parkson

Aerated Grit Removal ______

Other Grit Removal 1-Vortex Grit Removal System

Number of Treatment Trains 2

Primary treatment (please check) Yes ______ No X

\# of clarifiers ______ Diameter ______

Chemical addition Yes ______ No ______

If yes, chemical(s) used ______

Secondary Treatment (please check)

Trickling Filter ______ Rotating Biological Contactor ______

Activated Sludge ______ Oxidation Ditch X

Lagoon ______ Biological Nutrient Removal ______
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes ______ No X

If yes, chemical(s) used ______

Secondary Clarifiers

\# of clarifiers 2 Diameter 52 ft. dia

Chemical addition Yes X No ______

If yes, chemical(s) used Polymer may be used if needed.

Tertiary Treatment

Polishing Filters Yes X No ______

Type of Filter Dual Media # of Filters 3

Media/depth 18" Sand 18" Coal Area/Filter 113 ft²

Disinfection (please check)

Chlorine X Ultraviolot ______

Dechlorination Yes X No ______

Please provide a copy of the most recent monthly plant performance reporting form.

4. Sludge Processing/Ultimate Reuse or Disposal

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

Agricultural Application

Primary Sludge Thickening (please check)

Primary Tanks ______ Gravity ______ Belt Thickeners ______

Secondary Sludge Thickening (please check)

Gravity ______ Belt Thickeners ______

Centrifuge ______ Dissolved Air Flotation ______

Combined Sludge Thickening (please check)

Yes ______ No ______

Please Name Thickening Process ______

Sludge Digestion (please check)

Aerobic ______ Anaerobic ______

Other (name) ______

Sludge Dewatering (please check)

Drying Beds ______ Centrifuge ______

Belt Filter Press ______ Other (name) ______

Plant Screening Forms

High Purity Oxygen (O_2) Treatment Plants

MOORHEAD
MINNESOTA
WASTEWATER SYSTEMS DIVISION
PO BOX 779
2121 28 ST N
MOORHEAD MN 56561
(218) 299-5386
FAX (218) 299-5381

FACSIMILE TRANSMITTAL SHEET

To: George Kehrberger - Hydro Qual
David Stensel

Fax: 201-529-5728
206-685-9185

From: Bob Zimmerman

Date: 8/12/03

Re: Survey

Pages: 9

Message:

Fargo/Moorhead
All-America City
2000

TDD (for hearing and speech impaired only): (218) 299-5370

Wastewater Facility Screening Form
Preliminary Information

1. Plant Information

Plant Name: Moorhead Wastewater Treatment Facility

Contact Name: Robert Zimmerman

Phone: 218 299-5386 Fax: 218 299-5381

E-mail: bob.zimmerman@ci.moorhead.mn.us

Design Capacity: 6.0 MGD Present Flow: 4.2 MGD

2. Discharge Permit Concentration (mg/L)
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency[1]
BOD_5	12.0 mg/L	8.7 mg/L		24 hr comp 3/wk
D	N/A	77.0 mg/L		24 hr comp 1/wk
TSS	30.0 mg/L	7.0 mg/L		24 hr comp 3/wk
Settleable Solids	N/A	N/A		N/A
NH_3-N	Jun-Sep 647 kg/d @19 mg/L (river flow >50 cfs) Jun-Sep 108 kg/d @19 mg/L (river flow < 50 cfs)		37 kg/d 2.2 mg/L	24 hr comp 3/wk
NO_3-N	N/A	N/A		N/A
TKN	N/A	N/A		N/A
Total Nitrogen	N/A	N/A		N/A
Total Phosphorous	N/A	3.9 mg/L		24 hr comp 1/wk
Soluble Phosphorus	N/A	N/A		N/A
Fecal Coliform	200/100 mL	<4/100 mL		Grab 3/wk
pH	6.0 SU/9.0 SU	6.4 SU/7.4 SU		Grab 5/wk
Others(?) List				
Chlorine Residual	<0.038 or MDL	<0.04 mg/L		Grab 5/wk
Dissolved Oxygen	N/A	4.3 mg/L		Grab 5/wk

Receiving Water body: Red River of the North

[1] type - composite, grab
[1] frequency - # samples/week or month

Liquid Process Description

eatment (check)

arscreen 2 Comminutor ______

elf Cleaning Screens 2

erated Grit Removal 2

ther Grit Removal ______

umber of Treatment Trains 2

rimary treatment (please check) Yes x No ______

of clarifiers 2 Diameter Rectangular 90 ft x 36 ft (LxW)

hemical addition Yes ______ No x

f yes, chemical(s) used ______

econdary Treatment (please check)

rickling Filter ______ Rotating Biological Contactor ______

ctivated Sludge x High Purity Oxygen Activated Sludge Oxidation Ditch ______

n ______ Biological Nutrient Removal ______
i.e. (Anaerobic and/or anoxic compartments

hemical addition Yes ______ No x

f yes, chemical(s) used ______

econdary Clarifiers

of clarifiers 4 Diameter 60 ft

hemical addition Yes x No ______

f yes, chemical(s) used RAS chlorination used intermittently

Tertiary Treatment

Polishing Filters Yes ______ No ______

Type of Filter ______ # of Filters ______

Media/depth ______ Area/Filter ______

Disinfection (please check)

ine x Ultraviolot ______

Dechlorination Yes x No ______

Please provide a copy of the most recent monthly plant performance reporting form.

4. **Sludge Processing/Ultimate Reuse or Disposal**

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

Applied to agricultural land at agronomic rates.

Primary Sludge Thickening (please check)

Primary Tanks ________ Gravity ________ Belt Thickeners ________

Secondary Sludge Thickening (please check)

Gravity ________ Belt Thickeners ________

Centrifuge ________ Dissolved Air Flotation x

Combined Sludge Thickening (please check)

Yes ________ No x

Please Name Thickening Process ________

Sludge Digestion (please check)

Aerobic ________ Anaerobic x

Other (name) ________

Sludge Dewatering (please check)

Drying Beds ________ Centrifuge ________

Belt Filter Press ________ Other (name) Biosolids Storage Facility - gravity thickened and decanted

Additional Information

ndustrial Wastewater

ist name/type of any significant industrial wastewater load to the plant:

Busch Agricultural Resources - Malt House

Pactiv Corporation - molded fiber (paper) packaging

Burlington Northern & Sante Fe Railway - railway yard

stimated percent of plant BOD load: 40%

ollection System (check)

eparate sanitary sewers: x

ombined domestic/storm sewers: _____

Plant Sampling and Analyses

Influent

r composite	3/wk	Grab	5/wk	Other	
Frequency (days/week)					

Effluent

24 hr composite	3/wk	Grab	5/wk
Other		Location	
Frequency (days/week)			
Does plant have a lab?	yes		

Analyses done by plant lab (check)

BOD	x	TSS	x	PH	x	TKN	x
NH_3-N	x	NO_3-N		$NO2_3$-N		Total P	
Soluble Ortho P		Coliform	x	COD	x		

Others (List) _____

Supplemental Report Form

City of Moorhead, Minnesota Wastewater Treatment Facility

June 2003

NPDES PERMIT NUMBER MN0049069

OUTFALL NUMBER SD001

Date	Day of Week	Precip Inches	Effluent Flow MGD	Influent CBOD5 mg/L	Effluent CBOD5 mg/L	Percent Removal CBOD5	Effluent CBOD5 kg/day	Influent TSS mg/L	Effluent TSS mg/L	Percent Removal TSS	Effluent TSS kg/day	Influent pH Minimum Std Units	Influent pH Maximum Std Units	Effluent pH Std Units	Influent Phosphorus mg/L	Effluent Phosphorus mg/L	Effluent Phosphorus kg/day	Effluent DO mg/L	Fecal Coliform Number/100 ml	Effluent Chlorine Residual mg/L	Chlorine Used lbs	Dechlorination Agent Used lbs	Influent Ammonia Nitrogen mg/L	Effluent Ammonia Nitrogen mg/L	Effluent Ammonia Nitrogen kg/day
1	Sun	0.00	4.05									6.0	7.1								53	38			
2	Mon	0.02	4.25									6.3	7.4	7.0				6.2		<0.04	55	30			
3	Tue	0.00	4.15	225	9.8	96.6	154	205	12.8	93.8	201	6.4	7.4	7.1	5.62	2.67	42	6.8	<1	<0.04	55	30	19.9	5.6	68
4	Wed	0.00	4.08	217	9.0	96.9	139	199	9.0	96.0	123	6.4	7.8	7.1				7.0	1	<0.04	45	30	20.2	6.2	56
5	Thu	0.01	3.94	252	8.6	96.6	128	229	6.0	97.4	89	6.4	7.6	7.0				6.4	<1	<0.04	65	30	18.2	7.3	109
6	Fri	0.56	4.37									6.3	7.5	7.1				5.6		<0.04	69	37			
7	Sat	0.04	4.50									6.6	7.8								61	38			
8	Sun	0.02	4.13									6.5	7.8								56	35			
9	Mon	0.00	4.36									6.5	7.7	7.0				5.6		<0.04	66	40			
10	Tue	0.23	4.89	267	8.1	97.0	141	291	8.8	97.7	118	6.4	7.7	7.1	4.69	2.80	49	5.9	3.	<0.04	60	40	16.9	8.1	141
11	Wed	0.55	4.45	183	6.3	97.1	89	160	6.4	96.0	108	6.5	7.5	7.1				5.6	1	<0.04	60	50	16.6	7.9	133
12	Thu	0.07	4.97	200	6.1	97.6	96	139	6.2	96.3	98	6.5	7.7	7.1				6.0	4	<0.04	70	40	15.1	8.2	154
13	Fri	0.00	4.53									5.1	7.3	7.2				5.2		<0.04	60	38			
14	Sat	0.00	4.23									5.0	6.4								56	33			
15	Sun	0.00	4.66									5.0	6.6								54	32			
16	Mon	0.00	4.69									4.7	6.5	7.1				5.4		<0.04	60	40			
17	Tue	0.00	4.23	224	4.4	98.0	70	206	8.4	95.9	134	4.9	6.5	7.1	6.80	2.95	47	4.5	2	<0.04	60	40	17.2	5.6	50
18	Wed	0.00	3.96	242	7.2	97.0	108	196	9.6	95.1	144	4.8	6.5	7.1				5.7	2	<0.04	55	30	17.5	5.2	78
19	Thu	0.00	4.16	290	6.6	97.7	104	160	8.8	95.1	136	4.8	6.6	7.1				5.0	<1	<0.04	65	40	15.8	4.5	71
20	Fri	0.00	4.16									6.0	6.6	7.2				6.8		<0.04	56	38			
21	Sat	0.59	3.93									4.7	7.7								53	36			
22	Sun	1.14	5.16									5.5	8.7								70	47			
23	Mon	0.22	6.35									5.7	7.6	7.1				4.9		<0.04	80	50			
24	Tue	1.29	5.77	228	9.2	86.0	201	436	11.2	97.4	244	5.7	8.3	7.2	3.55	2.81	61	6.4	<1	<0.04	90	70	11.5	6.7	146
25	Wed	0.20	7.66	202	5.1	97.5	148	334	8.0	97.6	232	5.6	9.0	7.2				5.2	18	<0.04	75	60	10.5	6.1	177
26	Thu	0.49	6.37	189	5.2	97.2	125	240	4.0	98.3	98	5.7	8.0	7.3				4.7	2	<0.04	75	60	11.2	5.0	120
27	Fri	0.28	6.67									5.5	8.2	7.3				4.8		<0.04	79	57			
28	Sat	0.15	6.70									5.6	8.5								80	58			
29	Sun	0.00	6.40									5.5	8.8								75	55			
30	Mon	0.00	6.12									5.7	8.3	7.3				6.0		<0.04	75	40			
31	Tue																								
Total		5.85	146.94	2,719	83.6	1,163.1	1,503	2,815	95.2	1,156.5	1,727	N/A	N/A	N/A	19.36	11.23	199	118.9	<37	<0.84	1,923	1,281	190.5	76.4	1,402

Moorhead WWTP
2121 28th St N
Moorhead, MN 56561

DISCHARGE MONITORING RE

Moorhead city of
PO Box 779
Moorhead, MN 565610779

PERMIT #	LIMIT STATUS	FORMER #
MN0049069	INTERIM	

STATION INFORMATION:
WS-001 (Influent Waste Stream)
Waste Stream, Influent Waste
Attention: Robert Zimmerman

MONITORING PERIOD
FROM YEAR MO. DAY 2003/06/01 TO YEAR MO. DAY 2003/06/30

☐ No Flow

MPCA:MK

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
CBOD 05 Day (20 Deg C) 80082	SAMPLE VALUE	******	******	****	******	227	290	mg/L	✓	✓
	PERMIT REQ	******	******		******	REPORT CalMoAvg	REPORT CalMoMax		3 x Week	Comp24
TSS 00530	SAMPLE VALUE	******	******	****	******	235	436	mg/L	✓	✓
	PERMIT REQ	******	******		******	REPORT CalMoAvg	REPORT CalMoMax		3 x Week	Comp24
pH 00400	SAMPLE VALUE	******	******	****	4.7	******	9.0	SU	✓	✓
	PERMIT REQ	******	******		REPORT CalMoMin	******	REPORT CalMoMax		1 x Day	MeaCon
Phosphorus Total (as P) 00665	SAMPLE VALUE	******	******	****	******	4.84	******	mg/L	✓	✓
	PERMIT REQ	******	******		******	REPORT CalMoAvg	******		1 x Week	Comp24
Nitrogen, Ammonia Total (as N) 00610	SAMPLE VALUE	******	******	****	******	15.9	20.2	mg/L	✓	✓
	PERMIT REQ	******	******		******	REPORT CalMoAvg	REPORT CalMoMax		3 x Week	Comp24

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to:
MINNESOTA POLLUTION CONTROL AGENCY
520 LAFAYETTE RD
ST. PAUL, MN 55155-4194
ATTN: Discharge Monitoring Report

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

B. G. Messelt — 7/11/03
SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT — DATE

Robert H Zimmerman — 218-299-5386 — 7/9/03 — A2263
SIGNATURE OF CHIEF OPERATOR — PHONE — DATE — CERTIFICATION#

COMMENTS:

FACILITY NAME/ RESS:
Moorhead WWTP
2121 28th St N
Moorhead, MN 56561

WASTEWATER TREATMENT
DISCHARGE MONITORING RE T

Moorhead city of
PO Box 779
Moorhead, MN 565610779

PERMIT #	LIMIT STATUS	FORMER #
MN0049069	INTERIM	

STATION INFORMATION:
SD-001 (010 Main Discharge)
Surface Discharge, Effluent To Surface Water
Attention: Robert Zimmerman

MONITORING PERIOD

	YEAR/MO./DAY		YEAR/MO./DAY
FROM	2003/06/01	TO	2003/06/30

☐ No Discharge

MPCA:MK

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Flow 50050	SAMPLE VALUE	******	146.94	MG	******	4.90	******	mgd	✓	✓
	PERMIT REQ	******	REPORT CalMoTot		******	REPORT CalMoAvg	******		1 x Day	MeaCon
CBOD 05 Day (20 Deg C) 80082	SAMPLE VALUE	125	158	kg/day	******	7.0	9.1	mg/L	✓	✓
	PERMIT REQ	408 CalMoAvg	613 MxCalWkAvg		******	12 CalMoAvg	18 MxCalWkAvg		3 x Week	Comp24
CBOD 05 Day % Removal 80091	SAMPLE VALUE	******	******	****	96.9	******	******	%	✓	✓
	PERMIT REQ	******	******		85 MnCalMoAvg	******	******		3 x Week	Calcul
TSS 00530	SAMPLE VALUE	144	191	kg/day	******	7.9	8.9	mg/L	✓	✓
	PERMIT REQ	1021 CalMoAvg	1532 MxCalWkAvg		******	30 CalMoAvg	45 MxCalWkAvg		3 x Week	Comp24
TSS % Removal 81011	SAMPLE VALUE	******	******	****	96.4	******	******	%	✓	✓
	PERMIT REQ	******	******		85 MnCalMoAvg	******	******		3 x Week	Calcul
pH 00400	SAMPLE VALUE	******	******	****	7.0	******	7.3	SU	✓	✓
	PERMIT REQ	******	******		6.0 CalMoMin	******	9.0 CalMoMax		5 x Week	Grab
Phosphorus Total (as P) 00665	SAMPLE VALUE	******	******	****	******	2.81	******	mg/L	✓	✓
	PERMIT REQ	******	******		******	REPORT CalMoAvg	******		1 x Week	Comp24

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to:
MINNESOTA POLLUTION CONTROL AGENCY
520 LAFAYETTE RD
ST. PAUL, MN 55155-4194
ATTN: Discharge Monitoring Report

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

7/11/03
SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT — DATE

218-299-5386 7/9/03 A 2263
SIGNATURE OF CHIEF OPERATOR — PHONE — DATE — CERTIFICATION#

COMMENTS:

Moorhead WW
2121 28th St N
Moorhead, MN 56561

DISCHARGE MONITORING F RT

Moorhead city of
PO Box 779
Moorhead, MN 565610779

PERMIT #	LIMIT STATUS	FORMER #
MN0049069	INTERIM	

STATION INFORMATION:
SD-001 (010 Main Discharge)
Surface Discharge, Effluent To Surface Water
Attention: Robert Zimmerman

MONITORING PERIOD

	YEAR / MO. / DAY		YEAR / MO. / DAY
FROM	2003/06/01	TO	2003/06/30

☐ No Discharge

MPCA:MK

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Fecal Coliform, MPN/ Membrane Fltr 44.5C 48201	SAMPLE VALUE	******	******	****	******	< 2	******	#100ml	✓	✓
	PERMIT REQ	******	******		******	200 CalMoGeoMn	******		3 x Week	Grab
Chlorine Total Residual 50060	SAMPLE VALUE	******	******	****	******	******	< 0.04	mg/L	✓	✓
	PERMIT REQ	******	******		******	******	0.038 DailyMax		5 x Week	Grab
Nitrogen, Ammonia Total (as N) 00610	SAMPLE VALUE	117	******	kg/day	******	6.4	******	mg/L	✓	✓
	PERMIT REQ	647 CalMoAvg	******		******	19 CalMoAvg	******		3 x Week	Comp24
Oxygen, Dissolved 00300	SAMPLE VALUE	******	******	****	4.5	******	******	mg/L	✓	✓
	PERMIT REQ	******	******		REPORT CalMoMin	******	******		5 x Week	Grab

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to:
MINNESOTA POLLUTION CONTROL AGENCY
520 LAFAYETTE RD
ST. PAUL, MN 55155-4194
ATTN: Discharge Monitoring Report

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT — DATE 7/11/03

SIGNATURE OF CHIEF OPERATOR — PHONE (218-299-5386 — DATE 7/9/03 — CERTIFICATION# A 2263

COMMENTS:

ALL-AMERICA CITY

ROCHESTER
Minnesota

CITY OF ROCHESTER MINNESOTA INCORPORATED AUGUST 5 A.D. 1858

WATER RECLAMATION PLANT
301 37th St. N.W.
Rochester, MN 55901
(507) 281-6190
FAX #(507) 287-1389

FAX TRANSMITTAL COVER PAGE

DATE: 8/12/03 ~~4-25-03~~

FROM: Lyle J Zimmerman

WATER RECLAMATION PLANT
301 NW 37TH STREET
ROCHESTER, MN 55901

TO: Dr George Kehrberger

TOTAL PAGES, INCLUDING THIS PAGE: 5

FAX NUMBER SENT TO: 201 529 57~~82~~ 28 ✓ Wrong No

IF YOU NEED A RESEND OF ANY PAGE, PLEASE CALL (507) 281-6191. IF YOU DO NOT CALL, WE WILL ASSUME YOU RECEIVED THE PAGES SATISFACTORILY.

COMMENTS:

Wastewater Facility Screening Form
Preliminary Information

1. Plant Information

Plant Name: Water Reclamation Plant - Rochester MN

Contact Name: Lyle J. Zimmerman

Phone: (507) 281 6190 ext 3002 Fax: (507) 287-1389

E-mail: LZimmerman@Ci.Rochester.MN.US

Design Capacity: 19.1 MGD (Max Month) Present Flow: 13.7 MGD (Annual Avg)

2. Discharge Permit Concentration (mg/L)
(Provide Available Parameters)

	Permit Limit	2002 Aug. Actual Discharge	Expected Future	Sample Type/Frequency[1]
BOD_5	14	3	15	Comp 3/7
COD				
TSS	20 (1444 Kg/Day)	6	Freeze Mass @ 1444 Kg/Day ≐ 15 mg/l after expansion	Comp 3/7
Settleable Solids				
NH_3-N	1.6 year Round	0.10	Jun-Sep 3.0 Oct-Nov 13.2	Comp 3/7
NO_3-N		26	Dec-Mar 5.0 Apr-May 10.3	Comp. 1/month
TKN		1.2	—	Comp 1/month
Total Nitrogen				
Total Phosphorous	1.0 (72.2 Kg/Day)	0.8	Freeze Mass @ 72.2 Kg/Day or 0.7± mg/l after plant expands	Comp. 3/7
Soluble Phosphorus				
Fecal Coliform	200	12	200	Grab 3/7
pH	6.0 - 9.0	6.34	6 - 9	Grab 3/7
Others(?) List				

Receiving Water body: Zumbro River

[1] type - composite, grab
[1] frequency - # samples/week or month

3. Liquid Process Description

Pre-treatment (check)

Barscreen ____ Comminutor ____

Self Cleaning Screens ✓

Aerated Grit Removal ✓

Other Grit Removal ____

Number of Treatment Trains ____

Primary treatment (please check) Yes ✓ No ____

# of clarifiers 2 Diameter Rectangular 10000 sq ft/clarifier

Chemical addition Yes ✓ No ____

If yes, chemical(s) used Ferric Chloride

Secondary Treatment (please check)

Trickling Filter ____ Rotating Biological Contactor ____

Activated Sludge HPO 2 stage Activated Sludge Oxidation Ditch ____

Lagoon ____ Biological Nutrient Removal ____
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes ____ No ____

If yes, chemical(s) used [illegible]

Secondary Clarifiers

# of clarifiers 4 Intermediate
4 Final
Diameter 90' Intermediate
120' Final

Chemical addition Yes ✓ No ____

If yes, chemical(s) used Alum & Anionic Polymer to Final Clarifier Inf.

Tertiary Treatment

Polishing Filters Yes ____ No ____

Type of Filter ____ # of Filters ____

Media/depth ____ Area/Filter ____

Disinfection (please check)

Chlorine ✓ Ultraviolot ____

Dechlorination Yes ✓ No ____

Please provide a copy of the most recent monthly plant performance reporting form.

4. Sludge Processing/Ultimate Reuse or Disposal

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

Land application after annerobically digesting primary and WAS. Thicken WAS and digested sludge on gravity belt thickners to 6%.

Primary Sludge Thickening (please check)

Primary Tanks ______ Gravity ______ Belt Thickeners ______

Secondary Sludge Thickening (please check)

Gravity ______ Belt Thickeners ✓

Centrifuge ______ Dissolved Air Flotation ______

Combined Sludge Thickening (please check)

Yes ______ No ______

Please Name Thickening Process ______

Sludge Digestion (please check)

Aerobic ______ Anaerobic ✓

Other (name) ______

Sludge Dewatering (please check)

Drying Beds ______ Centrifuge ______

Belt Filter Press ______ Other (name) 6%-Thickend on GBT.

5. **Additional Information**

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant:

Food processing waste from dairies, canary and cheese processors.

Estimated percent of plant BOD load: 30-40%

Collection System (check)

Separate sanitary sewers: ✓

Combined domestic/storm sewers: ______

Plant Sampling and Analyses

Influent

24 hr composite ✓ Grab ______ Other ______

Frequency (days/week) 7

Effluent

24 hr composite ✓ Grab ______

Other ______ Location Outfall Line

Frequency (days/week) 7

Does plant have a lab? Yes

Analyses done by plant lab (check)

BOD	✓	TSS	✓	PH	✓	TKN	
NH_4-N	✓	NO_3-N		$NO2_3$-N		Total P	✓
Soluble Ortho P	✓	Coliform	✓	COD			

Others (List) ______

Plant Screening Forms

Trickling Filter Treatment Plants

City of Detroit Lakes
1025 Roosevelt Ave., P.O. Box 647 Detroit Lakes MN 56502

Office of Public Utilities
218-847-7609
FAX 218-847-8969
dlpublic@lakesnet.net

To

Dr. George Kehrberger

From

Jarrod Christen

you should receive 5 Sheets with cover sheet.

If you have questions Please call 218-846-7102

Thanks

Wastewater Facility Screening Form
Preliminary Information

1. Plant Information

Plant Name: City of Detroit Lakes

Contact Name: Jarrod Christen

Phone: ( ) 218-846-7102 Fax: ( )218-846-7109

E-mail: jchristen@lakesnet.net

Design Capacity: 1.64 MGD Present Flow: 1.3 MGD

Discharge Permit Concentration (mg/L)
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency(1)
OD$_5$	20 mg/L	3 mg/L		Grab 3 X Week
OD				
	20 mg/L	5 - 10 mg/L		Grab 3 X Week
ettleable Solids				
IH$_3$-N	Monitor Only			
IO$_3$-N	Monitor Only			
KN	Monitor Only			
otal Nitrogen	Monitor Only			
otal Phosphorous	1 mg/L	0.5 mg/L		Grab 3 X Week
oluble Phosphorus				
ecal Coliform	200 mpn	50 mpn		Grab 3 X Week
H	6.0 - 9.0	7.5		Grab 3 X Week
thers(?) List				

Receiving Water body: Lake St. Clair

ineffect since 1975

) - composite, grab
equency - # samples/week or month

Liquid Process Description

e-treatment (check)

rscreen Yes Comminutor ______

lf Cleaning Screens ______

rated Grit Removal Yes

ther Grit Removal ______

umber of Treatment Trains One(1)

imary treatment (please check) Yes X No ______

of clarifiers 2 Diameter 40'

hemical addition Yes ______ No X

yes, chemical(s) used ______

econdary Treatment (please check)

rickling Filter Yes (2 Different size and media) Rotating Biological Contactor ______

ctivated Sludge ______ Oxidation Ditch ______

n ______ Biological Nutrient Removal ______
i.e. (Anaerobic and/or anoxic compartments

hemical addition Yes ______ No X

f yes, chemical(s) used ______

econdary Clarifiers

of clarifiers 1 Diameter 40'X 60'

hemical addition Yes ______ No X

f yes, chemical(s) used ______

ertiary Treatment

Polishing Filters/Ponds Yes X No ~~X~~

Type of Filter ______ # of Filters ______

Media/depth ______ Area/Filter ______

Disinfection (please check)

rine X Ultraviolet ______

Dechlorination Yes ______ No X

Please provide a copy of the most recent monthly plant performance reporting form.

4. **Sludge Processing/Ultimate Reuse or Disposal**

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

ag application

Primary Sludge Thickening (please check)

Primary Tanks ____ Gravity X Belt Thickeners ____

Secondary Sludge Thickening (please check)

Gravity X Belt Thickeners ____

Centrifuge ____ Dissolved Air Flotation ____

Combined Sludge Thickening (please check)

es ____ No X

Please Name Thickening Process ____

Sludge Digestion (please check)

Aerobic ____ Anaerobic X

Other (name) ____

Sludge Dewatering (please check)

Drying Beds ____ Centrifuge ____

Belt Filter Press ____ Other (name) ____

After the trickling filter plant, the effluent goes to a three acre pond and then to a 25 acre pond. We spray irrigate 54 acres of crop land and also apply to 21 acres of infiltration basins in the summer months. We remove phosphorus chemically approximately January 1st to May 1st. In this process we use ferric sulfate. The effluent is chlorinated and filtered before discharge.

and small amount of polymer

Additional Information

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant:

None — See for discussion

Estimated percent of plant BOD load: ______

Collection System (check)

Separate sanitary sewers: X

Combined domestic/storm sewers: ______

Plant Sampling and Analyses

Influent

24 hr composite	X — (inf; eff grab)	Grab		Other	
Frequency (days/week)					

Effluent

24 hr composite	n — Nitrogen	Grab	X
Other		Location	
Frequency (days/week)			
Does plant have a lab?			

Analyses done by plant lab (check)

BOD	X	TSS	X	PH	X	TKN	
NH_4-N		NO_3-N		$NO2_3$-N		Total P	X
Soluble Ortho P	X	Coliform	X	COD			

Others (List) ______

Plant Screening Forms

Trickling Filter/Activated Sludge Treatment Plants

City Of Faribault

FACSIMILE TRANSMITTAL

To: Dr. David Stensel

From: Beckie VonRuden

Phone:

Phone: 507-333-0361

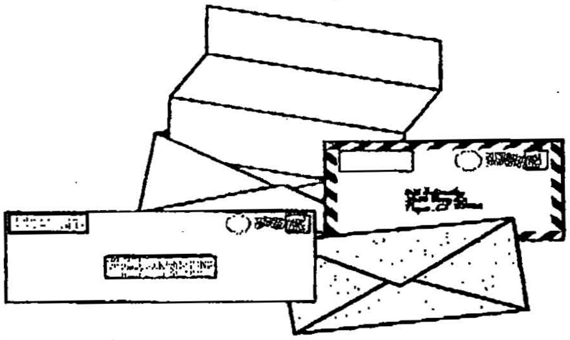
Fax: 206-685-9185

Fax: 507-384-0509

Re: Survey

Date: 8/12/03

Number of Pages including this cover sheet: 5



Please call immediately if you did not receive the number of pages we transmitted or if there was a problem with the transmission of this document. Thank you.

Comments:

Wastewater Facility Screening Form
Preliminary Information

1. **Plant Information**

Plant Name: City of Faribault

Contact Name: Dave Simens

Phone: 507-333-0360 Fax: 507() 333-2917

E-mail:

Design Capacity: 7 MGD Present Flow: 4.5 MGD

2. **Discharge Permit Concentration (mg/L)**
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency(1)
BOD_5	25 mgL	10 mgL		3x week
COD				
TSS	30 mgL	18 mgL		3x week
Settleable Solids				
NH_3-N	Monitor only	6 mgL		1 x month
NO_3-N				
TKN				
Total Nitrogen				
Total Phosphorous	Monitor only	4.0 mgL		1x week
Soluble Phosphorus				
Fecal Coliform	200 mpn			3x week
pH	6.0 - 9.0	7.0 - 8.0		1x daily
Others(?) List				

Receiving Water body: Cannon River

(1)type - composite, grab
(1)frequency - # samples/week or month

3. Liquid Process Description

Pre-treatment (check)

Barscreen X Comminutor ____

Self Cleaning Screens X

Aerated Grit Removal X

Other Grit Removal ____

Number of Treatment Trains 1

Primary treatment (please check) Yes X No ____

# of clarifiers 4 Diameter 54'

Chemical addition Yes ____ No X

If yes, chemical(s) used ____

Secondary Treatment (please check)

Trickling Filter X Rotating Biological Contactor ____

Activated Sludge X Oxidation Ditch ____

Lagoon - sludge storage X Biological Nutrient Removal ____
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes X No ____

If yes, chemical(s) used polymer - waste sludge

Secondary Clarifiers

# of clarifiers 4 Diameter 70'

Chemical addition Yes ____ No X

If yes, chemical(s) used ____

Tertiary Treatment

Polishing Filters Yes ____ No X

Type of Filter ____ # of Filters ____

Media/depth ____ Area/Filter ____

Disinfection (please check)

Chlorine X Ultraviolet ____

Dechlorination Yes X No ____

Please provide a copy of the most recent monthly plant performance reporting form.

4. **Sludge Processing/Ultimate Reuse or Disposal**

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

Agricultural App.

Primary Sludge Thickening (please check)

Primary Tanks ________ Gravity ________ Belt Thickeners ________

Secondary Sludge Thickening (please check)

Gravity X Belt Thickeners ________

Centrifuge ________ Dissolved Air Flotation ________

Combined Sludge Thickening (please check)

Yes ________ No X

Please Name Thickening Process Gravity thickened Activated waste sludge

Sludge Digestion (please check)

Aerobic ________ Anaerobic X

Other (name) ________

Sludge Dewatering (please check)

Drying Beds ________ Centrifuge ________

Belt Filter Press ________ Other (name) ________

5. Additional Information

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant:

Faribault Foods - cannery

Turkey Store - Turkey processing

Protient - soy protien

Estimated percent of plant BOD load: ______

Collection System (check)

Separate sanitary sewers: X

Combined domestic/storm sewers: ______

Plant Sampling and Analyses

Influent

24 hr composite	X	Grab		Other	
Frequency (days/week)	3				

Effluent

24 hr composite	X	Grab	
Other		Location	
Frequency (days/week)	3		
Does plant have a lab?	Yes		

Analyses done by plant lab (check)

BOD	X	TSS	X	PH	X	TKN	
NH_3-N	X	NO_3-N		NO2$_3$-N		Total P	
Soluble Ortho P		Coliform	X	COD			

Others (List) ______

600 Erie Road
Marshall MN 56258
Phone: 507-537-6776
Fax: 507-537-6201

CITY OF MARSHALL WASTEWATER TREATMENT FACILITY

Fax

To: HydroQual **From:** Bob VanMoer

Fax: 201-529-5728 **Pages:** ~~8~~ 9

Phone: **Date:** 8/11/03 & 8/12/03

Re: WW Screening Form **CC:**

☐ **Urgent** ☐ **For Review** ☐ **Please Comment** ☐ **Please Reply** ☐ **Please Recycle**

- **Comments:**

Additional information sent 8/12/03.

Wastewater Facility Screening Form
Preliminary Information

1. **Plant Information**

Plant Name: City of Marshall Wastewater Facility

Contact Name: Robert VanMoer

Phone: (507) 537-6776 Fax: (507) 537-6201

E-mail: bvanmoer@marshallmn.com

Design Capacity: 4.3 MGD Present Flow: 2.4 MGD

2. **Discharge Permit Concentration (mg/L)**
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency[1]
BOD$_5$	5 mg/1	3 mg/1	3 mg/1	24 hr. comp. 3x week
COD	-	-	-	-
TSS	30 mg/1	7 mg/1	7 mg/1	24 hr. comp. 3x wee
Settleable Solids	-	20	20	24 hr. comp. 7x wee
NH$_3$-N	1.1 Summer 2.3 Fall 9.4 Winter 2.4 Spring	.8	1.1 2.3 9.4 2.4	24 hr. Comp. 7x week
NO$_3$-N	—	—	—	—
TKN	—	—	—	—
Total Nitrogen	—	—	—	—
Total Phosphorous	-	7.5 mg/1	1	24 hr. comp. 3x wee
Soluble Phosphorus	-			
Fecal Coliform	200 organisms/100 ml	5	5	Grab - Daily
pH	6-9	7.5	7.5	24 hr. comp. Daily
Others(?) List	D.O. 7.5 mg/1	10.0	10.0	Grab - Daily

Receiving Water body: Redwood River

[1] type - composite, grab
[1] frequency - # samples/week or month

3. Liquid Process Description

Pre-treatment (check)

Barscreen ______ Comminutor ✓

Self Cleaning Screens ______

Aerated Grit Removal ______

Other Grit Removal Vortex

Number of Treatment Trains 1

Primary treatment (please check) Yes ✓ No ______

\# of clarifiers 2 Diameter 60'

Chemical addition Yes ______ No ✓

If yes, chemical(s) used ______

Secondary Treatment (please check)

Trickling Filter ✓ Rotating Biological Contactor ______

Activated Sludge ✓ Oxidation Ditch ______

Lagoon ______ Biological Nutrient Removal ______
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes ______ No ✓

If yes, chemical(s) used ______

Secondary Clarifiers

\# of clarifiers 2 Diameter 70'

Chemical addition Yes ______ No ✓

If yes, chemical(s) used ______

Tertiary Treatment

Polishing Filters Yes ✓ No ______

Type of Filter Traveling Bridge # of Filters 2

Media/depth Sand/Anthracite 20" Area/Filter 1216 sq. ft. each

Disinfection (please check)

Chlorine ______ Ultraviolet ✓

Dechlorination Yes ______ No ✓

Please provide a copy of the most recent monthly plant performance reporting form.

4. Sludge Processing/Ultimate Reuse or Disposal

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

Anaerobic Digestion, land apply liquid biosolids 2%-3% solids.

Primary Sludge Thickening (please check)

Primary Tanks ____ Gravity ____ Belt Thickeners ✓ (not currently used)

Secondary Sludge Thickening (please check)

Gravity ____ Belt Thickeners ✓ (not currently used)

Centrifuge ____ Dissolved Air Flotation ____

Combined Sludge Thickening (please check)

Yes ✓ No ____

Please Name Thickening Process We pump our WAS to primary clarifiers for thickening.

Sludge Digestion (please check)

Aerobic ____ Anaerobic X

Other (name) ____

Sludge Dewatering (please check) None

Drying Beds ____ Centrifuge ____

Belt Filter Press ____ Other (name) ____

5. Additional Information

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant:

ADM Corn Processing Plant (ethanol, corn sweetner, corn syrup, corn starch)

Schwan Food Company - Ice Cream Plant, Convenience Food Plant

Estimated percent of plant BOD load: 60%

Collection System (check)

Separate sanitary sewers: ✓

Combined domestic/storm sewers:

Plant Sampling and Analyses

Influent

24 hr composite ✓ Grab Other

Frequency (days/week) 7

Effluent

24 hr composite ✓ Grab

Other Location UV Bld.

Frequency (days/week) 7

Does plant have a lab? yes

Analyses done by plant lab (check)

BOD	✓	TSS	✓	PH	✓	TKN	
NH$_4$-N	✓	NO$_3$-N		NO2$_3$-N		Total P	✓
Soluble Ortho P	✓	Coliform	✓	COD	✓		

Others (List) UV Analyzer - Chlorides - Chlorine Residual - Heteroophic Plate Count
Volatile Solids - Conductivity

MPCA Monthly Discharge Monitoring Report

Marshall MN Permit #MN0022179 Jul, 2003

Date	Rainfall Inch	Snowfall Inchs	Inf Flow MGD	Inf CBOD MG/L	Eff CBOD MG/L	CBOD % Removal	Eff. CBOD KG	Inf TSS MG/L	Eff TSS MG/L	TSS % Removal	Eff. TSS KG	Inf. pH SU	Eff. pH SU	Eff DO mg/l	Eff Fecal No/100ml
07/01/03	0.00	0.00	2.40	430.00	1.20	99.72	9.53	330.00	8.80	97.33	69.85	6.70	7.60	10.30	0.00
07/02/03	0.00	0.00	2.50	460.00	1.50	99.67	12.47	435.00	2.80	99.36	23.28	6.60	7.50	10.30	0.00
07/03/03	0.00	0.00	2.40									6.60	7.50	10.40	
07/04/03	1.25	0.00	2.20									7.30	7.60	10.50	
07/05/03	0.00	0.00	2.10									7.20	7.60	10.60	
07/06/03	0.00	0.00	2.00	144.00	4.50	96.88	32.32	175.00	2.40	98.63	17.24	7.30	7.70	10.60	
07/07/03	0.00	0.00	2.40	280.00	7.20	97.43	65.32	460.00	4.80	98.96	43.55	7.10	7.50	10.50	0.00
07/08/03	0.15	0.00	2.50	277.00	3.70	98.66	29.37	235.00	2.40	98.98	19.05	7.00	7.50	10.80	0.00
07/09/03	0.55	0.00	2.40	393.00	4.50	98.85	39.12	630.00	2.00	99.68	17.39	7.00	7.60	10.10	0.00
07/10/03	0.02	0.00	2.40									6.80	7.60	10.60	
07/11/03	0.00	0.00	2.50									6.90	7.60	10.80	
07/12/03	0.00	0.00	2.70									7.00	7.50	11.00	
07/13/03	0.00	0.00	1.70									7.20	7.30	10.90	
07/14/03	0.37	0.00	2.30	365.00	4.00	98.90	31.75	670.00	4.80	99.28	38.10	7.00	7.40	10.40	
07/15/03	0.00	0.00	2.30	450.00	2.60	99.42	21.62	1,080.00	13.60	98.74	113.10	7.00	7.40	10.70	20.00
07/16/03	0.00	0.00	2.50	410.00	3.30	99.20	27.44	430.00	10.40	97.58	86.49	6.90	7.40	10.60	9.00
07/17/03	0.00	0.00	2.40	430.00	3.10	99.28	24.61	275.00	5.20	98.11	41.28	7.00	7.50	10.30	12.00
07/18/03	0.00	0.00	2.40									6.80	7.40	10.50	
07/19/03	0.00	0.00	2.20									7.00	7.50	10.00	
07/20/03	0.49	0.00	2.10									7.10	7.20	9.90	
07/21/03	0.00	0.00	2.40									7.00	7.00	9.50	
07/22/03	0.00	0.00	2.30	313.00	4.50	98.56	35.72	500.00	7.20	98.56	57.15	6.70	7.50	9.40	
07/23/03	0.00	0.00	2.30	530.00	2.20	99.58	17.46	390.00	6.40	98.36	50.80	7.00	7.40	9.70	0.00
07/24/03	0.00	0.00	2.30	355.00	2.00	99.44	15.88	510.00	2.80	99.45	22.23	6.80	7.70	10.00	78.00
07/25/03	0.00	0.00	2.40									7.00	7.60	9.70	85.00
07/26/03	0.00	0.00	2.30									7.00	7.20	9.90	
07/27/03	0.00	0.00	1.90	215.00	2.00	99.07	13.61	580.00	8.60	98.52	58.51	6.90	7.40	10.10	
07/28/03	0.00	0.00	2.30	278.00	2.00	99.28	15.88	430.00	5.70	98.67	45.25	7.00	7.40	10.00	
07/29/03	0.27	0.00	2.40	365.00	2.00	99.45	15.12	720.00	2.50	99.65	18.90	6.80	7.50	9.90	12.00
07/30/03	0.00	0.00	2.40									6.80	7.40	10.10	
07/31/03	0.07	0.00	2.40	510.00	2.40	99.53	19.05	955.00	4.00	99.58	31.75	6.90	7.80	9.90	
Minimum	0.00	0.00	1.70	144.00	1.20	96.88	9.53	175.00	2.00	97.33	17.24	6.60	7.00	9.40	0.00
Maximum	1.25	0.00	2.70	530.00	7.20	99.72	65.32	1,080.00	13.60	99.68	113.10	7.30	7.80	11.00	85.00
Total	3.17	0.00	71.80	6,205.00	52.70	1,682.93	426.27	8,805.00	94.40	1,679.45	753.92	215.40	231.80	318.00	216.00
Average	0.10	0.00	2.32	365.00	3.10	99.00	25.07	517.94	5.55	98.79	44.35	6.95	7.48	10.26	18.00
Geo Mean															23.58

MPCA Monthly Discharge Monitoring Report

Marshall MN Permit #MN0022179 Jul, 2003

Date	Inf NH3 MG/L	Eff NH3 MG/L	Eff Amm. KG	Inf. Phos. mg/l	Eff. Phos. mg/l	Eff. Chlorides MG/L	River 1 Ammonia MG/L	River 1 DO MG/L	River 1 Temp. Deg C	River 1 pH SU	River 1 Union. Amm. MG/L	River 1 Dilution Ratio	River 2 Ammonia MG/L	River 2 DO MG/L	River 2 Temp. Deg C	River 2 pH SU
07/01/03				11.60	7.10	410.00										
07/02/03																
07/03/03																
07/04/03																
07/05/03																
07/06/03					7.30											
07/07/03					8.50											
07/08/03																
07/09/03						380.00										
07/10/03	12.00	0.10	.88		6.70		0.10	8.50	19.00	8.00	0.00	3.70	0.10	8.20	19.00	8.10
07/11/03																
07/12/03																
07/13/03																
07/14/03																
07/15/03																
07/16/03						400.00										
07/17/03				14.00	7.40											
07/18/03																
07/19/03																
07/20/03																
07/21/03																
07/22/03																
07/23/03	5.30	0.13	1.14				0.04	9.10	19.00	8.00	0.00	1.42	0.08	8.30	19.00	8.10
07/24/03																
07/25/03						420.00										
07/26/03																
07/27/03					7.10											
07/28/03																
07/29/03						460.00										
07/30/03																
07/31/03																
Minimum	5.30	0.10	.88	11.60	6.70	380.00	0.04	8.50	19.00	8.00	0.00	1.42	0.08	8.20	19.00	8.10
Maximum	12.00	0.13	1.14	14.00	8.50	460,00	0.10	9.10	19.00	8.00	0.00	3.70	0.10	8.30	19.00	8.10
Total	17.30	0.23	2.02	25.60	44.10	2,070.00	0.14	17.60	38.00	16.00	0.00	5.12	0.18	16.50	38.00	16.20
Average	8.65	0.12	1.01	12.80	7.35	414.00	0.07	8.80	19.00	8.00	0.00	2.56	0.09	8.25	19.00	8.10
Geo Mean																

MPCA Monthly Discharge Monitoring Report

Marshall MN Permit #MN0022179 Jul, 2003

Date	River 2 Union. Amm. MG/L	River 3 Ammonia MG/L	River 3 DO MG/L	River 3 Temp. Deg C	River 3 pH SU	River 3 Union. Amm. MG/L	Week 1 CBOD MG/L	Week 2 CBOD MG/L	Week 3 CBOD MG/L	Week 4 CBOD MG/L	Week 5 CBOD MG/L
07/01/03							3.60				
07/02/03											
07/03/03											
07/04/03											
07/05/03											
07/06/03											
07/07/03											
07/08/03								4.07			
07/09/03											
07/10/03	0.00										
07/11/03											
07/12/03											
07/13/03											
07/14/03											
07/15/03									3.00		
07/16/03											
07/17/03											
07/18/03											
07/19/03											
07/20/03											
07/21/03											
07/22/03										2.44	
07/23/03	0.00										
07/24/03											
07/25/03											
07/26/03											
07/27/03											
07/28/03											
07/29/03											
07/30/03											
07/31/03											
	0.00						3.60	4.07	3.00	2.44	
	0.00						3.60	4.07	3.00	2.44	
	0.01						3.60	4.07	3.00	2.44	
	0.00						3.60	4.07	3.00	2.44	

MPCA Monthly Discharge Monitoring Report

Marshall MN Permit #MN0022179 Jul, 2003

Date	Week 1 TSS MG/L	Week 2 TSS MG/L	Week 3 TSS MG/L	Week 4 TSS MG/L	Week 5 TSS MG/L	ADM Effluent Flow MGD Discharged to River	CITY Effluent Flow MGD	ADM River Flow CFS	ADM Dilution Ratio
07/01/03	4.70					1.37	2.10	53.00	9.80
07/02/03						1.21	2.20	50.00	9.50
07/03/03						1.16	2.20	46.00	8.90
07/04/03						1.23	2.20	58.00	11.00
07/05/03						1.44	2.00	39.00	7.30
07/06/03						1.16	1.90	36.00	7.60
07/07/03						1.13	2.40	32.00	5.90
07/08/03		3.07				1.08	2.10	32.00	6.50
07/09/03						1.30	2.30	38.00	6.80
07/10/03						1.38	2.30	38.00	6.70
07/11/03						1.15	2.40	37.00	7.00
07/12/03						1.43	2.20	28.00	5.00
07/13/03						1.29	2.10	23.00	4.40
07/14/03						0.94	2.10	19.00	4.00
07/15/03			9.73			0.69	2.20	19.00	4.20
07/16/03						1.04	2.20	16.00	3.20
07/17/03						0.98	2.10	16.00	3.40
07/18/03						1.01	2.20	15.00	3.00
07/19/03						0.93	2.10	15.00	3.20
07/20/03						1.19	1.90	16.00	3.30
07/21/03						1.04	2.20	16.00	3.20
07/22/03				5.31		0.87	2.10	16.00	3.50
07/23/03						0.73	2.10	14.00	3.20
07/24/03						0.92	2.10	14.00	3.00
07/25/03						0.73	2.10	12.00	2.80
07/26/03						0.69	2.10	8.20	1.90
07/27/03						1.04	1.80	8.30	1.90
07/28/03						1.03	2.10	9.40	2.00
07/29/03						1.03	2.00	7.60	1.60
07/30/03						1.37	1.90	18.00	3.60
07/31/03						1.08	2.10	21.00	4.30
	4.70	3.07	9.73	5.31		0.69	1.80	7.60	1.60
	4.70	3.07	9.73	5.31		1.44	2.40	58.00	11.00
	4.70	3.07	9.73	5.31		33.64	65.80	770.50	151.70
	4.70	3.07	9.73	5.31		1.09	2.12	24.85	4.89

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief such information is true, complete, and accurate.

Signature of Principal Executive Officer or Authorized Agent.

8/12/03

Date

Wastewater Facility Screening Form
Preliminary Information

1. Plant Information

Plant Name: Glencoe WWTP

Contact Name: GARY SchREIFEIS

Phone: 320) -864-6954

Fax: 320 -864-6405

E-mail: garysch@hutchTEl.NET

Design Capacity: 1.6 MGD

Present Flow: .850 MGD

2. Discharge Permit Concentration (mg/L)
(Provide Available Parameters)

	Permit Limit		Actual Discharge	Expected Future	Sample Type/Frequency(1)	
	Tertiary	Secondary				
C BOD5	5mg/l	25mg/l	2.4 mg/l		C	3XW
COD						
TSS	30mg/l	30mg/l	6.4 mg/l		C	3XW
Settleable Solids						
NH4-N						
NO3-N						
TKN						
Total Nitrogen	June-Sept. 1.0 To	Dec-Mar 7.7 mg/l	0.08 mg/l		C	2XM
Total Phosphorous						
Soluble Phosphorus						
Fecal Coliform	200 MPN		<200 MPN		G	3XW
pH	6.0 - 9.0		7.9		G	7XW
Others(?) List						

Receiving Water body: Buffalo Creek 2B, 3B, 4A, 4B, 5, 6 Water

Post-it® Fax Note 7671	Date 8-4-03 # of pages ▶ 4
To George K.	From GARY S
Co./Dept.	Co. GlENCOE
Phone #	Phone # 320-864-6954
Fax # 201-529-5282	Fax # 320-864-6405

---

(1)type - composite, grab
(1)frequency - # samples/week or month

3. **Liquid Process Description**

Pre-treatment (check)

Barscreen/ WASHER PACKER ✓ Comminutor

Self Cleaning Screens ✓

Aerated Grit Removal

Other Grit Removal Cyclone

Number of Treatment Trains 1

Intermediate ~~Primary~~ treatment (please check) Yes ✓ No

# of clarifiers 2 Diameter Rectangular 57,200 gallons per tank 70' X 15' X 6.5

Chemical addition Yes No X

If yes, chemical(s) used

Secondary Treatment (please check)

Trickling Filter X Rotating Biological Contactor

Activated Sludge X 57' x 28' x 15' (2X) Oxidation Ditch

Lagoon Biological Nutrient Removal
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes No X

If yes, chemical(s) used

Secondary Clarifiers

# of clarifiers 4 Diameter 40 feet 12 feet deep

Chemical addition Yes No X

If yes, chemical(s) used

Tertiary Treatment

Polishing Filters Yes X No

Type of Filter # of Filters 4

Media/depth 36" Area/Filter 80 S.F. each

18" SAND
18" COAL

Disinfection (please check)

Chlorine X Ultraviolet

Dechlorination Yes X No

Please provide a copy of the most recent monthly plant performance reporting form. DMR attachment

4. **Sludge Processing/Ultimate Reuse or Disposal**

Please provide ultimate destination of plant solids (i.e. landfill, [✓ agricultural application], lagoon, etc.)

Round trip to ag. land 8-10 miles

Primary Sludge Thickening (please check)

Primary Tanks X Gravity ____ Belt Thickeners ____

Secondary Sludge Thickening (please check)

Gravity ____ Belt Thickeners ____

Centrifuge ____ Dissolved Air Flotation X

Combined Sludge Thickening (please check)

Yes ____ No X

Please Name Thickening Process ____

Sludge Digestion (please check)

Aerobic ____ Anaerobic X

Other (name) ____

Sludge Dewatering (please check)

Brying Beds X Centrifuge ____

Belt Filter Press ____ Other (name) ____

5. Additional Information

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant:

AMPI - Dairy

Estimated percent of plant BOD load: 48%

Collection System (check)

Separate sanitary sewers: X

Combined domestic/storm sewers: ______

Plant Sampling and Analyses

Influent

24 hr composite X Grab ______ Other ______

Frequency (days/[✓ week]) 3X

Effluent

24 hr composite X Grab ______

Other ______ Location ______

Frequency (days/[✓ week]) 3X

Does plant have a lab? YES

Analyses done by plant lab (check)

CBOD	X	TSS	X	PH	X	TKN	
NH_4-N		NO_3-N		NO2_3-N		Total P	
Soluble Ortho P		Coliform	X	COD			

Others (List) DO : Cl_2 :

City of
Little Falls

FAX TRANSMISSION COVER SHEET

DATE: 8-18-03

TO: **NAME:** DR. David Stensel

COMPANY:

FAX NUMBER: 206-685-9185

FROM: **LITTLE FALLS CITY HALL**

NAME: GREG McGillis

FAX NUMBER: (320) 616-5505

TOTAL PAGES (Including cover sheet): 5

MESSAGE:

Wastewater Facility Screening Form
Preliminary Information

1. **Plant Information**

Plant Name: Little Falls Waste Water

Contact Name: GREG M^c Gillis, ArtCherry

Phone: 320 -616-5540 Fax: 320 -616-5505

E-mail:

Design Capacity: 2.4 MGD Present Flow: 1.3 MGD

2. **Discharge Permit Concentration (mg/L)**
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency(1)
BOD$_5$	25mg/L	10mg/L	4mg/L	3/wk Composite
COD				
	30mg/L	~~120~~ 6mg/L	3mg/L	3/wk Comp.
ettleable Solids		5.		3/wk Comp.
H$_3$-N		10mg/L		1Xmonth comp
O$_3$-N				
KN				
otal Nitrogen				
otal Phosphorous		2.5mg/L		1XWEEK Comp
luble Phosphorus				~~1XWEEK Comp~~
cal Coliform GEOM MEAN	200 #/100ml	100 #/100ml	100 #	3/wk grab
H	6.0-9.0	7.0	7.0	1XDAY grab

thers(?) List: MERCURY, Chromium, Copper,

ceiving Water body: MISSISSIPPI RIVER

pe - composite, grab
equency - # samples/week or month

3. Liquid Process Description

Pre-treatment (check)

Barscreen ✓ Comminutor ____

Self Cleaning Screens ✓

Aerated Grit Removal ✓

Other Grit Removal ✓

Number of Treatment Trains ____

Primary treatment (please check) Yes ____ No ____

# of clarifiers 2 Diameter 40'

Chemical addition Yes ____ No X

If yes, chemical(s) used ____

Secondary Treatment (please check)

Trickling Filter ✓ Rotating Biological Contactor ____

Activated Sludge ✓ Oxidation Ditch ____

RF TOWER ✓ Biological Nutrient Removal ____
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes ____ No ____

If yes, chemical(s) used CAN USE polymer for SEttling
THIS IS APPLIED IN TROUGH of AERA~~ti~~on TANK
BEFORE clarification on Secondary clarifier.

Secondary Clarifiers

# of clarifiers 2 Diameter 73

Chemical addition Yes ____ No ____

If yes, chemical(s) used CAN USE polymer for SEttling

Tertiary Treatment

olishing Filters Yes ____ No ✓

ype of Filter ____ # of Filters ____

ledia/depth ____ Area/Filter ____

isinfection (please check)

le ✓ Ultraviolet ____

echlorination Yes ✓ No ____

ease provide a copy of the most recent monthly plant performance reporting form.

4. **Sludge Processing/Ultimate Reuse or Disposal**

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

Agriculture Application

Primary Sludge Thickening (please check)

Primary Tanks ______ Gravity ✓ Belt Thickeners ______

Secondary Sludge Thickening (please check)

Gravity ✓ Belt Thickeners ______

Centrifuge ______ Dissolved Air Flotation ______

Combined Sludge Thickening (please check)

es ______ No ______

Please Name Thickening Process ______

Sludge Digestion (please check)

Aerobic ______ Anaerobic ✓

Other (name) We are changing over to Class "A" Lime stabilization with pasterization October of 2003 hich will include a Centrifuge

Sludge Dewatering (please check)

Drying Beds ______ Centrifuge ______

Belt Filter Press ______ Other (name) ______

5. Additional Information

ndustrial Wastewater

List name/type of any significant industrial wastewater load to the plant: EThanol Plant-Does have preTreatment

Estimated percent of plant BOD load: ______

Collection System (check)

Separate sanitary sewers: ✓

Combined domestic/storm sewers: only a few blocks of combined sewer

Plant Sampling and Analyses

Influent

hr composite ✓ Grab ______ Other ______

Frequency (days/week) 3

Effluent

24 hr composite ✓ Grab ______

Other ______ Location Wastewater Plant

Frequency (days/week) 3

Does plant have a lab? YES

Analyses done by plant lab (check)

BOD	✓	TSS	✓	PH	✓	TKN	
NH_3-N		NO_3-N		$NO2_3$-N		Total P	
Soluble Ortho P		Coliform	✓	COD			

Others (List) Total Coliform Water Plant

Plant Screening Forms

Lagoon Treatment Plants

CITY OF REDWOOD FALLS
333 S Washington St. • P.O. Box 10
Redwood Falls • MN • 56283-0010
507.637.5755 phone • 507.637.2417 fax
e-mail: info@ci.redwood-falls.mn.us

FAX TRANSMISSION

To: MELISA MAROON

Fax Number: 1-201-529-5728

From: RON MANNZ, CITY ENG

Subject: MESERUB BROS. INN

Comments:

Date: AUG. 27, 2003

Pages: 21 **Including this cover page**

Wastewater Facility Screening Form
Preliminary Information

1. Plant Information

Plant Name: Redwood Falls Municipal Wastewater Facility

Contact Name: Ronald G. Mannz

Phone: 507 637-5755 Fax: 507 637-2417

E-mail: rmannz@ci.redwood-falls.mn.us

Design Capacity: 1.32 MGD (wet weather) Present Flow: high - .9333
low - .622
avg - .789 MGD
YTD - 10.266

2. Discharge Permit Concentration (mg/L)

(Provide Available Parameters)

	Permit Limit	(Yrly Avg) Actual Discharge	Expected Future	Sample Type/Frequency[1]
BOD_5	25 MG/L	Low 5.0 MG/L High 22.0 MG/L Avg 10.2 MG/L		24 HR. Comp/2 x month
COD				
TSS	45 MG/l	Low 11.0 MG/L High 104.0 MG/L Avg. 31.8 MG/L		24 HR. Comp/2 x month
Settleable Solids				
NH_4-N (ammonia)	June-Sept 7.5 MG/L Oct-Nov 9.7 MG/L Dec-March 94.0 MG/L	Low .08 MG/L High 33.0 MG/L Avg. 6.68 MG/L		24 HR. Comp/2 x month
NO_3-N				
TKN				
Total Nitrogen				
Total Phosphorous	No standard	Low 0.65 MG/L High 5.85 MG/L Avg. 2,48 MG/L		24 HR. Comp/2 x month
Soluble Phosphorus				
Fecal Coliform	April - October 200 organism/100 ML	GM Low 10 GM High 189 GM Avg. 48.9		GRAB
pH	6.0 - 9.0	Low .02 High 9.2 Avg. 8.5		GRAB
Others(?) List				
Unionized Ammonia	1.0 MG/L	Low .02 MG/L High 1.39MG/L Avg. .17 MG/L		24 HR. Comp/2 x month
Chlorides	873 MG/L	Low 566 MG/L High 993 MG/L Avg. 742 MG/L		24 HR. Comp/2 x month

Receiving Water body: Minnesota River

---

(1)type - composite, grab

(1)frequency - # samples/week or month

SEE ATTACHED

3. Liquid Process Description

Pre-treatment (check)

Barscreen ____________ Comminutor ____________

Self Cleaning Screens ____________

Aerated Grit Removal ____________

Other Grit Removal ____________

Number of Treatment Trains ____________

Primary treatment (please check) Yes ______ No ______

# of clarifiers ____________ Diameter ____________

Chemical addition Yes ______ No ______

If yes, chemical(s) used ____________

Secondary Treatment (please check)

Trickling Filter ____________ Rotating Biological Contactor ____________

Activated Sludge ____________ Oxidation Ditch ____________

Lagoon ____________ Biological Nutrient Removal ____________
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes ______ No ______

If yes, chemical(s) used ____________

Secondary Clarifiers

# of clarifiers ____________ Diameter ____________

Chemical addition Yes ______ No ______

If yes, chemical(s) used ____________

Tertiary Treatment

Polishing Filters Yes ______ No ______

Type of Filter ____________ # of Filters ____________

Media/depth ____________ Area/Filter ____________

Disinfection (please check)

Chlorine ____________ Ultraviolot ____________

Dechlorination Yes ______ No ______

Please provide a copy of the most recent monthly plant performance reporting form.

SEE ATTACHED

4. Sludge Processing/Ultimate Reuse or Disposal

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

____

____

Primary Sludge Thickening (please check)

Primary Tanks ________ Gravity ________ Belt Thickeners ________

Secondary Sludge Thickening (please check)

Gravity ________ Belt Thickeners ________

Centrifuge ________ Dissolved Air Flotation ________

Combined Sludge Thickening (please check)

Yes ________ No ________

Please Name Thickening Process ______________________________

Sludge Digestion (please check)

Aerobic ________ Anaerobic ________

Other (name) ______________________________

Sludge Dewatering (please check)

Brying Beds ________ Centrifuge ________

Belt Filter Press ________ Other (name) ________

SEE ATTACHED

5. Additional Information

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant:

Estimated percent of plant BOD load: ____

Collection System (check)

Separate sanitary sewers: ____

Combined domestic/storm sewers: ____

Plant Sampling and Analyses

Influent

24 hr composite ____ Grab ____ Other ____

Frequency (days/week) ____

Effluent

24 hr composite ____ Grab ____

Other ____ Location ____

Frequency (days/week) ____

Does plant have a lab? ____

Analyses done by plant lab (check)

BOD ____ TSS ____ PH ____ TKN ____

NH_4-N ____ NO_3-N ____ NO2$_3$-N ____ Total P ____

Soluble Ortho P ____ Coliform ____ COD ____

Others (List) ____

#3 LIQUID PROCESS DESCRIPTION

NPDES PERMIT APPLICATION - APPENDIX A

The 1993 Legislature revised the Minnesota Pollution Control Agency's responsibilities in Minnesota Statutes Section 115.03, subd. 1(e)(10) "Requiring that applicants for wastewater discharge permits evaluate in their applications the potential reuses of the discharged wastewater;"

As a result of this 1993 Law, the Minnesota Pollution Control Agency has been charged with requiring permit applicants to evaluate the reuse potential of their wastewater prior to discharge.

Therefore, please provide, in narrative form in the space below, an evaluation of reuse potential of your wastewater prior to discharge to a receiving stream, lake, or storm sewer. Some ideas include water conservation measures, use of cooling tower blowdown for thermal discharges, lawn watering or irrigation of parks and public property, wetland reclamation/development/recharge.

POTENTIAL REUSE OF WASTEWATER EFFLUENT - The City of Redwood Falls is currently investigating the potential of using the wastewater effluent from our facility for golf course irrigation. The Redwood Falls Golf Club is currently developing an additional nine holes at their current location. The expansion of nine holes will place the course adjacent to our facility. Initial discussion was favorable, with the Club expressing interest in exploring this option. Construction of the additional nine holes is anticipated to begin in the summer of 2001 and open to play the summer of 2002.

Minnesota Pollution Control Agency

TRANSMITTAL FORM

MPCA USE ONLY
Application Number
MN
Date Received
Month Day Year

COMPLETE APPLICATION BY PRINTING OR TYPING. PLEASE MAKE A PHOTOCOPY FOR YOUR RECORDS.

FACILITY INFORMATION

Facility Owner ☒ and/or Operator ☐ (Public Entity, City or Business Firm legally responsible for facility operation) [see Minn. R. 7001:0050]

Permittee Name: City of Redwood Falls Phone: 607) 637-5755 FAX: (507) 637-2417

Mailing Address: P.O. Box 10 City: Redwood Falls

State: MN Zip: 56283 Type of ownership Public ☒ / Private ☐

Facility Location No Post Office Boxes allowed. Actual physical location of facility -- must use actual street or highway address (or Section/Township/Range coordinates). *If applying for a permit that can cover more than one site (e.g. aggregate and/or hot mix asphalt operations), write NA.*

Facility Name: Redwood Falls Area Wastewater Treatment Fac. Phone: 607) 637-5755

Location Address: Redwood County Rd. No. 25

Facility is located in the SE quarter of the SE quarter of section 19 township Honner

of Redwood county. Township # 113N Range # 35 East ☐ West ☒

City: Redwood Falls State: MN Zip: 56283

Is the facility located on tribal land? ☐ yes ☒ no If yes, apply to EPA Region V, John Coletti; (312) 886-6106.

Technical Agent or Consulting Engineer Ted Field Title: Engineer

Name of firm or organization: Bonestroo, Rosene, Anderlik and Associates

Mailing Address: 2335 W. Hwy. 36 Phone: (612 636-4600

City: St. Paul State: MN Zip: 55113

Contact Person (Operator, Plant Manager, City Official): Ron Mannz Title: City Engineer

APPLICATION INFORMATION

Reason for Application (check all that apply):

☒ Expiration of existing permit (reissue) ☐ Modification to existing permit ☐ Agency request
☐ New permit/facility ☐ Land Application Site Approval ☐ Other, please specify

Type of Application (check all that apply):

☒ Municipal / ☐ Industrial / ☐ Stormwater / ☐ Dredge / ☐ Pretreatment / ☐ Feedlot / ☐ Water Treatment Plant / ☐ Sanitary Sewer / ☐ Biosolids / ☐ Aquaculture

Have you ever applied for, or do you currently have a National Pollutant Discharge Elimination System (NPDES) or State Disposal System (SDS)permit for this facility? ☒ yes ☐ no

If yes, please list permit number(s) MN 0020401

Name on existing permit Redwood Falls Municipal Wastewater Treatment Facility

Printed on recycled paper containing at least 10% fibers from paper recycled by consumers

List all current MPCA permits or certificates, and their numbers, which also may apply to this facility: __________

None

If this is a new or expanded facility, has an Environmental Impact Statement or an Environmental Assessment Worksheet been prepared?

yes ☐ no ☒ If yes, note the title and date: __________

Annual Permit fee invoice should be mailed to ☒ Owner/operator address ☐ Facility location address ☐ Not applicable

Discharge Monitoring Report forms should be mailed to ☒ Owner/operator address ☐ Facility location address ☐ Not applicable

APPLICATION FEES

An application fee is required under Minn. Stat. § 116.07, subd. 4d (1990) and Minn. R. ch 7002 (Permit Fee Rules). This application fee must be submitted with the permit application.

<u>Application fees are as follows</u>:

Sanitary Sewer	$240.00
Construction Stormwater	$240.00
All other applications [including non-construction storm water]	$85.00

<u>Reminder</u>

✓ Did you sign attachment form(s)?

✓ Attach your application fee?

✓ Enclose completed attachments?

Applications that are submitted without an authorized signature, the required application fee, and attachments <u>will be returned</u>. Please make your check payable to the Minnesota Pollution Control Agency. Send the completed permit application, attachments (including plans and specifications, if applicable) and check to:

Minnesota Pollution Control Agency
Water Quality Division
Point Source Section
520 Lafayette Road North
St. Paul, Minnesota 55155-4194

For more information please contact:

In Metro Area: Water Quality Division Customer Service Center at (612) 296-7162
Outside Metro Area: 1-800-657-3864 and ask for Water Quality Customer Service Center

Minnesota Pollution
Control Agency

ATTACHMENT FOR BIOSOLIDS INFORMATION SHEET

MPCA USE ONLY
Application Number
MN
Date Received
Month Day Year

COMPLETE APPLICATION BY PRINTING OR TYPING. PLEASE MAKE A PHOTOCOPY FOR YOUR RECORDS.

PERMITTEE N/A

1. Facility Type IV Certified Operator's Name: ____________________
Certification Expiration Date: ____________________
Business Telephone Number: ( ) ____________________

2. Describe and diagram all biosolids treatment and storage facilities and attach an actual laboratory report of the analysis (include information on quantity and quality of any biosolids transferred to your facility).

Facility diagram:

Treatment Description: How is Class A or B pathogen reduction achieved? (Include information on time, temperature, detention times, pathogen or indicator organism data.)

How is vector attraction reduction met?

3. How are biosolids utilized or disposed? ____________________

☐ Land Applied ☐ Transferred to another WWTF ☐ Other (specify) ____________________

4. If your biosolids are transferred to another facility for treatment or disposal, list the name of the facility and the name of applicators, contractors, or distributors who will utilize or dispose of the biosolids and the amount transferred annually.

Name of the Facility	Name of Applicators	Contractors	Distributors	Amount Transferred Annually

5. Estimate how often biosolids will be hauled to the land application site(s)? (i.e., monthly, weekly, 2 x per year)

Printed on recycled paper containing at least 10% fibers from paper recycled by consumers

6. How many dry tons of biosolids are expected to be generated annually at your facility? (Answer *must be* in dry tons per year)

____________________ total dry tons per year

Total dry tons per year = <u>gallons x % solids (do not change to a decimal)</u>
24,000

7. Representative Sampling - Describe how and when samples will be taken to be representative of the biosolids which are applied to the land.

____

____

____

8. Include the following with this application form:

A. A topographic map of the treatment facility extending one mile beyond the property boundaries, showing the location of any sludge management facilities, or sites and bodies of water. Show the location of any wells known by the applicant or in public record used for drinking water within one-quarter mile of the treatment facility boundary.

B. Any ground water monitoring data, and a description of the well locations and approximate depth to ground water if this information is not already on file at the MPCA.

9. CERTIFICATION AND SIGNATURE

Federal regulations (Section 309(c)(2) of the Clean Water Act and State regulations (Minn. R. 7001.0070) require the authorized signer to be one of the following:

A. For corporation, a principal executive officer of at least the level of vice president;
B. For a partnership or sole proprietorship, a general partner or the proprietor, respectively; or
C. For a municipality, State, Federal, or other public facility, either a principal executive officer or ranking executive official.
D. If the operator of the facility is different than the owner, both the operator and the owner according to items A to C.

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person, or persons, who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment."

PRINTED NAME Sam TITLE Mayor

AUTHORIZED SIGNATURE________________ DATE________________

STATE TAX I.D. # ________________ FEDERAL TAX I.D. # ________________

Reminder:
Did you sign the form?
Attach your application fee?
Enclose completed attachments?

Applications submitted without an authorized signature, the required application fee and attachments, <u>will be returned</u>. Please make your check payable to the Minnesota Pollution Control Agency. Send completed permit application, attachments (including plans and specifications, if applicable) and check to:

Minnesota Pollution Control Agency
Water Quality Division
Point Source Section
520 Lafayette Road North
St. Paul, Minnesota 55155-4194

Minnesota Pollution Control Agency

ATTACHMENT FOR MUNICIPAL FACILITIES

National Pollutant Discharge Elimination System (NPDES)
Permit For Municipal Surface Water Discharge
Wastewater Treatment Facilities

MPCA USE ONLY
Application Number
MN
Date Received
Month Day Year

COMPLETE APPLICATION BY PRINTING OR TYPING. PLEASE MAKE A PHOTOCOPY FOR YOUR RECORDS.
This form applies to municipal and privately owned facilities that treat domestic wastewater for disposal into a surface water of the state.

PERMITTEE: City of Redwood Falls

WASTEWATER TREATMENT AND DISCHARGE

1. Provide a complete description of your existing or proposed wastewater treatment system: The Redwood Falls Area Wastewater Treatment Facility is a 6 cell aerated pond system with a continuous discharge. Pond area totals approximately 19.5 acres. Pond volume totals 49.5 mg. Detention time is approximately 67 days, at avg. flow of 0.736 mgd. Discharge is to the Minnesota River at outfall 010. Influent is pretreated with a bar screen and grit chamber. Central Bi-Products pumps up to 30 mgy of treated wastewater to the area facility. Central Bi-Products wastewater is then treated for additional ammonia removal and is blended with Redwood Falls wastewater for dilution of chlorine.

2. Were any changes or additions made to the wastewater collection or treatment system since your last permit was issued? ☐ Yes ☒ No

If yes, please describe and provide the date the new or upgraded system began operating:

3. Do you plan to make any changes or additions to the wastewater collection or treatment system within the next five years? ☐ Yes ☒ No

If yes, please describe:

4. What is the classification of your wastewater treatment facility? Please check one: ☐ A ☐ B ☐ C ☐ D

5. Name of Wastewater Treatment Facility Operator: David Johnson (Cert. #B-5218)
Certification (please check all that apply): ☐ A ☒ B ☐ C ☐ D ☐ Type IV ☐ Type V
Certification Expiration Date: 9/15/2001
Number of staff assigned to operate and maintain the facility: 4
The percent of time each operator spends at the facility: 5%

6. Design flows of the existing or proposed facility in million gallons per day:
Average wet weather design flow: 1.321 mgd
Average dry weather design flow: 0.824 mgd
Annual average design flow: 0.8 mgd
Actual Documented Average Dry Weather Flow 0.581 mgd (6 yr. average)

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7. Design influent concentration in milligrams per liter and/or the design loading in pounds per day for the following parameters :

				kg/day
5-day Biochemical Oxygen Demand (BOD_5):	25	mg/l	125	~~lbs/day~~
Total Suspended Solids (TSS):	45	mg/l	225	~~lbs/day~~
Total Phosphorus:	N/A	mg/l	N/A	~~lbs/day~~
Ammonia Nitrogen: (varies with time of year)	7.5-64	mg/l	37.4 - 319	x~~lbs/day~~

8. Is the wastewater discharge continuous, controlled, intermittent, or periodic/seasonal? continuous

If the discharge is intermittent or periodic/seasonal, please describe the frequency using average days per year and/or the months of the discharge.

9. How many separate discharge points (outfalls) are in your treatment system, *not* including bypass points? 1

10. Identify the discharge route to the receiving waters for each discharge point (outfall) identified in question 9 above. (Example: 010-a 50 foot ditch to the Mississippi River.)

Outfall Point Number	Route to Receiving Waters
010	A 1,500 foot un-named ditch to Minnesota River

11. What type of disinfection is used or proposed for the effluent: None

If disinfection is by chlorination, does this facility dechlorinate? N/A

If you dechlorinate, what type of chemical is used? N/A

12. Do you conduct 4-hour influent and effluent sampling? ☐ Yes ☒ No

Do you conduct 24-hour influent and effluent composite sampling? ☒ Yes ☐ No

If yes, are your samples flow composited or time composited? ☐ Flow Composited ☒ Time Composited

13. Provide the name of the laboratory that analyzes your samples: Minnesota Valley Testing - New Ulm, MN

Provide the Minnesota Department of Health Laboratory Certification Number for this laboratory: 027-015-125

14. What type of equipment and/or methods do you use to measure the following parameters:

Dissolved oxygen: Winkler titration

pH: Hach Meter

Total residual chlorine: N/A

Influent Flow drexelbrook calibration frequency 2 x/year

Effluent Flow militronics calibration frequency 2 x/year

Is flow monitoring accurate within plus or minus 10%? ☐ Yes ☐ No ☒ Not Sure

15. Does the treatment facility contain any bypass points? ☒ **Yes** ☐ **No** **If yes, how many?** 1

Also, if yes, answer the following questions regarding the bypass(es):

- Is/are the bypass structure(s) manual or automatic? manual
- Is/are the bypass structure(s) controlled and kept locked? yes
- Was/were the bypass structure(s) approved in the plans and specifications? yes, structure 020 to Redwood River
- Provide the number of bypass incidents in the past five years: none

Wet weather ______ incidents ______ average hours of duration ______ flow discharge estimate

Dry weather ______ incidents ______ average hours of duration ______ flow discharge estimate

16. Have any bypass events occurred in any part of the sanitary collection system in the past five years? ☐ Yes ☒ No
If yes, provide the bypass location(s), the number of events, estimate of the flow bypassed and describe the reasons for each event:

17. Is the treatment facility equipped with a standby power supply? ☐ Yes ☒ No

18. Is the treatment facility equipped with an alarm system? ☐ Yes ☒ No

19. How many lift stations are equipped with standby power? 2
Please describe the standby power for each lift station equipped: generators

20. How many lift stations are equipped with an alarm system? all
Please describe the alarm system for each lift station equipped: alarm light and horn

CONTRIBUTORS TO THE TREATMENT FACILITY

21. Please complete the following chart for any industrial or non-domestic wastewater received:

NAME/TYPE OF CONTRIBUTOR	FLOW (mgd)	CHARACTERISTICS OF WASTEWATER
Central Bi-Products	30 million/year	rendering bi-products which are pre-treated

22. Are any of the contributors listed above considered a "Significant Industrial User (SIU)" or have the potential to adversely impact the treatment facility? (A "SIU" is defined as any industrial user that discharges an average of 25,000 gallons per day or more of processed wastewater to the wastewater treatment facility, excluding sanitary, noncontact cooling, and boiler blowdown wastewater; process wastewater which makes up at least 5% of the facility's design BOD loading; or has the potential, in the opinion of the Permittee or MPCA, to adversely impact the Permittee's treatment works or the quality of the effluent.) ☒ Yes ☐ No
If yes, please identify: CBI effluent exceeds discharge standard for chloride. At times TSS are high due to ALGE blooms

23. Do you currently have a pretreatment agreement or permit with any of the contributors listed above?
☒ Yes ☐ No
If yes, please identify: see attached agreement

24. Do you anticipate any new contributors or significant changes in volume or quality of discharges from existing contributors to the treatment facility? ☐ Yes ☒ No

If yes, please explain:

25. Is septage, leachate, holding tank waste, or any other type of wastewater transported into the treatment system?

☒ Yes ☐ No

If yes, describe the waste and provide an estimate of the amount in gallons per year:

20,000 GPY of septage

INCLUDE THE FOLLOWING WITH THIS APPLICATION FORM

26. Does your facility generate biosolids (sewage sludge) or do you intend to become a "preparer" of biosolids (sewage sludge) within the next five years? ☐ Yes ☒ No

If yes, complete *Biosolids Information Sheet*, included with this application form.

27. Do you monitor ground water? ☐ Yes ☒ No

If yes, provide a list of the wells, lysimeters, or tile drains that are sampled with a map showing the ground water monitoring points or location of tile drains.

28. Do you monitor the receiving water? ☐ Yes ☒ No

If yes, identify the location(s) of the receiving water monitoring and the parameter(s) you are required to monitor.

29. If this is an application for reissuance of an existing permit, review your existing NPDES/SDS permit to see if it has special testing requirements for the application for reissuance of the permit. If so, be sure to comply with those requirements. The existing permit also may have special requirements for reports or other submittals for the application for reissuance of the permit. Be sure to comply with these requirements also. Failure to complete the application for reissuance of a permit as required by the permit is a violation of the permit itself and is subject to enforcement action.

30. A detailed map (either U.S. Geological Survey, County Soil Survey, or County Plat) showing the location of the wastewater treatment facility, each discharge point and/or land application site, and all receiving waters. Show the location of any bypass points described in questions 15 and 16 above. see attachment

31. A schematic diagram (flow chart) showing the route of wastewater flow through the treatment facility from the intake point to the discharge point(s). Show the location of any bypass points described above. see attachment

32. If this application is for a stabilization pond facility with a controlled discharge, complete the enclosed supplemental information sheet. N/A

33. If the system is currently covered under a NPDES/SDS permit, has the system been in compliance with the permit limits during the last five years? ☐ Yes ☒ No

If no, please explain. At times TSS and Chloride exceeded permit limits. See answer to question #22 on reverse side of this page

CERTIFICATION

Federal regulations (Section 309(c)(2) of the Clean Water Act and State regulations (Minn. R. 7001.0070) require the authorized signer to be one of the following:

A. For corporation, a principal executive officer of at least the level of vice president;
B. For a partnership or sole proprietorship, a general partner or the proprietor, respectively; or
C. For a municipality, State, Federal, or other public facility, either a principal executive officer or ranking executive official.
D. If the operator of the facility is different than the owner, both the operator and the owner according to items A to C.

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person, or persons, who manage the system, or these persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment."

PRINTED NAME Sam ~~Jeffrey W. Weldon~~ TITLE Mayor ~~City Administrator~~

AUTHORIZED SIGNATURE __________ DATE __________

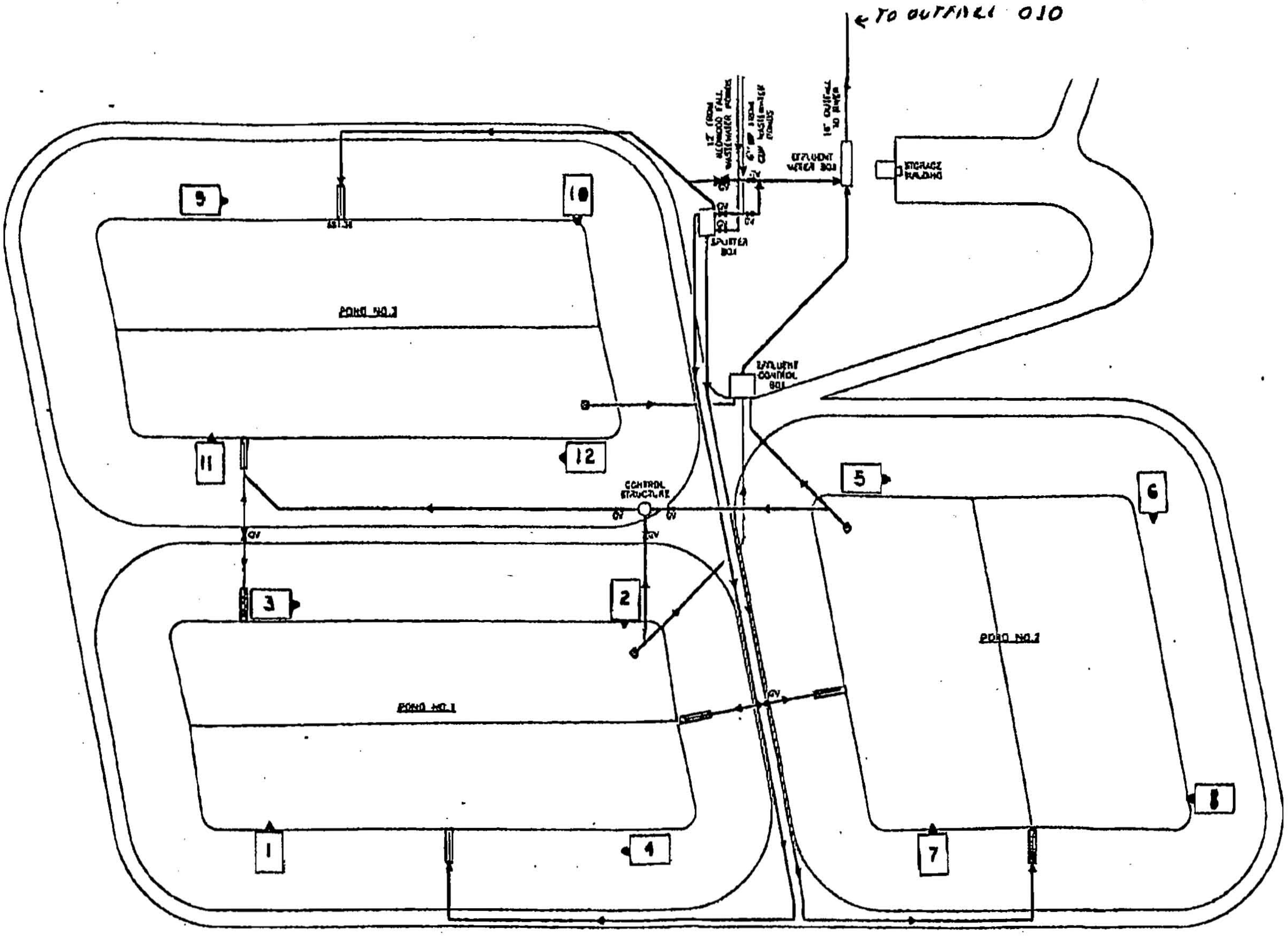
STATE TAX I.D. # __________ FEDERAL TAX I.D. # __________

Reminder:

✓Did you enclose the Transmittal Form?
✓Did you enclose any necessary attachments?
✓Did you sign the form?
✓Attach your application fee?

Applications submitted without an authorized signature, the required application fee and attachments, will be returned. Please make your check payable to the Minnesota Pollution Control Agency. Send completed permit application, attachments (including plans and specifications, if applicable) and check to:

Minnesota Pollution Control Agency
Water Quality Division
Point Source Section
520 Lafayette Road North
St. Paul, Minnesota 55155-4194



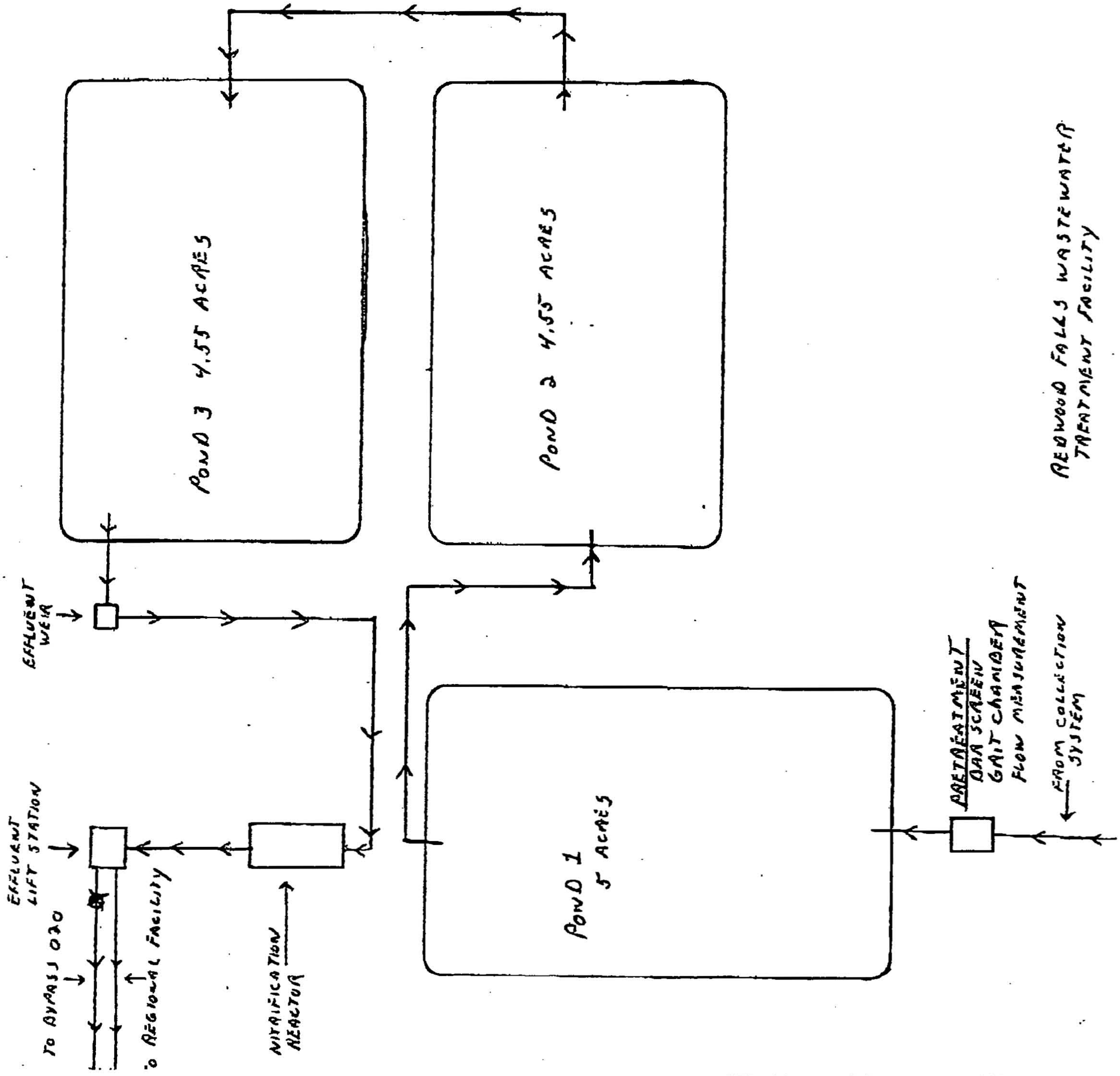
Bonestroo
Rosene
Anderlik &
Associates

SITE PIPING PLAN

REDWOOD FALLS, MINNESOTA
REGIONAL WASTEWATER TREATMENT FACILITIES

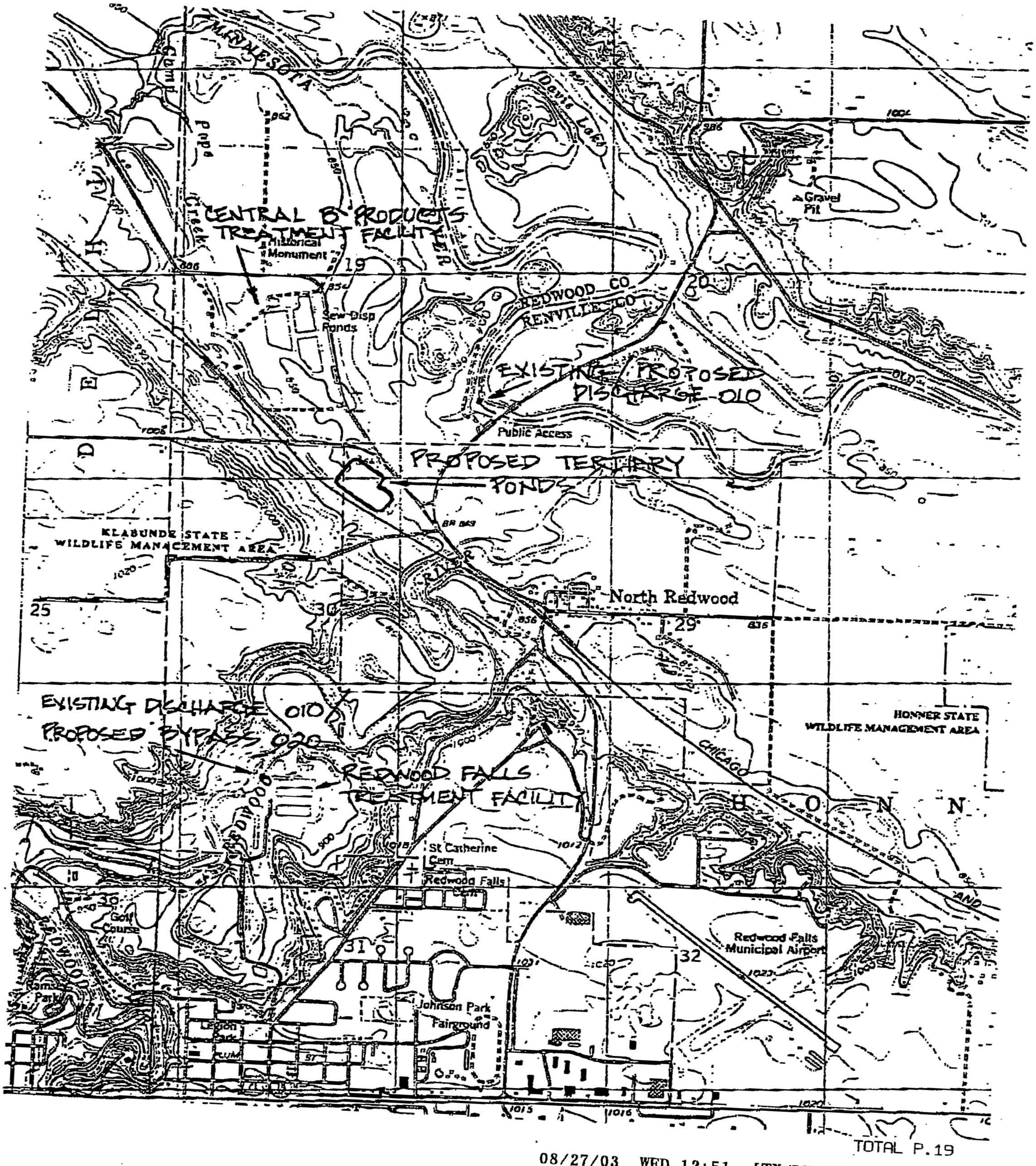
19357F12.DWG 3-97 COMM. 19357

FIGURE 3.8-1



REDWOOD FALLS WASTEWATER TREATMENT FACILITY

4. LOCATION OF PERMITTED FACILITY AND/OR ACTIVITY



CITY OF THIEF RIVER FALLS
ELECTRIC DEPARTMENT
P.O. Box 528
803 South Barzen Avenue
Thief River Falls, Minnesota 56701

Phone: (218) 681-5816 **Fax:** (218) 681-8225

FAX COVER SHEET/MESSAGE FORM

Date: 8-5-03
To: Hydro Qual
Fax No: 1-201-529-5728
Attn: DR. George Kehrberger
Number of Copies Including Cover Sheet: 7
Please Respond By:
Operator's Initials:

Information requested

Steve Swanson WW Supt
Thanks

Wastewater Facility Screening Form
Preliminary Information

Plant Information

Plant Name: Thief River Falls WWTP

Contact Name: Steve Swanson

Phone: 218-681-4425 Fax: 218-681-5820

E-mail: admin@citytrf.net

Design Capacity: 2.570 MGD Present Flow: 1.532 MGD

2. **Discharge Permit Concentration (mg/L)**
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency(1)
BOD5	15 mo /25 week	6 mo / 6 week	Gradual increase	grab/2X week
COD				
	45mo/65week	32mo/32week	Gradual increase	grab/2X week
Settleable Solids				
NH4-N				
NO3-N				
TKN				
Total Nitrogen	NONE	4.34	Gradual increase	grab /1X month
Total Phosphorous	NONE	5.60	Gradual increase	grab/2X week
Soluble Phosphorus				
Fecal Coliform	200 #/100 ml	91 #/100 ml	Gradual increase	grab/2X week
pH	6-9	7.48 min/7.57 max	Gradual increase	grab /2X week
Others(?) List Mercury	NONE	3.70 ng/L	Gradual increase	grab/1X discharge

Receiving Water body: Red Lake River

(1)pe - composite, grab
quency - # samples/week or month

3. Liquid Process Description

Pre-treatment (check)

Screen ✓ Comminutor ______

Self Cleaning Screens ______

Aerated Grit Removal ______

Other Grit Removal ______

Number of Treatment Trains ______

Primary treatment (please check) Yes ______ No ✓

# of clarifiers ______ Diameter ______

Chemical addition Yes ______ No ______

If yes, chemical(s) used ______

Secondary Treatment (please check)

Trickling Filter ______ Rotating Biological Contactor ______

Activated Sludge ______ Oxidation Ditch ______

Lagoon ✓ Biological Nutrient Removal ______
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes ______ No ✓

If yes, chemical(s) used ______

Secondary Clarifiers

# of clarifiers 0 Diameter ______

Chemical addition Yes ______ No ✓

If yes, chemical(s) used ______

Tertiary Treatment

Polishing Filters Yes ______ No ✓

Type of Filter ______ # of Filters ______

Media/depth ______ Area/Filter ______

Disinfection (please check)

Chlorine ______ Ultraviolet ______

Dechlorination Yes ______ No ✓

Please provide a copy of the most recent monthly plant performance reporting form.

4. Sludge Processing/Ultimate Reuse or Disposal

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

Pond Facility - no sludge disposal

Primary Sludge Thickening (please check)

Primary Tanks ________ Gravity ________ Belt Thickeners ________

Secondary Sludge Thickening (please check)

Gravity ________ Belt Thickeners ________

Centrifuge ________ Dissolved Air Flotation ________

Combined Sludge Thickening (please check)

Yes ________ No ________

Please Name Thickening Process ________________________

Sludge Digestion (please check)

Aerobic ________ Anaerobic ________

Other (name) ________________________

Sludge Dewatering (please check)

Drying Beds ________ Centrifuge ________

Belt Filter Press ________ Other (name) ________

5. Additional Information

strial Wastewater

ist name/type of any significant industrial wastewater load to the plant:

Dean Foods - Fluid milk - CBOD, TSS

Northern Pride, Inc. - Turkey Processing - CBOD, TSS

Arctic Cat, Inc. - Recreational Vehicles

Estimated percent of plant BOD load: 50

Collection System (check)

Separate sanitary sewers: ✓

Combined domestic/storm sewers: ______

Plant Sampling and Analyses

Influent

24 hr composite ______ Grab ✓ Other ______

Frequency (days/week) 1X / 3 month

Effluent

24 hr composite ______ Grab ✓

Other ______ Location Discharge

Frequency (days/week) 2X/week

Does plant have a lab? ✓

Analyses done by plant lab (check)

BOD	✓	TSS	✓	PH	✓	TKN	
NH_4-N		NO_3-N		$NO2_3$-N		Total P	✓
Soluble Ortho P		Coliform	✓	COD			

Others (List) ______

Thief River Fal TP
803 Barzen Ave
Thief River Falls, MN 56701

DISCHARGE MONITORING F RT

PERMITTEE NAME/ADDRESS:
Thief River Falls city of
PO Box 528
Thief River Falls, MN 567010528

PERMIT #	LIMIT STATUS	FORMER #
MN0021431	FINAL	

STATION INFORMATION:
SD-004 (010 - from 88 acre secondary cell)
Surface Discharge, Effluent To Surface Water
Attention: Steve Swanson

MONITORING PERIOD
FROM YEAR/MO/DAY 2003/06/01 TO YEAR/MO/DAY 2003/06/30

☐ No Discharge

MPCA:MK

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Flow	SAMPLE VALUE	******	85.135	MG	******	7.739	******	mgd	✓	✓
50050	PERMIT REQ	******	REPORT CalMoTot		******	REPORT CalMoAvg	******		1 x Day	MeaCon
CBOD 05 Day (20 Deg C)	SAMPLE VALUE	156	156	kg/day	******	6	6	mg/L	✓	✓
80082	PERMIT REQ	813 CalMoAvg	1355 MxCalWkAvg			15 CalMoAvg	25 MxCalWkAvg		2 x Week	Grab
TSS	SAMPLE VALUE	864	864	kg/day	******	32	32	mg/L	✓	✓
00530	PERMIT REQ	2430 CalMoAvg	3522 MxCalWkAvg		******	45 CalMoAvg	65 MxCalWkAvg		2 x Week	Grab
pH	SAMPLE VALUE	******	******		7.48	******	7.57	SU	✓	✓
00400	PERMIT REQ	******	******		6.0 CalMoMin	******	9.0 CalMoMax		2 x Week	Grab
Phosphorus Total (as P)	SAMPLE VALUE	142	******	kg/day	******	5	******	mg/L	✓	✓
00665	PERMIT REQ	REPORT CalMoAvg	******		******	REPORT CalMoAvg	******		2 x Week	Grab
Fecal Coliform, MPN/ Membrane Fltr 44.5C	SAMPLE VALUE	******	******		******	91	******	#/100ml	✓	✓
48201	PERMIT REQ	******	******		******	200 CalMoGeoMn	******		2 x Week	Grab
Nitrogen, Ammonia Total (as N)	SAMPLE VALUE	******	******		******	4.34	******	mg/L	✓	✓
00610	PERMIT REQ	******	******		******	REPORT CalMoAvg	******		1 x Month	Grab

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to:
MINNESOTA POLLUTION CONTROL AGENCY
520 LAFAYETTE RD
ST. PAUL, MN 55155-4194
ATTN: Discharge Monitoring Report

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

SIGNATURE OF PRINCIPAL EXECUTIVE OFFICES OR AUTHORIZED AGENT — DATE 7-2-03

Steve Swanson
SIGNATURE OF CHIEF OPERATOR — PHONE 681-4425 — DATE 7-1-03 — CERTIFICATION# C-8175

COMMENTS:

Thief River Fal TP
803 Barzen Ave
Thief River Falls, MN 56701

DISCHARGE MONITORING R RT

Thief River Falls city of
PO Box 528
Thief River Falls, MN 567010528

PERMIT #	LIMIT STATUS	FORMER #
MN0021431	FINAL	

STATION INFORMATION:
SD-004 (010 - from 88 acre secondary cell)
Surface Discharge, Effluent To Surface Water
Attention: Steve Swanson

MONITORING PERIOD

FROM YEAR MO DAY 2003/06/01 TO YEAR MO DAY 2003/06/30

☐ No Discharge

MPCA:MK

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Oxygen, Dissolved	SAMPLE VALUE	******	******		5.6	******	******	mg/l	✓	✓
00300	PERMIT REQ				REPORT CalMoMin				2 x Week	Grab

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to:
MINNESOTA POLLUTION CONTROL AGENCY
520 LAFAYETTE RD
ST. PAUL, MN 55155-4194
ATTN: Discharge Monitoring Report

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

Dale 7-2-03
SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER [✓ OR] AUTHORIZED AGENT DATE

Steve Swanson 681-4425 7-1-03 C-8175
SIGNATURE OF CHIEF OPERATOR PHONE DATE CERTIFICATION#

COMMENTS:

CITY OF WARROAD

DARREL ANDERSON, CITY SUPERINTENDENT
121 Main Ave NE, P.O. Box 50
Warroad, MN 56763
(218) – 386-1873

DATE: 8-4-03 # of Pages: 5

TO: Dr. David Stensel / Dr George Kehrberger

FAX #: 206-685-9185 / 201-529-5782

FROM: Amy

FAX #: 218-386-3837

COMMENTS:

Phosphorus Survey

To: →

Attn Ken

320-650-2830

Wastewater Facility Screening Form
Preliminary Information

1. Plant Information

Plant Name: City of Warroad

Contact Name: Darrel Anderson supt

Phone: ( ) 218-386-1873 Fax: ( ) 218-386-3837

E-mail: Citysupt@mncable.net

Design Capacity: .369 MGD Present Flow: .311 MGD

Treatment Ponds

2. Discharge Permit Concentration (mg/L)
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency(1)
BOD_5	25 mg/L	15 mg/L		Grab / week
COD	N/A	—		
TSS	45 mg/L	41 mg/L		Grab / week
Settleable Solids	—			
NH_4-N	—			
NO_3-N	—			
TKN	—			
Total Nitrogen	—			
Total Phosphorous	—			
Soluble Phosphorus	—			
Fecal Coliform	200 organ/100mL	170 org/100mL		Grab /week
pH	6.0 – 9.0	8.5		Grab /week
Others(?) List				

Receiving Water body: Roseau County Watershed (County Ditch)

(1)type - composite, grab
(1)frequency - # samples/week or month

3. Liquid Process Description N/A

Pre-treatment (check)

Barscreen ____ Comminutor ____

Self Cleaning Screens ____

Aerated Grit Removal ____

Other Grit Removal ____

Number of Treatment Trains ____

Primary treatment (please check) N/A Yes ____ [✓ No]

# of clarifiers ____ Diameter ____

Chemical addition Yes ____ No ____

If yes, chemical(s) used ____

Secondary Treatment (please check)

Trickling Filter ____ Rotating Biological Contactor ____

Activated Sludge ____ Oxidation Ditch ____

[✓ Lagoon] Biological Nutrient Removal ____
i.e. (Anaerobic and/or anoxic compartments

Chemical addition Yes ____ [✓ No]

If yes, chemical(s) used ____

Secondary Clarifiers N/A

# of clarifiers ____ Diameter ____

Chemical addition Yes ____ No ____

If yes, chemical(s) used ____

Tertiary Treatment N/A

Polishing Filters Yes ____ No ____

Type of Filter ____ # of Filters ____

Media/depth ____ Area/Filter ____

Disinfection (please check) N/A

Chlorine ____ Ultraviolot ____

Dechlorination Yes ____ No ____

Please provide a copy of the most recent monthly plant performance reporting form.

4. Sludge Processing/Ultimate Reuse or Disposal

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

N/A

Primary Sludge Thickening (please check) N/A

Primary Tanks ______ Gravity ______ Belt Thickeners ______

Secondary Sludge Thickening (please check) N/A

Gravity ______ Belt Thickeners ______

Centrifuge ______ Dissolved Air Flotation ______

Combined Sludge Thickening (please check) N/A

Yes ______ No ______

Please Name Thickening Process ______

Sludge Digestion (please check) N/A

Aerobic ______ Anaerobic ______

Other (name) ______

Sludge Dewatering (please check) N/A

Brying Beds ______ Centrifuge ______

Belt Filter Press ______ Other (name) ______

5. Additional Information

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant:

Marvin Windows

Estimated percent of plant BOD load: 30%

Collection System (check)

Separate sanitary sewers: X

Combined domestic/storm sewers: ______

Plant Sampling and Analyses

Influent

24 hr composite	X	Grab		Other	
Frequency (days/week)	Quarterly				

Effluent

24 hr composite	~~X~~	Grab	X
Other	Pond worden	Location	
Frequency (days/week)			
Does plant have a lab?	no		

Analyses done by plant lab (check)

BOD		TSS	X	PH		TKN	
NH_3-N		NO_3-N		$NO2_3$-N		Total P	
Soluble Ortho P		Coliform		COD			

Others (List) DO

Plant Screening Forms

Rotating Biological Contactor (RBC) Treatment Plants

Wastewater Facility Screening Form
Preliminary Information

1. **Plant Information**

Plant Name: Brainerd and Baxter wastewater Treatment Plant

Contact Name: mike Larson

Phone: (218) -825-3237 Fax: (218) -825-3258

E-mail: mlarson@BPU.ORG

Design Capacity: 3.13 MGD Present Flow: 2.70 MGD

2. **Discharge Permit Concentration (mg/L)**
(Provide Available Parameters)

	Permit Limit	Actual Discharge	Expected Future	Sample Type/Frequency[1]
BOD_5	25 P.P.M.	11.4	Same	3x week 24 HR composi
COD				
TSS	30 P.P.m.	9.4	Same	3 x week 24 HR composi
Settleable Solids				
NH_4-N				
NO_3-N				
TKN				
Ammonia ? Total Nitrogen	NONE	17.5 P.P.M.	unsure	1 composite a month
Total Phosphorous	None	2.4 P.P.m	1 P.P.M.	1 composite a month
Soluble Phosphorus		60 to 80 colonies a month geometric mean	UNSURE	
Fecal Coliform	200 organisms/100mL.		UNSURE	
pH	6.0 - 9.0	7.2	Same	Daily
Others(?) List	Cl2 <0.1 P.P.M (0.038)			Daily

Receiving Water body: Mississippi River

[1] type - composite, grab
[1] frequency - # samples/week or month

3. Liquid Process Description

Pre-treatment (check)

Barscreen ____ Comminutor ____

Self Cleaning Screens Parkson -

Aerated Grit Removal Aerated grit with auger

Other Grit Removal and wemco grit pump

Number of Treatment Trains ____

Primary treatment (please check) Yes ✓ No ____ Length width Depth

# of clarifiers 2 Diameter 100' 20' 10'

Chemical addition Yes ____ No ✓

If yes, chemical(s) used ____

Secondary Treatment (please check) 12 RBC's

Trickling Filter ____ Rotating Biological Contactor ✓

Activated Sludge ____ Oxidation Ditch ____

Lagoon ____ Biological Nutrient Removal ____
i.e. (Anaerobic and/or anoxic compartments ____

Chemical addition Yes ____ No ____

If yes, chemical(s) used ____

Secondary Clarifiers

# of clarifiers 2 Diameter 65'

Chemical addition Yes ____ No ✓

If yes, chemical(s) used ____

Tertiary Treatment

Polishing Filters Yes ____ No ✓

Type of Filter ____ # of Filters ____

Media/depth ____ Area/Filter ____

Disinfection (please check)

Chlorine ✓ Ultraviolot ____

Dechlorination Yes ✓ No ____

Please provide a copy of the most recent monthly plant performance reporting form.

4. Sludge Processing/Ultimate Reuse or Disposal

Please provide ultimate destination of plant solids (i.e. landfill, agricultural application, lagoon, etc.)

agricultural application

Primary Sludge Thickening (please check)

Primary Tanks _____ Gravity ✓ Belt Thickeners _____

Secondary Sludge Thickening (please check)

Gravity ✓ Belt Thickeners _____

Centrifuge _____ Dissolved Air Flotation _____

Combined Sludge Thickening (please check)

Yes _____ No ✓

Please Name Thickening Process _____

Sludge Digestion (please check)

Aerobic _____ Anaerobic ✓

Other (name) _____

Sludge Dewatering (please check)

Drying Beds _____ Centrifuge _____

Belt Filter Press _____ Other (name) _____

5. **Additional Information**

Industrial Wastewater

List name/type of any significant industrial wastewater load to the plant:

AcRometal & metal anodizing Both

NorthStar Plating

Estimated percent of plant BOD load: ______

Collection System (check)

Separate sanitary sewers: ✓

Combined domestic/storm sewers: ______

Plant Sampling and Analyses

Influent

24 hr composite ✓ Grab ______ Other ______

Frequency (days/week) 3

Effluent

24 hr composite ✓ Grab ______

Other 3 Location ______

Frequency (days/week) ______

Does plant have a lab? yes

Analyses done by plant lab (check)

BOD ✓ TSS ✓ PH ✓ TKN ______

NH_4-N ______ NO_3-N ______ $NO2_3$-N ______ Total P ______

oluble Ortho P ______ Coliform ✓ COD ______

thers (List) ______

Appendix 1.3

Site Visit Presentation

HydroQual

Environmental
Engineers & Scientists

Minnesota Environmental Science and Economic Review Board

Wastewater Phosphorus Control and Reduction Initiative

Wastewater Phosphorus Control and Reduction Initiative

Minnesota Environmental Science and Economic Review Board (MESERB)

George Kehrberger, Dennis Scannell, Gary Grey - HydroQual, Inc.

H. David Stensel - Univ. of WA

The Problem with Phosphorus

- Enriches nutrients in receiving waters to decrease water quality
  - Increases algae growth
  - Increases weed growth
- Problems
  - Taste and odor
  - Fish habitat – lowers DO
  - Aesthetics

Objectives

- Provide a description of Best Management Practices (BMP) for effective phosphorus control
- Demonstrate BMP alternatives through evaluation of different types of WWTPs
- Develop protocol for BMP evaluations
- Provide technology transfer via report and seminars

Wastewater Treatment Facilities Located Across State

- 17 facilities selected
- Different designs
  - Activated sludge
    - High purity oxygen
    - Oxidation ditch
    - Conventional
    - Biological Nutrient Removal
  - Trickling filter/activated sludge
  - Trickling filter
  - Rotating Biological Contactor
  - Aerated lagoons

Wastewater Treatment Facilities (continued)

- Different sizes
  - 0.30 to 19.5 Mgal/day
- Different sludge handling methods
  - Aerobic digestion
  - Anaerobic digestion
  - Land application
- Different phosphorus removal needs at present
  - Treated effluent less than 1 mg/L
  - No standard yet

Approach

- Characterize Selected Existing WWTPs
- Identify range of applicable P removal alternative designs
- Systematically evaluate effectiveness and impact of alternatives
- Identify most appropriate Best Management Practice

Information Needed for WWTPs

- Design capacity and loadings
- Existing permit requirements
- Receiving water body
- Plant layout
- Unit sizes and equipment
- Treatment performance
  - 1 year of data
  - Data collection methods
  - Plant monitoring procedures
- Wastewater characteristics
- Sludge processing methods
- Ultimate sludge disposal/reuse options

Site Visit Agenda

- Introduction – goals and approach
- Phosphorus removal technology summary
- Facility Tour
- Permit information
- Plant design details
- Obtain latest facility plan report
- Obtain plant performance reporting data

Site Visit Agenda (continued)

- Plant monitoring data
- Influent wastewater characterization data
- Sludge processing approach and data
- Review data collection methods by plant and laboratory capabilities

Phosphorus Removal Technology

- Chemical precipitation
- Enhanced biological phosphorus removal (EBPR)
- Combined Chemical and EBPR

Chemical Precipitation

- Types of Chemicals
  - Metal salts – alum or ferric
    - Forms alum or ferric phosphate precipitate
    - Uses alkalinity, decreases pH
    - Causes modest increase in sludge production
    - Costs
  - Lime
    - At high pH causes calcium phosphate precipitate
    - Not desirable due to handling and sludge production

Application Issues For Metal Salts for P Removal

- Dose
  - Stoichiometric at high P concentration – mole/mole
  - Increases as P conc. Decreases below 1.0 mg/L
    - 2 – 4 moles/mole
- Dose location
  - Primary treatment – needs control
  - Activated sludge
  - Prior to final final clarifier
  - Tertiary treatment mode

Biological Phosphorus Removal

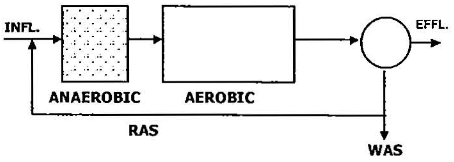
- Bacteria consume BOD and store large amounts of phosphorus – 20-30% dry wgt
- Phosphorus is removed via sludge wasting with phosphorus accumulating organisms (PAOs)
- Phosphorus can be released by bacteria with some return to treatment system

Biological Phosphorus Removal Requires an Anaerobic Contact Zone Followed by an Aerobic Zone

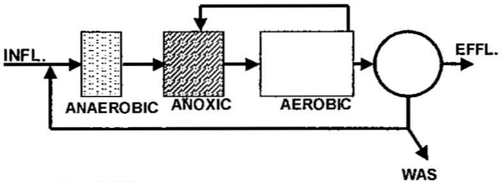
- Anaerobic means none or little oxygen and nitrate or nitrite
- Mixed liquor is mixed and contacted with influent wastewater
- Contact times typically 45 to 60 minutes
- Need aerobic SRT of 4 days or greater

A Number Of Process Configurations Can Use EBPR

Anaerobic/Aerobic Process



Phoredox With Anoxic/Aerobic Minimize NO^{-}_{3}-N to Anaerobic Zone

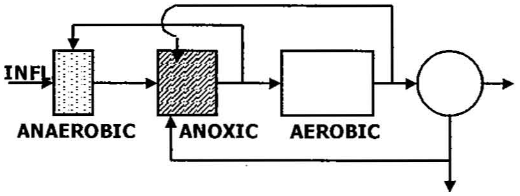


Or A2/O

1980s – Other Processes Used to Minimize Nitrate Effect on Bio P removal

UCT PROCESS

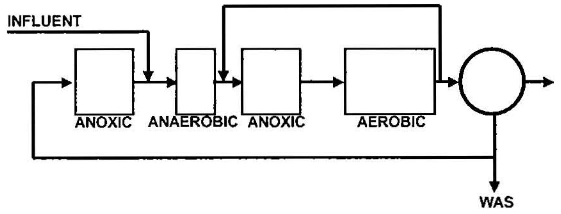
1 mg of NO3-N consumes COD for about 0.4 mg of P



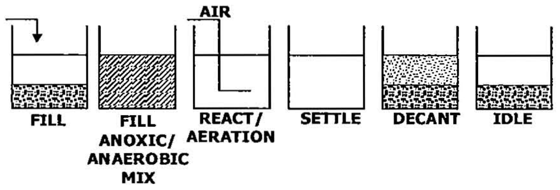
VIP Process another form

Alternatively Remove Nitrate in RAS Anoxic Zone

JHB PROCESS



Sequencing Batch Reactors Demonstrated BNR in late 1970s and early 1980s



Key Findings for Bio P Removal

- Specific organism selected (Acinetobacter-Rhodocyclus -)
- Wastewater characteristics important
  - NO_3-N bad (1 mg addition ~ 0.4 mg P)
  - Readily biodegradable COD good (Hac)
- Stoichiometric parameters defined
- Transient loading effects important

Useful Stoichiometry

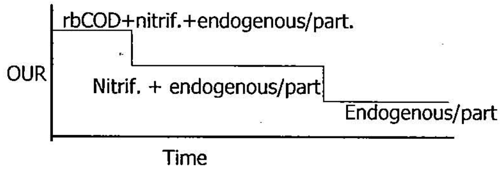
- Anaerobic contact
  - 0.5 mg P release/mg Hac
- Effect of readily biodegradable COD (rbCOD) addition
  - 1 mg P removed/10 mg Hac
  - 0.3 mg P/mg biomass
- Effect of NO3-N on rbCOD
  - 6.6 mg rbCOD/mg NO3-N
- Effect of DO on rbCOD
  - 2.3 mg rbCOD/mg DO

Bio P Removal Related to VFA availability

- Total BOD/P is a crude parameter
- How much VFA is available in anaerobic contact zone?
  - VFA/P ratios reported range from 10 – 20 g/g
- Approximate VFA production from readily biodegradable COD (rbCOD)
- VFA potential test method proposed
  - VFA/rbCOD ranged from 0.80 to 1.8

Readily Biodegradable COD (rbCOD) In Influent Can Be Used To Indicate Bio P Removal Potential

- rbCOD is "true" soluble degradable COD
- Can be measured by respirometric method



- Also measured by floc/filtration procedure

Floc/Filtration Method

- Method of Mamais and Jenkins:
  - *Water Research*, **27**, 195-197, 1993.
  - Zinc Flocculation at pH 10.5 Followed by Filtration. (0.45 μm filter)
  - 100 mL sample
    - Add 1 mL of 100 mg/L ZnSO4 soln – stir not shaken
    - Add 2 mM NaOH soln to raise pH, stir, floc, settle, filter
  - Influent and effluent samples
  - COD Analysis.
  - rbCOD ranges (20 – 30%)

How To Increase VFA for Bio P Removal?

- Add acetate or sugar to anaerobic zone
- Produce VFA by fermentation of primary sludge
  - 0.10 t0 0.20 g VFA/g VSS applied
  - 2-4 day SRT
- VFA produced from RAS fermentation
- Consistent feeding of VFA may improve performance
  - i.e. lower overall VFA/P ratio

Factors That Affect P Removal Efficiency By The EBPR Processes

- Wastewater characteristics
  - VFA availability
  - Variable loading
- Biological process design
  - SRT, aerobic zone, nitrate in recycle
- Recycle loads

Combined Chemical and EBPR Processes

- Chemical prior to biological process
- Chemical in biological process
- Chemical as polishing step
- Combinations of above

Summary

- A number of "tools" available for phosphorus removal
  - Chemical methods
  - Biological methods
- Site specific conditions affect EBPR process designs and P removal efficiency
- Site conditions and permit level affect combination chemical/biological design processes

APPENDIX 2.1.1

ALEXANDRIA LAKE AREA SANITARY DISTRICT WWTF

(ALEXANDRIA LAKE)

HydroQual

Environmental
Engineers & Scientists

Appendix 2.1.1

Alexandria Lake Area Sanitary District WWTF

Summary of Plant Data

Table 2.1.1.A: Plant Design Parameters

Parameter	Value	Units
1. Plant Loadings		
Flow		
Design Average Flow	3.25	MGD
Annual Average Flow	2.57	MGD
BOD		
Design	6,501	lb/day
Annual Average	5,151	lb/day
% Industrial	35%	
TSS		
Design	5,192	lb/day
Annual Average	4,113	lb/day
2. Treatment Unit Sizes		
Grit Chamber	1	
Volume	20,197	gallons
Depth	13	feet
Area	216	sq. feet
Primary Clarifier	2	
Volume	130,869	gallons
Depth	11	feet
Diameter	45	feet
Area	1,590	sq. feet
Overflow Rate$^{(1)}$	803	gpd/ft^2
Detention time$^{(1)}$	1.9	hours
Aeration Tanks	2	
Volume	103,231	gallons
Depth	15	feet
Area	920	sq. feet
Detention time$^{(1)}$	1.5	hours
Secondary Clarifier	2	
Volume	213,269	gallons
Depth	12	feet
Diameter	55	feet
Area	2,376	sq. feet
Overflow Rate$^{(1)}$	806	gpd/ft^2
Detention time$^{(1)}$	3.1	hours
SC Tank	1	
Volume	495,718	gallons
Depth	15	feet
Diameter	75	feet
Area	4,418	sq. feet
Sand/Anthracite Filters	6	
Overflow Rate$^{(1)}$	1.97 - 2.95	gpd/ft^2
3. Sludge Handling		
Thickening	None	
Digestion	Aerobic	
Volume per tank	410,679	gallons
Depth	15	feet
Area	3,660	sq. feet
Storage	None	
Sludge Dewatering	Centrifuge	
Sludge Disposal		
Land application		

(1) - based on design dry weather flow

Table 2.1.1.B: NPDES Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Ammonia	Monitor	mg/L	Monthly Average	Jan-Dec	3/week	24 hr comp
$CBOD_5$	25	mg/L	Monthly Average	Jan-Dec	3/week	24 hr comp
$CBOD_5$	40	mg/L	Weekly Average	Jan-Dec	3/week	24 hr comp
$CBOD_5$	85	% Removal	Monthly Average	Jan-Dec	3/week	Calculation
Total Residual Chlorine	0.038	mg/L	Daily Max	April,Oct	7/week	Grab
Fecal Coliform	200	#/100 mL	Monthly Geo Mean	April - Oct	3/week	Grab
Total Mercury	Monitor	ng/L	Single Value	Mar, Jun, Sep, Dec	1/month	Grab
Dissolved Oxygen	Monitor	mg/L	Monthly Minimum	Jan-Dec	7/week	Grab
pH	6.0-9.0	SU	Monthly Min/Max	Jan-Dec	7/week	Grab
Total Phosphorus	1.0	mg/L	Monthly Average	Jan-Dec	3/week	24 hr comp
Total Suspended Solids	30	mg/L	Monthly Average	Jan-Dec	3/week	24 hr comp
Total Suspended Solids	40	mg/L	Weekly Average	Jan-Dec	3/week	24 hr comp
Total Suspended Solids	85	% Removal	Monthly Average	Jan-Dec	3/week	Calculation

Table 2.1.1.C: Biological Secondary Treatment Process Design Information

Month 2002	RAS MGD	SRT days	F/M kg/kg	MLSS mg/L	MLVSS %
January	1.41	0.55	0.70	1,863	74.0%
February	1.35	-	0.90	2,664	72.0%
March	1.32	-	0.74	2,374	71.0%
April	1.30	6.3	0.29	2,495	71.0%
May	1.50	6.4	0.34	2,346	73.5%
June	1.50	7.1	0.42	2,464	72.0%
July	1.51	8.0	0.55	2,340	73.0%
August	1.37	9.8	0.44	2,442	73.5%
September	1.25	8.1	0.42	2,312	72.4%
October	1.22	9.5	0.52	2,461	71.4%
November	1.24	9.3	0.24	2,451	71.9%
December	1.23	9.4	0.29	2,461	74.9%
Average	1.35	7.43	0.49	2,389	72.5%

Table 2.1.1.D: Wastewater Characterization

Influent

Month 2002	Flow MGD	BOD5 mg/L	BOD5 lb/day	COD mg/L	TSS mg/L	TSS lb/day	Total Phos mg/L	BOD/P (mg/L)/(mg/L)
January	2.3	288.8	5,544	523.3	200.5	3,849	7.0	41.2
February	2.3	326.0	6,256	584.5	197.7	3,794	6.5	49.8
March	2.4	209.3	4,175	476.0	170.0	3,392	6.2	33.9
April	2.6	203.1	4,436	504.2	186.0	4,063	6.2	32.6
May	2.8	202.8	4,746	460.9	184.5	4,319	6.0	33.9
June	2.7	216.6	4,922	451.5	191.8	4,359	6.0	36.3
July	3.1	232.5	5,917	421.7	192.7	4,905	5.9	39.5
August	2.8	250.9	5,834	423.7	203.5	4,731	6.9	36.2
September	2.6	223.2	4,782	439.9	184.1	3,945	6.9	32.3
October	2.5	294.5	6,170	523.5	213.5	4,473	7.0	42.1
November	2.4	212.3	4,324	491.9	183.5	3,738	7.0	30.5
December	2.4	218.3	4,351	492.5	190.7	3,802	7.5	29.3
Average	2.6	239.8	5,121	482.8	191.6	4,114	6.6	36.5

Effluent

Month 2002	Flow MGD	BOD5 mg/L	BOD5 lb/day	TSS mg/L	TSS lb/day	Total Phos mg/L
January	2.3	5.0	96	2.0	38	0.71
February	2.3	3.1	59	1.6	30	0.36
March	2.3	2.6	50	1.3	26	0.38
April	2.5	2.9	60	3.8	79	0.66
May	2.8	3.4	80	3.2	74	0.50
June	2.7	3.8	86	3.0	68	0.25
July	2.9	3.4	81	2.0	47	0.34
August	2.8	2.2	50	1.4	33	0.39
September	2.6	2.7	57	1.9	40	0.35
October	2.3	3.1	59	2.0	37	0.27
November	2.2	2.6	47	1.5	26	0.40
December	2.2	2.5	46	1.2	23	0.32
Average	2.5	3.1	64	2.1	43	0.41

Table 2.1.1.E: Plant Performance - Percent Removal

Month	CBOD5	TSS	Total Phos
2002			
January	98.3%	99.0%	89.9%
February	99.1%	99.2%	94.6%
March	98.8%	99.2%	93.8%
April	98.6%	98.0%	89.4%
May	98.3%	98.3%	91.6%
June	98.2%	98.4%	95.8%
July	98.6%	99.0%	94.2%
August	99.1%	99.3%	94.4%
September	98.8%	99.0%	94.9%
October	98.9%	99.1%	96.2%
November	98.8%	99.2%	94.3%
December	98.9%	99.4%	95.7%
Average	98.7%	98.9%	93.7%

Table 2.1.1.F: Probability Analysis

	Influent				Effluent		
% Occurrence[1]	TSS mg/L	COD mg/L	BOD mg/L	TP mg/L	TSS mg/L	BOD mg/L	TP mg/L
10%	156	371	174	5.3	1.0	2.0	0.20
50%	190	474	228	6.3	2.0	3.0	0.29
90%	236	589	320	7.8	4.0	5.0	0.52

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter

APPENDIX 2.1.2

GRAND RAPIDS WWTF

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Appendix 2.1.2

Grand Rapids WWTF

Summary of Plant Data

Table 2.1.2.A: Plant Design Parameters

Parameter	Value	Units
1. Plant Loadings		
Flow		
Design Flow	15.2	MGD
Annual Average Flow	8.8	MGD
% Industrial	46%	
BOD		
Design	38,908	lb/day
Annual Average	23,330	lb/day
% Industrial	62%	
TSS		
Design	34,007	lb/day
Annual Average	19,501	lb/day
% Industrial	87%	
2. Treatment Unit Sizes		
Flocculation Basins	2	
Volume	0	gallons
Depth	16	feet
Area	1,000	sq. feet
Detention time(1)	0.5	hours
Primary Clarifier	3	
Volume	0.85	gallons
Depth	14.5	feet
Diameter	100	feet
Area	7,854	sq. feet
Overflow Rate(1)	330	gpd/ft^2
Detention time(1)	7.0	hours
Aeration Tanks	2	
Volume	7.8	gallons
Depth	18	feet
Area	58,000	sq. feet
Detention time(1)	42.6	hours
Final Clarifier	2	
Volume	0.56	gallons
Depth	9.5	feet
Diameter	100	feet
Area	7,854	sq. feet
Overflow Rate(1)	970	gpd/ft^2
Detention time(1)	3.0	hours
Final Clarifier	1	
Volume	2.82	gallons
Depth	14.0	feet
Diameter	185	feet
Area	26,880	sq. feet
Overflow Rate(1)	970	gpd/ft^2
Detention time(1)	7.7	hours
Effluent Polishing Ponds	2	
Volume	19.75	gallons
Depth	20.0	feet
Area	132,000	sq. feet
Detention time(1)	108	hours
Effluent Polishing Ponds	2	
Volume	16	gallons
Depth	20	feet
Area	106,000	sq. feet
Detention time(1)	87	hours
3. Sludge Handling		
Thickening	Gravity Thickeners	
Digestion	None	
Storage	None	
Sludge Dewatering	Belt Filter Press	
Sludge Disposal	Landfill	

(1) - based on design dry weather flow

Table 2.1.2.B: NPDES Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Ammonia	8	mg/L	Monthly Avg	Jun - Sept	3/week	24 hr comp
$CBOD_5$	25	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
$CBOD_5$	40	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp
$CBOD_5$	85	% Removal	Monthly Min	Jan - Dec	3/week	24 hr comp
Total Residual Chlorine	0.038	mg/L	Monthly Max	April - Oct	1/day	Grab
Fecal Coliform	200	#/100 mL	Monthly Geo Mean	April - Oct	3/week	Grab
Total Mercury	Monitor	ng/L	Single Value	Jan - Dec	1/Quarter	Grab
Dissolved Oxygen	Monitor	mg/L	Monthly Min	Jan - Dec	1/day	Grab
pH	6.0-9.0	SU	Monthly Min/Max	Jan - Dec	1/day	Grab
Total Phosphorus	Monitor	mg/L	Monthly Avg	Jan - Dec	1/week	24 hr comp
Total Suspended Solids	30	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
Total Suspended Solids	45	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp
Total Suspended Solids	85	% Removal	Monthly Min	Jan - Dec	3/week	24 hr comp
Total Zinc	Monitor	ug/L	Single Value	Jan - Dec	1/month	Grab

Table 2.1.2.C: Biological Secondary Treatment Process Design Information

Month	RAS	WAS	F/M	MLSS	MLVSS
2002-2003	MGD	GPD	lb/lb	mg/L	mg/L
October	6.0	0.31	0.09	3,943	2,821
November	9.5	0.20	0.17	3,558	2,132
December	9.5	0.29	0.10	4,261	2,540
January	9.1	0.34	0.20	2,978	1,744
February	10.3	1.0	0.24	2,849	1,741
March	9.4	0.22	0.19	3,293	2,146
April	8.1	0.39	0.05	4,453	2,661
May	5.5	0.35	0.07	3,586	2,171
June	5.5	1.49	0.05	3,846	2,256
July	5.5	1.86	0.05	4,138	2,074
August	5.5	0.15	0.05	3,992	2,112
September	5.4	0.19	0.04	4,646	2,503
Average	7.4	0.56	0.11	3,795	2,242

Table 2.1.2.D: Wastewater Characterization

Influent

Month 2002-2003	Flow MGD	BOD5 mg/L	BOD5 lb/d	TSS mg/L	TSS lb/d
October	10.6	444	39,229	214	18,959
November	11.5	405	38,892	290	27,859
December	11.5	399	38,160	240	22,920
January	10.4	350	30,274	262	22,614
February	8.1	288	19,547	254	17,208
March	7.9	317	20,948	219	14,463
April	7.1	258	15,225	309	18,223
May	6.5	258	14,058	259	14,082
June	7.1	288	17,023	337	19,904
July	8.1	230	15,560	268	18,199
August	8.5	214	15,157	301	21,350
September	8.2	232	15,881	266	18,236
Average	8.8	307	23,330	268	19,501

Effluent

Month 2002-2003	Flow MGD	BOD5 mg/L	BOD5 lb/d	TSS mg/L	TSS lb/d	Total Phos mg/L
October	8.8	5.2	382	5.2	382	0.33
November	8.4	4.9	338	18.3	1,277	1.06
December	8.5	4.4	313	16.1	1,141	1.40
January	8.2	1.9	129	11.3	774	0.21
February	7.1	2.5	147	13.2	776	0.17
March	7.9	3.3	217	14.9	985	0.42
April	7.1	1.8	104	12.7	747	0.17
May	6.5	1.8	96	8.8	479	0.20
June	7.1	2.6	153	13.1	773	0.26
July	7.2	1.3	79	9.0	540	0.70
August	7.5	1.7	106	6.9	431	0.92
September	7.2	1.5	90	7.2	433	0.86
Average	7.6	2.7	179	11.4	728	0.56

Table 2.1.2.E: Plant Performance - Percent Removal

Month	BOD5	TSS
2002-2003		
October	98.8%	97.6%
November	98.8%	93.7%
December	98.9%	93.3%
January	99.5%	95.7%
February	99.1%	94.8%
March	99.0%	93.2%
April	99.3%	95.9%
May	99.3%	96.6%
June	99.1%	96.1%
July	99.4%	96.7%
August	99.2%	97.7%
September	99.4%	97.3%
Average	99.2%	95.7%

Table 2.1.2.F: Probability Analysis

	Influent		Effluent		
	TSS	BOD	TSS	BOD	TP
% Occurrence[(1)]	mg/L	mg/L	mg/L	mg/L	mg/L
10%	132	189	6.2	1.3	0.2
50%	247	294	12.7	2.1	0.6
90%	416	467	18.8	5.7	1.1

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter

APPENDIX 2.1.3

NEW ULM WWTF

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Appendix 2.1.3

New Ulm WWTF

Summary of Plant Data

Table 2.1.3.A: Plant Design Parameters

Parameter	Value	Units
1. Plant Loadings		
Flow		
Design Flow	6.77	MGD
Annual Average Flow	2.55	MGD
% Industrial	34%	
BOD		
Design	21,828	lb/day
Annual Average	8,141	lb/day
% Industrial	80%	
TSS		
Design	15,412	lb/day
Annual Average	5,755	lb/day
2. Treatment Unit Sizes		
Treatment Trains	2	
Primary Clarifier	2	
Volume	248,745.00	gallons
Depth	10.0	feet
Diameter	65	feet
Area	3,318	sq. feet
Detention time(1)	4.7	hours
Aeration Tanks	4	
Volume	737,350	gallons
Depth	13	feet
Area	7,396	sq. feet
Detention time(1)	28	hours
Final Clarifier	3	
Volume	298,500	gallons
Depth	12	feet
Diameter	65	feet
Area	3,318	sq. feet
Detention time(1)	8.4	hours
Cl_2 Contact Tank	2	
Volume	68,816	gallons
Depth	5	feet
Area	2,000	sq. feet
Detention time(1)	1.3	hours
3. Sludge Handling		
Thickening	Gravity Thickeners	
Digestion	Aerobic	4
Volume	58,798	gallons
Depth	14.1	feet
Diameter	29.5	feet
Area	683	sq. feet
Storage	Tank	4
Volume	800,000	gallons
Sludge Dewatering	None	
Sludge Disposal	Land Application	

(1) - based on design dry weather flow

Table 2.1.3.B: NPDES Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
$CBOD_5$	25	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
$CBOD_5$	40	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp
Fecal Coliform	200	#/100 mL	Monthly Geo Mean	April - Oct	3/week	Grab
Fecal Coliform	400	#/100 mL	Monthly Geo Mean	April - Oct	3/week	Grab
pH	6.0-9.0	SU	Monthly Min/Max	Jan - Dec	1/day	Grab
Total Phosphorus	Monitor	mg/L	Monthly Avg	Jan - Dec	1/month	Grab
Total Suspended Solids	30	mg/L	Monthly Avg	Jan - Dec	7/week	24 hr comp
Total Suspended Solids	45	mg/L	Weekly Avg	Jan - Dec	7/week	24 hr comp

Table 2.1.3.C: Wastewater Characterization

Influent

Month 2002-2003	Flow MGD	CBOD$_5$ mg/L	CBOD$_5$ lb/d	TSS mg/L	TSS lb/d	TP mg/L	BOD:P
September	2.7	296	6,647	204	4,574		
December	2.4	375	7,371	262	5,145		
January	2.3	595	11,408	420	8,053		
February	2.3	421	8,095	282	5,411	13	32
March	2.3	371	7,213	260	5,052	8.0	46
April	2.4	382	7,577	260	5,165	7.3	52
May	2.8	360	8,530	236	5,594	8.0	45
June	2.6	360	7,812	257	5,594	9.1	40
July	2.8	361	8,356	267	6,183	9.2	39
August	2.7	393	8,970	292	6,673	8.0	49
September	2.7	340	7,568	263	5,863	8.8	39
Average	2.5	387	8,141	273	5,755	8.9	43

Effluent

Month 2002-2003	Flow MGD	CBOD$_5$ mg/L	CBOD$_5$ lb/d	TSS mg/L	TSS lb/d	TP mg/L	Ammonia mg/L	NO$_3$ mg/L
September	2.7	2.8	62	3.5	78		< 0.08	38.3
December	2.4	3.3	66	3.4	67		< 0.08	39.4
January	2.3	4.3	83	3.9	75		< 0.08	38.4
February	2.3	4.7	90	4.8	92	5.6	< 0.12	31.3
March	2.3	4.4	86	6.0	117	6.2	< 0.51	38.1
April	2.4	4.2	82	5.9	117	4.6	< 0.21	44.1
May	2.8	3.5	83	5.0	119	4.7	< 0.08	47.2
June	2.6	2.8	62	4.5	99	3.9	< 0.08	40.8
July	2.8	3.2	74	3.5	81	4.4	< 0.16	48.3
August	2.7	2.5	58	3.3	76	4.6	< 0.08	54.9
September	2.7	2.3	50	2.8	63	4.8	0.00	43.1
Average	2.5	3.5	72	4.2	89	4.8	< 0.13	42.2

Table 2.1.3.D: Plant Performance - Percent Removal

Month	CBOD5	TSS	TP
2002-2003			
September	99.1%	98.3%	
December	99.1%	98.7%	
January	99.3%	99.1%	
February	98.9%	98.3%	58.0%
March	98.8%	97.7%	22.9%
April	98.9%	97.7%	37.1%
May	99.0%	97.9%	40.4%
June	99.2%	98.2%	57.5%
July	99.1%	98.7%	52.1%
August	99.4%	98.9%	42.1%
September	99.3%	98.9%	45.4%
Average	99.1%	98.4%	44.4%

Table 2.1.3.E: Probability Analysis

	Influent			Effluent				
%	TSS	BOD	TP	TSS	BOD	TP	NH_3	NO_3
Occurrence(1)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
10%	164	271	5.7	3.0	2.0	4.4	0.080	32
50%	253	378	8.0	4.0	3.0	5.6	0.080	42
90%	364	462	11	6.0	5.0	7.1	0.21	53

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter

APPENDIX 2.2.1

ST. CLOUD WWTF

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Appendix 2.2.1

St. Cloud WWTF

Summary of Plant Data

Table 2.2.1.A: Plant Design Parameters

Parameter	Value	Units
1. Plant Loadings		
Flow		
Design Flow	13.0	MGD
Annual Average Flow	10.8	MGD
Industrial	2.2	MGD
BOD		
Design	15,578	lb/day
Annual Average	26,800	lb/day
% Industrial	17.1%	
TSS		
Design	16,547	lb/day
Annual Average	26,100	lb/day
% Industrial	17.5%	
2. Treatment Unit Sizes		
Primary Clarifier	4	
Volume	273,000	gallons
Depth	8	feet
Area	4,563	sq. feet
Overflow Rate(1)	712	gpd/ft^2
Detention time(1)	2	hours
Aeration Tanks	3	
Volume	1,070,000	gallons
Depth	15	feet
Area	9,537	sq. feet
Detention time(1)	5.93	hours
Final Clarifier	3	
Volume	647,000	gallons
Depth	12	feet
Diameter	96	feet
Area	7,238	sq. feet
Overflow Rate(1)	599	gpd/ft^2
Detention time(1)	3.58	hours
Cl_2 Contact Tank	2	
Volume	142,000	gallons
Detention time(1)	0.52	hours
3. Sludge Handling		
Sludge Thickening		
Belt Thickeners and Dissolved Air Flotation		
Digestion		
Anaerobic Digesters	4	
Diameter	60	ft
Capacity	575,000	gallons
Storage	Tank	
Sludge Disposal	Land Application	

(1) - based on design dry weather flow

Table 2.2.1.B: NPDES Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
$CBOD_5$	25	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
$CBOD_5$	40	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp
$CBOD_5$	85	% Removal	Monthly Avg	Jan - Dec	3/week	24 hr comp
Total Residual Chlorine	0.038	mg/L	Monthly Max	April - Oct	1/day	Grab
Fecal Coliform	200	#/100 mL	Monthly Geo Mean	April - Oct	3/week	Grab
Total Mercury	Monitor	ng/L	Monthly Avg	Mar, Jun, Sep, Dec	1/month	Grab
Dissolved Oxygen	Monitor	mg/L	Monthly Min	Jan - Dec	1/day	Grab
pH	6.0-9.0	SU	Monthly Min/Max	Jan - Dec	1/day	Grab
Total Phosphorus	Monitor	mg/L	Monthly Avg	Jan - Dec	1/week	24 hr comp
Total Suspended Solids	30	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
Total Suspended Solids	45	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp
Total Suspended Solids	85	% Removal	Monthly Avg	Jan - Dec	3/week	24 hr comp

Table 2.2.1.C: Biological Secondary Treatment Process Design Information

Month	RAS	SRT	F/M	MLSS	MLVSS
2002-2003	MGD	days	lb/lb	mg/L	mg/L
October	0.20	8.6	0.18	3,189	2,413
November	0.20	9.7	0.18	3,483	2,779
December	0.18	9.3	0.17	3,769	2,935
January	0.19	8.4	0.13	3,906	3,134
February	0.24	9.3	0.16	3,215	2,601
March	0.18	9.3	0.16	3,542	2,800
April	0.20	8.9	0.17	3,466	3,200
May	0.23	8.7	0.18	2,779	2,164
June	0.23	9.4	0.18	2,486	1,947
July	0.23	9.1	0.18	2,358	1,853
August	0.23	8.7	0.21	2,007	1,613
September	0.19	8.6	0.20	2,180	1,800
Average	0.21	9.0	0.17	3,032	2,437

Table 2.2.1.D: Digester Process Characteristics

Month 2002-2003	Volatile Acids mg/L	Alkalinity mg/L	% Tot Solids %	% Tot Vol. Solids %
October	513	3,740	2.12	63.3
November	411	3,558	1.80	65.3
December	387	3,762	2.00	63.8
January	555	3,887	2.06	64.5
February	512	4,396	2.34	65.8
March	492	4,490	2.33	65.4
April	970	4,390	2.59	64.9
May	724	4,535	2.75	61.4
June	688	4,851	2.93	58.9
July	602	4,741	3.13	59.6
August	597	4,609	2.88	61.3
September	590	4,184	2.25	62.8
Average	637	4,453	2.58	62.7

Table 2.2.1.E: Wastewater Characterization

Influent

Month 2002-2003	Flow MGD	CBOD5 mg/L	CBOD5 lb/d	COD mg/L	TSS mg/L	TSS lb/d	TKN mg/L	Ammonia mg/L	Total Phos mg/L	BOD/P (mg/L)/(mg/L)
October	12.7	119	12,665	461	141	14,977	25.0	17.6	5.2	23.1
November	11.7	139	13,574	462	154	14,965	27.4	19.8	4.8	29.1
December	10.5	150	13,135	532	158	13,837	31.0	21.8	5.5	27.2
January	10.2	164	13,975	159	158	13,418	32.1	23.4	5.6	29.6
February	10.1	154	13,049	164	179	15,157	32.8	24.2	5.7	27.0
March	9.8	171	13,966	178	166	13,562	34.0	25.8	5.9	28.7
April	10.6	165	14,529	182	166	14,614	30.9	25.5	6.2	26.6
May	10.9	141	12,838	177	153	13,924	28.2	21.3	5.0	28.2
June	10.9	123	11,179	185	154	13,965	26.5	19.6	5.0	24.8
July	11.0	132	12,100	194	138	12,661	23.0	19.3	4.7	28.0
August	10.6	165	14,606	204	130	11,518	25.0	20.1	5.4	30.5
September	10.6	101	8,951	432	136	12,051	24.6	15.2	3.8	26.3
Average	10.8	144	12,881	278	153	13,721	28.4	21.1	5.2	27.4

Effluent

Month 2002-2003	Flow MGD	CBOD5 mg/L	CBOD5 lb/d	TSS mg/L	TSS lb/d	TKN mg/L	Ammonia mg/L	Total Phos mg/L
October	12.7	5.0	536	7.7	822	6.2	4.3	1.5
November	11.7	6.0	585	10.4	1,009	13.6	11.2	0.71
December	10.5	6.3	550	8.9	783	15.3	12.1	0.80
January	10.2	9.0	762	13.3	1,134	12.1	19.9	1.9
February	10.1	9.0	757	9.9	840	6.5	20.9	1.6
March	9.8	6.0	491	5.9	486	10.3	20.4	0.91
April	10.6	6.9	608	9.1	805	15.0	21.9	1.0
May	10.9	4.8	436	6.1	554	8.5	15.3	0.50
June	10.9	2.7	247	3.8	343	5.0	11.4	0.29
July	11.0	3.8	349	4.9	449	3.5	2.8	0.51
August	10.6	4.4	392	6.8	602	4.3	0.81	2.0
September	10.6	4.0	354	6.9	607	4.9	2.7	1.3
Average	10.8	5.7	506	7.8	703	8.8	12.0	1.1

Table 2.2.1.F: Plant Performance - Percent Removal

Month 2002-2003	CBOD5	TSS	Ammonia	Total Phos
October	95.8%	94.5%	75.6%	71.5%
November	95.7%	93.3%	43.4%	85.2%
December	95.8%	94.3%	44.6%	85.4%
January	94.5%	91.6%	14.9%	66.3%
February	94.2%	94.5%	13.7%	71.2%
March	96.5%	96.4%	21.0%	84.7%
April	95.8%	94.5%	14.3%	83.1%
May	96.6%	96.0%	28.1%	90.1%
June	97.8%	97.5%	42.0%	94.1%
July	97.1%	96.5%	85.4%	89.1%
August	97.3%	94.8%	96.0%	63.6%
September	96.0%	95.0%	82.5%	65.9%
Average	96.1%	94.9%	46.8%	79.2%

Table 2.2.1.G: Probability Analysis

	Influent						Effluent				
% Occurrence[1]	TSS mg/L	COD mg/L	BOD mg/L	TP mg/L	TKN mg/L	NH3 mg/L	TSS mg/L	BOD mg/L	TP mg/L	TKN mg/L	NH3 mg/L
10%	118	105	116	4.0	25	17	3.5	3.0	0.33	3.3	1.0
50%	180	205	163	5.2	30	21	7.0	5.6	1.0	14	11
90%	135	563	452	6.5	34	26	13	9.0	5.6	26	22

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter

APPENDIX 2.2.2

FERGUS FALLS WWTP

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Appendix 2.2.2

Fergus Falls WWTP

Summary of Plant Data

Table 2.2.2.A: Plant Design Parameters

Parameter	Value	Units
1. Plant Loadings		
Flow		
Design Flow	2.81	MGD
Maximum Storm Flow	7.75	MGD
Annual Average	1.76	MGD
BOD		
Design	6,600	lb/day
Annual Average	3,336	lb/day
TSS		
Design	6,248	lb/day
Annual Average	3,000	lb/day
2. Treatment Unit Sizes		
Primary Clarifier	2	
Volume	139,500	gallons
Depth	10	feet
Diameter	50	feet
Area	3,926	sq. feet
Overflow Rate(1)	716	gpd/ft^2
Detention time(1)	3.8	hours
Aeration Tanks	2	
Volume	550,000	gallons
Depth	15	feet
Area	4,960	sq. feet
Detention time(1)	15.0	hours
Aeration Blowers (number)	4	
Aeration Blowers (capacity)	8,000	cfm
Final Clarifier	2	
Volume	298,000	gallons
Depth	12	feet
Diameter	65	feet
Area	5,655	sq. feet
Overflow Rate(1)	497	gpd/ft^2
Detention time(1)	8.1	hours
Disinfection	2	
Volume	78,091	gallons
Depth	7.5	feet
Area	696	sq. feet
Detention time(1)	2.1	hours
3. Sludge Handling		
Thickening	None	
Digestion	Anaerobic	3
Diameter	50	ft
Capacity	471,000	gallons, each
Storage	None	
Dewatering		
Belt Filter Press		
Sludge Storage Tank	1.48	MG
Sludge Disposal		
Haul or Land Application		

(1) - based on design dry weather flow

Table 2.2.2.B: NPDES Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Ammonia	4.3	mg/L	Monthly Average	Jun-Sept	3/week	24 hr comp
$CBOD_5$	25	mg/L	Monthly Average	Jan-Dec	3/week	24 hr comp
$CBOD_5$	40	mg/L	Weekly Average	Jan-Dec	3/week	24 hr comp
$CBOD_5$	85	% Removal	Monthly Average	Jan-Dec	3/week	Calculation
Total Residual Chlorine	0.038	mg/L	Daily Max	April - Oct	7/week	Grab
Fecal Coliform	200	#/100 mL	Monthly Geo Mean	April - Oct	3/week	Grab
Total Mercury	Monitor	ng/L	Single Value	Mar, Jun, Sep, Dec	1/month	Grab
Total Lead	Monitor	ug/L	Single Value	Jul	1/month	Grab
Total Copper	Monitor	ug/L	Single Value	Jul	1/month	Grab
Dissolved Oxygen	Monitor	mg/L	Monthly Minimum	Jan-Dec	7/week	Grab
pH	6.0-9.0	SU	Monthly Min/Max	Jan-Dec	7/week	Grab
Total Phosphorus	1.0	mg/L	Monthly Average	Jan-Dec	3/week	24 hr comp
Total Suspended Solids	30	mg/L	Monthly Average	Jan-Dec	3/week	24 hr comp
Total Suspended Solids	45	mg/L	Weekly Average	Jan-Dec	3/week	24 hr comp
Total Suspended Solids	85	% Removal	Monthly Average	Jan-Dec	3/week	Calculation

Table 2.2.2.C: Biological Secondary Treatment Process Design Information

Month 10/02-10/03	RAS MGD	SRT days	F/M kg/kg	MLSS mg/L	MLVSS %
October	Goal: 1 MGD	59	0.20	4,666	72.5
November		57	0.15	6,178	68.6
December		55	0.14	7,271	67.5
January		53	0.13	6,561	71.5
February		53	0.13	5,927	72.2
March		53	0.15	5,122	73.6
April		56	0.21	4,409	75.5
May		63	0.08	7,083	73.8
June		65	0.12	7,004	73.7
July		66	0.11	8,154	69.2
August		60	0.12	7,433	69.4
September		57	0.13	7,537	65.5
Average	-	58	0.14	6,445	71.1

NOTE: SRT based on maximum wasting capacity of 30,000 gpd

Table 2.2.2.D: Wastewater Characterization

Influent

Month 10/02-10/03	Flow MGD	BOD5 mg/L	BOD5 lb/d	TSS mg/L	TSS lb/d	Ammonia mg/L	Total Phos mg/L	BOD/P (mg/L)/(mg/L)
October	1.80	191	2,858	224	3,354	23	5.1	37
November	1.73	192	2,779	228	3,292	27	5.8	33
December	1.66	205	2,823	272	3,759	2.0	6.5	32
January	1.61	200	2,680	226	3,035	22	5.8	34
February	1.61	179	2,404	194	2,607	22	5.9	31
March	1.61	180	2,414	227	3,042	21	5.4	33
April	1.72	204	2,925	210	3,014	20	5.5	37
May	1.89	168	2,647	215	3,388	21	6.1	27
June	1.96	160	2,611	194	3,170	18	5.9	27
July	1.99	153	2,549	197	3,270	19	5.8	26
August	1.79	180	2,697	194	2,898	20	6.4	28
September	1.70	200	2,841	219	3,115	21	6.5	31
Average	1.76	184	2,686	217	3,162	20	5.9	31

Effluent

Month 10/02-10/03	Flow MGD	BOD5 mg/L	BOD5 lb/d	TSS mg/L	TSS lb/d	Ammonia mg/L	Total Phos mg/L
October	1.77	2.0	30	4.4	65	0.5	0.85
November	1.71	2.2	31	7.9	113	6.3	0.67
December	1.63	2.2	30	7.1	97	2.1	0.34
January	1.59	2.8	37	8.5	112	3.3	0.37
February	1.61	2.5	34	7.3	98	13.0	0.36
March	1.65	3.6	49	7.9	109	18.7	0.39
April	1.78	4.7	70	6.6	98	18.6	0.68
May	1.90	3.5	55	8.4	133	17.7	0.83
June	1.98	3.3	54	4.6	76	1.5	0.44
July	1.97	2.4	40	5.7	94	1.0	0.58
August	1.77	3.1	46	7.3	108	0.9	0.83
September	1.69	4.2	59	5.0	70	2.3	0.85
Average	1.75	3.0	44	6.7	98	7.2	0.60

Table 2.2.2.E: Plant Performance - Percent Removal

Month	$CBOD_5$	TSS	Ammonia	Total Phos
2002-2003				
October	99.0%	98.0%	97.8%	83.5%
November	98.9%	96.5%	76.7%	88.6%
December	98.9%	97.4%		94.8%
January	98.6%	96.3%	85.1%	93.6%
February	98.6%	96.2%	40.1%	93.9%
March	98.0%	96.5%	12.0%	92.7%
April	97.7%	96.8%	8.6%	87.5%
May	97.9%	96.1%	16.4%	86.5%
June	98.0%	97.6%	91.7%	92.7%
July	98.4%	97.1%	94.9%	90.0%
August	98.3%	96.2%	95.5%	87.1%
September	97.9%	97.7%	89.2%	86.9%
Average	98.3%	96.9%	64.3%	89.8%

Table 2.2.2.F: Probability Analysis

	Influent				Effluent				
%	TSS	BOD	TP	NH_3	TSS	BOD	TP	NH_3	NO_3
Occurrence[1]	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
10%	170	141	5.0	13.6	3.0	2.0	0.28	0.05	1.0
50%	214	185	5.7	20.5	6.0	2.0	0.40	2.7	5.6
90%	277	224	7.0	25.7	11.0	4.0	1.1	21	13

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter

APPENDIX 2.3.1

WADENA WWTF

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Appendix 2.3.1

Wadena WWTF

Summary of Plant Data

Table 2.3.1.A - Plant Design Parameters

Parameter	Value	Units
1. Plant Loadings		
Flow		
Design Dry Weather Flow	0.50	MGD
Design Wet Weather Flow	0.75	MGD
Annual Average Flow	0.32	MGD
BOD		
Design	640	lb/day
Annual Average	412	lb/day
TSS		
Design	849	lb/day
Annual Average	549	lb/day
2. Treatment Unit Sizes		
Primary Clarifier	1	
Volume per tank	65,802	gallons
Depth	7	feet
Diameter	40	feet
Area	1,257	sq. feet
Overflow Rate$^{(1)}$	398	gpd/ft^2
Detention time$^{(1)}$	3.2	hours
Oxidation Ditch	4 passes	
Middle Passes (2)	110	ft
Inner Pass	15.5	ft
Outer Pass	16+	ft
Depth	8.5	ft
Width of Pass	16	ft
Volume per tank	396,000	gallons
Depth	8.5	feet
Detention time$^{(1)}$	19.0	hours
Final Clarifier	2	
Volume per tank	103,403	gallons
Depth	11	feet
Diameter	40	feet
Area	1,257	sq. feet
Overflow Rate$^{(1)}$	199	gpd/ft^2
Detention time$^{(1)}$	9.9	hours
Cl_2 Contact Tank	1	
Volume per tank	6,970	gallons
Depth	4.67	feet
Area	200	sq. feet
Detention time$^{(1)}$	0.3	hours
Effluent Filter	2	
Anthracite and Anthrasand	12 ft x 12 ft	
Media Depth	11	ft
Filter Area	150	ft media/filter
3. Sludge Handling		
Thickening	None	
Digestion	Anaerobic	
Primary Digestion		
Diameter	40	ft
Capacity	189,000	gallons
Secondary Digestion		
Diameter	35	ft
Capacity	130,000	gallons
Storage		
Tank	2	
Capacity per tank	250,000	gallons
Dewatering	None	
Disposal	858,000	gallons/year
Land Apply in Spring and Fall; Store in Winter and Summer		

(1) - based on design dry weather flow

Table 2.3.1.B: NPDES Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Ammonia	15	mg/L	Monthly Avg	Dec - March	1/week	24 hr comp
Ammonia	8.0	mg/L	Monthly Avg	April - May	1/week	24 hr comp
Ammonia	2.0	mg/L	Monthly Avg	June - Sept	1/week	24 hr comp
Ammonia	8.0	mg/L	Monthly Avg	Oct - Nov	1/week	24 hr comp
$CBOD_5$	10	mg/L	Monthly Avg	Jan - Dec	1/week	24 hr comp
$CBOD_5$	15	mg/L	Weekly Avg	Jan - Dec	1/week	24 hr comp
$CBOD_5$	85	% Removal	Monthly Avg	Jan - Dec	1/week	Calculation
Total Residual Chlorine	0.038	mg/L	Daily Max	April - Oct	1/day	Grab
Fecal Coliform	200	#/100 mL	Monthly Geo Mean	April - Oct	1/week	Grab
Dissolved Oxygen	7.0	mg/L	Monthly Min	Jan - Dec	1/day	Grab
pH	6.0-9.0	SU	Monthly Min/Max	Jan - Dec	1/week	Grab
Total Phosphorus	Monitor	mg/L	Monthly Avg	Jan - Dec	1/week	24 hr comp
Total Suspended Solids	30	mg/L	Monthly Avg	Jan - Dec	1/week	24 hr comp
Total Suspended Solids	45	mg/L	Weekly Avg	Jan - Dec	1/week	24 hr comp
Total Suspended Solids	85	% Removal	Monthly Avg	Jan - Dec	1/week	Calculation

Table 2.3.1.C - Biological Secondary Treatment Process Design Information

Month 2002-2003	RAS gal/day	WAS gal/day	SRT days	SVI	MLSS mg/L	RAS Solids mg/L	WAS Solids mg/L
October	432,000	7,710	16.5	374	1,640	2,906	8,117
November	432,000	8,910	19.3	390	1,818	3,118	6,676
December	423,871	9,200	24.8	433	1,824	2,871	5,175
January	432,000	12,755	18.0	392	1,907	3,130	5,408
February	432,000	10,232	18.9	340	1,453	2,371	5,225
March	432,000	11,390	18.1	415	1,865	3,023	6,149
April	432,000	9,503	17.5	343	1,794	3,149	6,287
May	430,645	11,532	21.0	442	2,041	3,779	5,166
June	404,500	10,600	15.1	483	1,599	3,121	5,788
July	408,935	5,294	31.5	443	1,939	3,879	7,234
August	432,000	5,610	23.2	335	1,692	2,843	7,753
September	432,000	4,300	29.4	284	1,948	3,301	9,422
Average	426,996	8,920	21.1	389	1,793	3,124	6,533

Table 2.3.1.D: Wastewater Characterization

Influent

Month 2002-2003	Flow MGD	CBOD5 mg/L	CBOD5 lb/d	TSS mg/L	TSS lb/d	Ammonia mg/L	Total Phos mg/L	BOD/P (mg/L)/(mg/L)
October	0.330	158	433	180	495	25	7.7	20
November	0.320	124	331	175	468	26		
December	0.309	158	407	172	443	28	3.6	44
January	0.308	183	471	147	378	26	11	17
February	0.315	127	333	209	549	23	6.6	19
March	0.303	148	374	167	421	21	6.3	24
April	0.310	179	463	210	543	25	6.4	28
May	0.333	164	456	233	646	25	8.9	19
June	0.350	141	411	237	691	19	5.3	27
July	0.360	146	440	226	679	17	5.3	28
August	0.321	153	409	232	621	18	9.7	16
September	0.309	161	414	255	656	22	5.6	29
Average	0.322	153	412	204	549	23	6.9	24

Effluent

Month 2002-2003	Flow MGD	CBOD5 mg/L	CBOD5 lb/d	TSS mg/L	TSS lb/d	Ammonia mg/L	Total Phos mg/L
October	0.330	2.3	6	1.3	4	0.51	5.9
November	0.320	2.0	5	1.8	5	0.72	
December	0.309	1.9	5	1.2	3	0.47	5.3
January	0.308	2.4	6	1.8	5	2.2	8.5
February	0.315	2.5	7	1.7	5	12.4	7.4
March	0.303	3.1	8	2.0	5	6.3	7.2
April	0.310	2.6	7	1.2	3	0.59	5.1
May	0.333	2.4	7	1.8	5	0.28	7.6
June	0.350	1.6	5	1.1	3	0.53	6.3
July	0.360	2.1	6	1.0	3	0.23	4.7
August	0.321	2.3	6	1.4	4	0.44	7.0
September	0.309	2.0	5	1.1	3	0.93	3.4
Average	0.322	2.3	6	1.5	4	1.2	6.2

Table 2.3.1.E: Plant Performance - Percent Removal ($CBOD_5$, TSS, Ammonia)

Month	CBOD5	TSS	Ammonia
2002-2003			
October	98.5%	99.3%	97.9%
November	98.4%	99.0%	97.2%
December	98.8%	99.3%	98.3%
January	98.7%	98.7%	91.6%
February	98.0%	99.2%	46.0%
March	97.9%	98.8%	70.7%
April	98.6%	99.4%	97.7%
May	98.5%	99.2%	98.9%
June	98.9%	99.5%	97.1%
July	98.6%	99.6%	98.6%
August	98.5%	99.4%	97.5%
September	98.8%	99.6%	95.8%
Average	98.5%	99.2%	90.6%

Table 2.3.1.F: Probability Analysis

	Influent				**Effluent**			
%	**TSS**	**BOD**	**TP**	**NH3**	**TSS**	**BOD**	**TP**	**NH3**
Occurrence(1)	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
10%	117	116	3.5	17	0.7	1.5	3.2	0.10
50%	200	152	5.4	24	1.4	2.2	5.8	0.53
90%	266	191	9.9	27	2.3	3.1	9.6	4.7

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter

APPENDIX 2.3.2

WHITEWATER RIVER PCF

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Appendix 2.3.2

Whitewater River PCF

Summary of Plant Data

Table 2.3.2.A: Plant Design Parameters

Parameter	Value	Units
Flow		
Design Capacity	0.80	MGD
Annual Average	0.66	MGD
Industrial input	0.12	MGD
BOD		
Design BOD	3,089	lb/day
Annual Average BOD	2,422	lb/day
TSS		
Design TSS	2,298	lb/day
Annual Average TSS	1,833	lb/day
2. Treatment Unit Sizes		
Oxidation Ditch	2	
Volume/Unit	598,400	gallons
Area	12,600	sq. ft.
Depth	6.25	feet
Detention time(1)	36	hours
Clarifier	2	
Volume/Unit	193,800	gallons
Area	2,124	sq. ft.
Depth	12	feet
Tertiary Filter	3	
Diameter	12	ft
Height	13	ft
Surface Area	113	sq. ft.
Hydraulic Loading Rate	3.5	gpm/sq. ft.
Anthracite Depth	18	in
Sand Depth	18	in
Chlorine Contact Tank	1	
Volume	27,700	gallons
Area	758	sq. ft.
Depth	11	feet
3. Sludge Handling		
Thickening	None	
Digestion	None	
Storage		
Lagoon	1	
Volume	693,400	gallons
Sludge Disposal		
Land Application		

(1) - based on design flow

Table 2.3.2.B: NPDES Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
$CBOD_5$	5	mg/L	Monthly Avg	Jan - Dec	1/week	24 hr comp
Total Suspended Solids	30	mg/L	Monthly Avg	Jan - Dec	1/week	24 hr comp
Fecal Coliform Organisms	200	#/100 mL	Monthly Geo Mean	April - Oct	1/week	Grab
Total Residual Chlorine	0.038	mg/L	Monthly Avg	Jan - Dec	1/day	Grab
Total Phosphorus	Monitor	mg/L	Monthly Avg	Jan - Dec	1/week	24 hr comp
pH	6.0-9.0	su	Monthly Min/Max	Jan - Dec	1/day	Grab
Ammonia-N	Monitor	mg/L	Monthly Max	June - Sept	1/month	24 hr comp

Table 2.3.2.C: Wastewater Characterization

Influent

Month 2002 - 2003	Flow MGD	CBOD5 mg/L	CBOD5 lb/d	TSS mg/L	TSS lb/d	TP mg/L	BOD:P
September	0.60	424	2,131	240	1,206	12	35
October	0.54	418	1,876	175	786	11	39
November	0.58	378	1,821	200	963	12	32
December	0.58	384	1,850	226	1,091	11	34
January	0.47	790	3,118	557	2,199	12	68
February	0.42	665	2,328	398	1,391	11	58
March	0.60	548	2,756	960	4,828	14	40
April	0.71	608	3,619	345	2,053	9.5	64
May	1.02	312	2,658	288	2,453	6.4	49
June	0.86	318	2,286	254	1,826	8.4	38
July	0.81	339	2,290	267	1,803	8.1	42
August	0.75	372	2,335	223	1,400	10	37
Average	0.66	463	2,422	344	1,833	10	45

Effluent

Month 2002 - 2003	Flow MGD	CBOD5 mg/L	CBOD5 lb/d	TSS mg/L	TSS lb/d	NH4-N Total mg/L	TP mg/L
September	0.60	3.0	15	7.0	35	0.24	7.5
October	0.54	2.8	13	2.3	10	0.82	6.3
November	0.58	3.0	14	1.4	7	0.23	6.6
December	0.58	2.6	13	1.9	9	0.27	7.2
January	0.47	3.0	12	5.8	23	0.25	8.4
February	0.42	3.3	11	2.5	9	0.23	8.4
March	0.60	3.6	18	17	83	0.24	8.8
April	0.71	2.7	16	2.3	14	0.25	6.8
May	1.02	2.3	19	3.8	32	0.21	3.4
June	0.86	1.7	12	3.0	21	0.24	5.7
July	0.81	2.2	15	4.7	32	0.22	6.1
August	0.75	2.4	15	9.1	57	0.29	8.9
Average	0.66	2.7	14	5.0	28	0.29	7.0

Table 2.3.2.D: Plant Performance - Percent Removal

Month 2002 - 2003	CBOD5	TSS	TP
September	99.3%	97.1%	37.6%
October	99.3%	98.7%	41.2%
November	99.2%	99.3%	44.4%
December	99.3%	99.2%	36.3%
January	99.6%	99.0%	28.1%
February	99.5%	99.4%	27.2%
March	99.4%	98.3%	36.4%
April	99.6%	99.3%	28.0%
May	99.3%	98.7%	47.2%
June	99.5%	98.8%	31.9%
July	99.3%	98.2%	23.7%
August	99.3%	95.9%	12.2%
Average	99.4%	98.5%	32.9%

Table 2.3.2.E: Probability Analysis

	Influent			Effluent			
% Occurrence(1)	TSS mg/L	BOD mg/L	TP mg/L	TSS mg/L	BOD mg/L	NH_3 (T) mg/L	TP mg/L
10%	188	259	7.0	1.8	2.2	0.21	4.5
50%	244	381	9.5	2.7	2.8	0.24	6.7
90%	413	614	12.4	8.2	3.3	0.31	8.5

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter

APPENDIX 2.4.1

MOORHEAD WWTF

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Appendix 2.4.1

Moorhead WWTF

Summary of Plant Data

Table 2.4.1A: Plant Design Parameters

Parameter	Value	Units
1. Plant Loadings		
Flow		
Design Flow	6.0	MGD
Annual Average Flow	3.9	MGD
% Industrial	25%	
BOD		
Design	13,357	lb/day
Annual Average	8,575	lb/day
% Industrial	55%	
TSS		
Design	9,372	lb/day
Annual Average	6,042	lb/day
% Industrial	11%	
2. Treatment Unit Sizes		
Primary Clarifier	2	
Volume	290,000	gallons
Depth	12	feet
Area	3,240	sq. feet
Overflow Rate$^{(1)}$	925	gpd/ft^2
Detention time$^{(1)}$	2.3	hours
Aeration Tanks		
High Purity Oxygen	2	
Volume	510,000	gallons
Depth	12	feet
Area	5,700	sq. feet
Detention time$^{(1)}$	4.1	hours
Final Clarifier	4	
Volume	250,000	gallons
Depth	12	feet
Diameter	60	feet
Area	2,827	sq. feet
Overflow Rate$^{(1)}$	530	gpd/ft^2
Detention time$^{(1)}$	4.0	hours
Chlorine Disinfection Tank	1	
Volume	36,500	gallons
Depth	17	feet
Area	288	sq. feet
Detention time$^{(1)}$	0.15	hours
Polishing Ponds/Nitrification Basin	3	
Total Area	9.6	acres
Total detention time$^{(1)}$	4.3	days
3. Sludge Handling		
Thickening		
Air Flotation Thickeners	2	
Capacity	63,500	gallons
Digestion		
Anaerobic Digesters	3	
Diameter	60	ft
Capacity (maximum)	550,000	gallons
Storage BioSolids Tank		
Sludge Dewatering (thickening only)	None	
Sludge Disposal	Land Application	

(1) Based on design flow

Table 2.4.1.B: NPDES Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Ammonia	19(1)	mg/L	Monthly Avg	June - Sept	3/week	24 hr comp
$CBOD_5$	12	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
$CBOD_5$	18	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp
$CBOD_5$	85	% Removal	Monthly Avg	Jan - Dec	3/week	24 hr comp
Total Residual Chlorine	0.038	mg/L	Daily Max	April - Oct	1/day	Grab
Fecal Coliform	200	#/100 mL	Monthly Geo Mean	April - Oct	3/week	Grab
Dissolved Oxygen	Monitor	mg/L	Monthly Min	Jan - Dec	5/week	Grab
pH	6.0-9.0	SU	Monthly Min/Max	Jan - Dec	5/week	Grab
Total Phosphorus	Monitor	mg/L	Monthly Avg	Jan - Dec	1/week	24 hr comp
Total Suspended Solids	30	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
Total Suspended Solids	45	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp
Total Suspended Solids	80	% Removal	Monthly Avg	Jan - Dec	3/week	24 hr comp

(1)Ammonia discharge load is 647 kg/day @ 19 mg/L (River flow > 50 cfs)

(1)Ammonia discharge load is 108 kg/day @ 19 mg/L (River flow > 50 cfs)

Table 2.4.1.C: Biological Secondary Treatment Process Design Information

Month	RAS		SRT		F/M		MLSS		MLVSS	
	North	South	North	South	North	South	North	South	North	South
2002	MGD		days		lb/lb		mg/L		mg/L	
January	0.27	2.02	46.1	1.3	0.32	0.68	3,296	2,476	2,880	2,183
February	0.99	1.02	4.4	7.3	0.38	0.43	2,405	2,073	2,117	1,873
March	1.01	1.01	2.5	4.1	0.42	0.34	2,422	2,766	2,211	2,421
April	1.01	1.01	1.8	4.3	0.42	0.38	2,279	2,537	1,968	2,172
May	1.01	1.01	1.8	4.6	0.39	0.34	2,384	2,786	2,008	2,356
June	1.01	1.01	2.1	3.9	0.38	0.40	2,149	2,240	1,732	1,822
July	1.01	1.01	2.2	3.1	0.42	0.38	1,938	2,076	1,626	1,747
August	1.01	1.03	3.3	3.3	0.45	0.45	1,841	1,863	1,644	1,642
September	1.11	1.13	4.2	3.7	0.36	0.41	2,358	2,152	2,120	1,938
October	1.15	1.01	3.3	2.8	0.39	0.50	2,188	1,800	1,894	1,592
November	1.15	1.07	2.7	3.0	0.38	0.53	1,964	1,949	1,823	1,771
December	1.22	1.22	-	1.3	-	0.70	-	2,498	-	2,135
Average	1.00	1.13	6.77	3.56	0.39	0.46	2,293	2,268	2,002	1,971
Plant Average	1.06		5.17		0.43		2,281		1,986	

Table 2.4.1.D: Digester Process Characteristics

	Volatile Acids		Alkalinity		To Biosolids Storage	
Month	**Digester 1**	**Digester 2**	**Digester 1**	**Digester 2**	**Tot Solids**	**Tot Vol. Solids**
2002	**mg/L**		**mg/L**		**%**	**%**
January	252	548	4,035	5,995	1.60	61.4
February	93	248	4,470	6,625	1.96	59.2
March	128	526	4,245	5,987	1.80	59.9
April	114	422	4,452	6,456	1.71	63.4
May	210	690	4,705	6,925	1.86	64.6
June	359	990	4,454	7,563	2.00	63.4
July	545	683	4,310	6,800	2.20	59.0
August	546	564	3,938	7,275	2.02	58.1
September	246	425	3,630	7,160	1.97	56.6
October	100	806	3,283	5,800	-	-
November	213	446	2,650	6,063	2.28	64.8
December	140	229	3,040	6,890	1.48	59.7
Average	275	584	3,829	6,770	1.94	61.2
Plant Average	429		5,300			

Table 2.4.1.E: Wastewater Characterization

Influent

Month 2002	Flow MGD	CBOD5 mg/L	CBOD5 lb/d	TSS mg/L	TSS lb/d	Ammonia mg/L	Total Phos mg/L	BOD/P (mg/L)/(mg/L)
January	3.6	261	7,784	188	5,616	24	7.0	37.2
February	3.6	287	8,587	178	5,326	22	6.3	45.3
March	3.5	276	8,168	183	5,411	23	6.5	42.5
April	3.7	284	8,764	201	6,192	22	7.0	40.8
May	4.0	254	8,578	182	6,138	16	5.7	44.3
June	4.7	226	8,940	169	6,682	14	4.9	45.8
July	4.5	219	8,197	175	6,527	15	5.2	41.9
August	3.8	258	8,212	162	5,156	18	5.8	44.4
September	3.7	273	8,473	206	6,390	23	6.5	41.7
October	3.6	310	9,288	192	5,744	22	6.8	45.8
November	3.7	276	8,617	202	6,300	24	7.0	39.3
December	4.0	280	9,290	211	7,025	23	7.2	38.7
Average	3.9	267	8,575	187	6,042	20	6.3	42.3

Effluent

Month 2002	Flow MGD	CBOD5 mg/L	CBOD5 lb/d	TSS mg/L	TSS lb/d	Ammonia[(1)] mg/L	Total Phos mg/L
January	3.6	11.0	328	7.2	216	30	4.9
February	3.6	9.4	280	4.8	144	20	4.6
March	3.5	6.3	187	3.3	98	22	4.2
April	3.7	8.7	270	4.1	125	18	3.7
May	4.0	8.5	287	7.1	239	21	3.3
June	4.7	8.2	324	7.5	295	17	2.9
July	4.5	7.9	294	11.9	445	16	3.3
August	3.8	9.0	288	13.6	434	15	3.8
September	3.7	7.5	234	6.6	206	18	4.3
October	3.6	7.4	222	7.1	212	20	4.0
November	3.7	9.8	305	7.1	223	18	4.2
December	4.0	10.6	351	4.2	140	19	3.7
Average	3.9	8.7	281	7.0	231	19	3.9

(1) Note: The ammonia data are for 2002. Nitrification process went on line in 2003.

Table 2.4.1.F: Plant Performance - Percent Removal

Month	CBOD5	TSS	Ammonia[1]	Total Phos
2002				
January	95.8%	96.2%		29.6%
February	96.7%	97.3%	8.5%	27.0%
March	97.7%	98.2%	6.6%	35.5%
April	96.9%	98.0%	18.7%	46.8%
May	96.7%	96.1%		42.8%
June	96.4%	95.6%		41.5%
July	96.4%	93.2%		36.0%
August	96.5%	91.6%	15.2%	34.9%
September	97.2%	96.8%	22.0%	34.8%
October	97.6%	96.3%	9.2%	40.8%
November	96.5%	96.5%	25.1%	40.8%
December	96.2%	98.0%	16.7%	48.6%
Average	96.7%	96.1%	15.3%	38.3%

(1)Nitrification process went on line in 2003.

Table 2.4.1.G: Probability Analysis

	Influent				Effluent			
% Occurrence[1]	TSS mg/L	BOD mg/L	TP mg/L	NH_3 mg/L	TSS mg/L	BOD mg/L	TP mg/L	NH_3[2] mg/L
10%	142	216	5.2	14.5	3.6	6.2	2.9	12.5
50%	186	270	6.4	21.6	6.2	8.4	4.0	18.0
90%	231	313	7.4	25.0	12.0	11.7	4.6	27.3

(1)Percent of samples with concentrations less than the concentration specified

Based on the development of percent occurrence/probability plots for each parameter

(2)Note: The ammonia data are for 2002. Nitrification process went on line in 2003.

APPENDIX 2.4.2

ROCHESTER WRP

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Appendix 2.4.2

Rochester WRP

Summary of Plant Data

Table 2.4.2.A: Plant Design Parameters

Parameter	Value	Units
1. Plant Loadings		
Flow		
Design Flow (Max Monthly)	19.1	MGD
Ann Avg Flow (1993 - 2002)	12.5	MGD
Ann Avg Flow (2003)	13.2	MGD
BOD		
Design	59,961	lb/day
Annual Average	31,749	lb/day
% Industrial	30 - 40%	
TSS		
Design	33,717	lb/day
Annual Average	20,563	lb/day
2. Treatment Unit Sizes		
Equalization Basin 1	1	
Volume	1,781,006	gallons
Depth	13.5	feet
Area	17,637	sq. feet
Detention time(1)	3.2	hours
Equalization Basin 2	1	
Volume	3,805,824	gallons
Depth	12	feet
Area	42,400	sq. feet
Detention time(1)	6.9	hours
Grit Basins	2	
Volume	35,904	gallons
Depth	16	feet
Diameter		feet
Area	300	sq. feet
Preaeration Basins	2	
Volume	140,250	gallons
Depth	15	feet
Diameter		feet
Area	1,250	sq. feet
Primary Clarifier	2	
Volume	782,441	gallons
Depth	10	feet
Diameter		feet
Area	10,460	sq. feet
Overflow Rate(1)	1,826	gpd/ft^2
Detention time(1)	2.9	hours
1st Stage Aeration	2	
Volume	- 593,762	gallons
Depth	15	feet
Area	5,292	sq. feet
Detention time(1)	2.2	hours
Intermediate Clarifiers	2	
Volume	490,728	gallons
Depth	10	feet
Diameter	90	feet
Area	6,362	sq. feet
Overflow Rate(1)	3,002	gpd/ft^2
Detention time(1)	1.8	hours
Intermediate Clarifiers	2	
Volume	681,071	gallons
Depth	14	feet
Diameter	90	feet
Area	6,362	sq. feet
Overflow Rate(1)	3,002	gpd/ft^2
Detention time(1)	2.5	hours
2nd State Aeration	3	
Volume	927,754	gallons
Depth	15	feet
Area	8,269	sq. feet
Detention time(1)	5.1	hours
Intermediate Clarifiers	4	
Volume	1,201,979	gallons
Depth	14	feet
Diameter	120	feet
Area	11,310	sq. feet
Overflow Rate(1)	1,689	gpd/ft^2
Detention time(1)	8.8	hours
Cl_2 Contact Tank	3	
Volume	261,800	gallons
Depth	7	feet
Area	5,000	sq. feet
Detention time(1)	1.4	hours
3. Sludge Handling		
Sludge Thickening		
Belt Thickeners		
Digestion		
Anerobic Digestion	6	units
Total Capacity	5.80	MG
Storage	None	
Sludge Dewatering		
Gravity Belt Thickener		
Sludge Disposal	Land Application	

(1) - based on design flow

Table 2.4.2.B: Effluent Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Ammonia (NH_4-N)	1.6	mg/L	Monthly Avg	Jan - Dec	1/week	24 hr comp
$CBOD_5$	14	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
Fecal Coliform	200	MPN/100mL	Monthly Geo Mean	Jan - Dec	3/week	Grab
pH	6.5-8.5	SU	Monthly Min/Max	Jan - Dec	1/day	Grab
Total Phosphorus	1	mg/L	Monthly Avg	Jan - Dec	1/week	24 hr comp
Total Suspended Solids	20	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
Turbidity	25	NTU	Monthly Avg	Jan - Dec	1/day	Grab
Dissolved Oxygen	5	mg/L	Monthly Min	Jan - Dec	1/day	Grab

Table 2.4.2.C - Biological Secondary Treatment Process Design Information

	RAS		RAS		SRT	
Month	**1st Stage**	**2nd Stage**	**1st Stage**	**2nd Stage**	**1st Stage**	**2nd Stage**
2003	**MGD**		**MGD**		**days**	
January	3.4	5.2	0.29	0.012	1.0	48.5
February	4.0	5.2	0.35	0.022	0.9	52.7
March	4.2	5.4	0.40	0.022	0.9	47.8
April	4.4	5.4	0.35	0.022	1.2	47.5
May	5.3	5.3	0.35	0.019	1.1	49.9
June	4.8	6.0	0.34	0.027	0.8	35.7
July	5.3	6.4	0.27	0.058	1.4	20.0
August	5.7	6.1	0.31	0.035	1.2	32.6
September	4.5	6.2	0.29	0.028	1.2	40.8
October	4.5	6.2	0.29	0.028	1.2	41.1
November	4.5	6.3	0.37	0.027	1.0	43.8
December	4.5	6.2	0.34	0.028	1.8	44.3
Average	4.6	5.8	0.33	0.027	1.1	42.1

	MLSS		MLVSS		MLVSS	
Month	**1st Stage**	**2nd Stage**	**1st Stage**	**2nd Stage**	**1st Stage**	**2nd Stage**
2003	**mg/L**		**%**		**mg/L**	
January	2,499	3,995	88.2%	65.4%	2,204	2,613
February	2,380	4,203	88.6%	65.2%	2,109	2,740
March	2,250	4,222	89.2%	66.7%	2,007	2,816
April	2,010	4,438	91.8%	66.5%	1,845	2,951
May	2,208	4,634	90.8%	65.4%	2,005	3,031
June	1,921	4,674	92.8%	66.6%	1,783	3,113
July	1,794	4,803	94.1%	66.2%	1,688	3,180
August	1,903	3,606	94.3%	63.2%	1,795	2,279
September	1,941	3,883	94.1%	59.3%	1,826	2,303
October	2,297	4,054	94.4%	56.7%	2,168	2,299
November	2,224	4,286	94.1%	57.4%	2,093	2,460
December	1,887	4,304	92.0%	60.0%	1,736	2,582
Average	2,110	4,259	92.0%	63.2%	1,938	2,697

Table 2.4.2.D: Wastewater Characterization

Influent

Month 2003	Flow MGD	COD mg/L	sol COD mg/L	CBOD$_5$ mg/L	CBOD$_5$ lb/d	TSS mg/L	TSS lb/d	VSS mg/L	TKN mg/L	Ammonia* mg/L	Total Phos mg/L	Soluble P mg/L	BOD/P mg/L)/(mg/L	Alkalinity mg/L
January	12.5			386	40,241	193	20,120		Yearly Average = 31.4 mg/L (1993 - 2002)	20.9	9.1		42.4	
February	12.7			418	44,378	211	22,401			19.5	10.1		41.5	
March	12.5			374	39,021	205	21,388			20.8	10.3		36.2	
April	12.8			366	39,041	189	20,160			19.7	9.6		38.1	
May	14.4			307	36,921	177	21,287			18.3	8.2		37.3	
June	13.8			345	39,563	205	23,508			16.1	8.9		38.8	
July	14.3	503	190	320	38,030	204	24,244	167		15.9	8.5		37.8	
August	13.5	597	213	320	36,109	199	22,455	176		15.3	9.3	5.3	34.5	340
September	12.7			368	39,009	197	20,882			17.7	9.5		38.8	
October	13.2			470	51,781	260	28,645			18.5	9.9		47.6	
November	13.1			461	50,328	287	31,332			20.0	9.8		47.1	
December	12.4			382	39,569	213	22,063			23.2	9.3		40.9	
Average	13.2	550	202	376	41,166	212	23,207	171		18.8	9.4	5.3	40.1	340

Effluent

Month 2003	Flow MGD	CBOD$_5$ mg/L	CBOD$_5$ lb/d	TSS mg/L	TSS lb/d	TKN mg/L	Ammonia* mg/L	NO$_3$-N mg/L	Total Phos mg/L	Soluble P mg/L	Alkalinity mg/L
January	12.5	3.0	313	5.0	521	Yearly Average = 1.4 mg/L (1993 - 2002)	0.38	Yearly Average = 23 mg/L (1996 - 2002)	0.81		
February	12.7	4.0	425	7.0	743		0.07		0.85		
March	12.5	4.0	417	7.0	730		0.16		0.82		
April	12.8	3.0	320	6.0	640		0.07		0.87		
May	14.4	3.0	361	7.0	842		0.04		0.78		
June	13.8	3.0	344	5.0	573		0.05		0.78		
July	14.3	3.0	357	5.0	594		0.07		0.73		
August	13.5	3.0	339	7.0	790		0.06		0.79	0.71	180
September	12.7	3.0	318	5.0	530		0.04		0.69		
October	13.2	3.0	331	8.0	881		0.14		0.78		
November	13.1	3.0	328	6.0	655		0.05		0.65		
December	12.4	3.0	311	4.0	414		0.03		0.71		
Average	13.2	3.2	347	6.0	660		0.10		0.77	0.71	180

NOTE: Ammonia data from 2002

Table 2.4.2.E: Plant Performance - Percent Removal

Month **2003**	**CBOD5**	**TSS**	**Ammonia**	**Total Phos**
January	99.2%	97.4%	98.2%	91.2%
February	99.0%	96.7%	99.6%	91.5%
March	98.9%	96.6%	99.2%	92.1%
April	99.2%	96.8%	99.6%	90.9%
May	99.0%	96.0%	99.8%	90.6%
June	99.1%	97.6%	99.7%	91.2%
July	99.1%	97.5%	99.6%	91.4%
August	99.1%	96.5%	99.6%	91.4%
September	99.2%	97.5%	99.8%	92.8%
October	99.4%	96.9%	99.2%	92.1%
November	99.3%	97.9%	99.8%	93.3%
December	99.2%	98.1%	99.9%	92.4%
Average	99.1%	97.1%	99.5%	91.7%

NOTE: Ammonia data from 2002

Table 2.4.2.F: Probability Analysis

	Influent					Effluent					
% Occurrence(1)	TSS mg/L	BOD$_5$ mg/L	TP mg/L	TKN mg/L	NH$_3$ mg/L	TSS mg/L	BOD$_5$ mg/L	TP mg/L	TKN mg/L	NH$_3$ mg/L	NO$_3$ mg/L
10%	144	249	7.2	27	16	4.0	3.0	0.51	1.2	0.040	20.2
50%	195	340	8.9	32	19	5.0	3.0	0.72	1.4	0.065	23.0
90%	250	449	10.6	36	21	8.0	4.0	1.0	1.8	0.158	24.8

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter

NOTES:

TSS, BOD$_5$ and TP based on daily data from 2002 - 2003
TKN based on annual averages from 1993 - 2002
NH$_3$ based on monthly averages from 2002
NO$_3$ based on annual averages from 1996 - 2002

APPENDIX 2.5.1

DETROIT LAKES WWTF

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Appendix 2.5.1

Detroit Lakes WWTF

Summary of Plant Data

Table 2.5.1.A: Plant Design Parameters

Parameter	Value	Units
1. Plant Loadings		
Flow		
Design Flow	1.64	MGD
Annual Average Flow	1.06	MGD
BOD		
Design	2,611	lb/day
Annual Average	1,684	lb/day
TSS		
Design	2,299	lb/day
Annual Average	1,492	lb/day
2. Treatment Unit Sizes		
Primary Clarifier	2	
Volume	94,000	gallons
Depth	10	feet
Diameter	40	feet
Area	1,257	sq. feet
Overflow Rate(1)	1,305	gpd/ft^2
Detention time(1)	2.8	hours
Rock Filter	1	
Diameter	91	feet
Area	6,504	sq. feet
Clay Tile Filter	1	
Diameter	50	feet
Area	1,963	sq. feet
Final Clarifier	1	
Volume	145,000	gallons
Depth	8	feet
Area	2,400	sq. feet
Overflow Rate(1)	683	gpd/ft^2
Detention time(1)	2.1	hours
Aeration Pond	1	
Volume	7,800,000	gallons
Depth	8	feet
Area	130,680	sq. feet
Stabilization Pond	1	
Volume	40,700,000	gallons
Depth	5	feet
Area	1,089,000	sq. feet
Spray Irrigation	1	
Area	2,352,240	sq. feet
Rapid Infiltration Basin	1	
Volume		gallons
Area	914,760	sq. feet
3. Sludge Handling		
Sludge Thickening	Gravity	
Digestion	Anaerobic	
Primary Digestor	1	
Volume per tank	289,000	ft
Depth	24	gallons
Diameter	45	
Area	1,590	
Secondary Digestor	1	
Volume per tank	360,000	ft
Depth	25	gallons
Diameter	50	
Area	1,963	
Storage	Tank	
Volume	160,000	gallons
Dewatering	None	
Sludge Disposal	Land Application	

(1) - based on design flow

Table 2.5.1.B: NDPES Permit Limits

Spray Irrigation

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Area of Disposal, Used	31.13	Acres	Instantaneous Max	May - Oct	1/month	Estimate
Organic Matter, Total in Soil	Monitor	%	Single Value	Sep - Aug	1/Year	Composite
pH, 1 to 1 Soil to Water	Monitor	SU	Single Value	Sep - Aug	1/Year	Composite
Phosphorus (In Soil)	Monitor	lb/acr	Single Value	Sep - Aug	1/Year	Composite
Potassium (In Soil)	Monitor	lb/acr	Single Value	Sep - Aug	1/Year	Composite
Specific Conductance	Monitor	mmh/cm	Instantaneous Max	Sep - Aug	1/Year	Composite

Chemical Precipitation Discharge

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Ammonia	Monitor	mg/L	Single Value	Jan - Dec	3/week	Grab
$CBOD_5$	20	mg/L	Monthly Avg	Jan - Dec	3/week	Grab
$CBOD_5$	30	mg/L	Weekly Avg	Jan - Dec	3/week	Grab
$CBOD_5$	85	% Removal	Monthly Avg	Jan - Dec	3/week	Calculation
Total Residual Chlorine	Monitor	mg/L	Daily Maximum	April - Oct	1/day	Grab
Fecal Coliform	200	#/100 mL	Monthly Geo Mean	April - Oct	3/week	Grab
Total Mercury	Monitor	ng/L	Single Value	Mar, Jun, Sep, Dec	1/month	Grab
Dissolved Oxygen	Monitor	mg/L	Monthly Min	Jan - Dec	1/day	Grab
pH	6.0-9.0	SU	Monthly Min/Max	Jan - Dec	1/day	Grab
Total Phosphorus	1	mg/L	Monthly Avg	Jan - Dec	1/week	Grab
Total Suspended Solids	20	mg/L	Monthly Avg	Jan - Dec	3/week	Grab
Total Suspended Solids	30	mg/L	Weekly Avg	Jan - Dec	3/week	Grab
Total Suspended Solids	85	% Removal	Monthly Avg	Jan - Dec	3/week	Calculation

Rapid Infiltration Discharge

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Ammonia	N/A	N/A	N/A	N/A	N/A	N/A
$CBOD_5$	20	mg/L	Monthly Avg	April - Dec	3/week	Grab
$CBOD_5$	30	mg/L	Weekly Avg	April - Dec	3/week	Grab
Total Residual Chlorine	Monitor	mg/L	Daily Maximum	April - Dec	1/day	Grab
Fecal Coliform	200	#/100 mL	Monthly Geo Mean	April - Dec	3/week	Grab
Total Mercury	Monitor	ng/L	Single Value	Mar, Jun, Sep, Dec	1/month	Grab
Dissolved Oxygen	Monitor	mg/L	Monthly Min	April - Dec	1/day	Grab
pH	6.0-9.0	SU	Monthly Min/Max	April - Dec	1/day	Grab
Total Phosphorus	1	mg/L	Monthly Avg	April - Dec	1/week	Grab
Total Suspended Solids	20	mg/L	Monthly Avg	April - Dec	3/week	Grab
Total Suspended Solids	30	mg/L	Weekly Avg	April - Dec	3/week	Grab

Table 2.5.1.C: Wastewater Characterization

Influent Data (Willow St. Plant)

Month	Flow	CBOD_5	CBOD_5	TSS	TSS	Total Phos	BOD/P
2002-2003	MGD	mg/L	lb/d	mg/L	lb/d	mg/L	(mg/L)/(mg/L)
October	1.00	154	1,284	118	986	5.1	30
November	0.97	199	1,614	148	1,199	5.2	38
December	0.95	195	1,547	174	1,382	6.8	29
January	0.96	240	1,924	185	1,487	6.7	36
February	0.97	213	1,729	169	1,369	7.1	30
March	1.01	204	1,718	206	1,730	6.2	33
April	1.03	195	1,678	186	1,598	4.7	42
May	1.11	172	1,597	144	1,338	5.7	30
June	1.20	169	1,689	151	1,514	4.3	39
July	1.31	174	1,901	170	1,859	3.5	50
August	1.20	187	1,871	185	1,856	5.8	32
September	1.05	189	1,658	181	1,588	5.3	36
Average	1.06	191	1,684	168	1,492	5.5	35

Effluent Data (Willow St. Plant)

Month	Flow	CBOD_5	CBOD_5	TSS	TSS	Total Phos
2002-2003	MGD	mg/L	lb/d	mg/L	lb/d	mg/L
October	1.00	16.9	141	12.9	108	4.5
November	0.97	17.6	142	17.8	144	4.5
December	0.95	39.4	313	25.8	205	4.9
January	0.96	35.7	287	21.8	175	4.6
February	0.97	39.7	322	28.3	230	4.3
March	1.01	35.8	301	29.2	246	4.2
April	1.03	29.0	250	20.5	177	4.0
May	1.11	22.9	213	17.8	166	4.9
June	1.20	19.4	194	45.4	454	4.0
July	1.31	11.3	124	18.0	197	2.9
August	1.20	11.4	114	18.3	184	4.4
September	1.05	10.4	91	14.5	127	4.2
Average	1.06	24.1	208	22.5	201	4.3

Influent Data (Chemical Precipitation)

Month	Flow	CBOD_5	CBOD_5	TSS	TSS
2002-2003	MGD	mg/L	lb/d	mg/L	lb/d
January	1.07	14	115	16	128
February	0.96	19	147	18	140
March	0.87	27	218	28	221
January	0.88	28	223	24	192
February	1.03	43	362	29	243
March	0.98	42	361	51	441
April	0.78	24	221	35	327
Average	0.94	28	235	29	242

Table 2.5.1.C: Wastewater Characterization

Effluent Data (Chemical Precipitation)

Month	Flow	$CBOD_5$	$CBOD_5$	TSS	TSS	Total Phos
2002-2003	MGD	mg/L	lb/d	mg/L	lb/d	mg/L
January	1.07	7.5	61	8.3	67	0.47
February	0.96	12	99	6.8	54	0.31
March	0.87	20	157	15.4	124	0.38
January	0.88	9.7	78	7.3	59	0.30
February	1.03	14	121	8.4	70	0.35
March	0.98	13	110	6.5	56	0.30
April	0.78	11	104	9.9	92	0.46
Average	0.94	12.5	104	8.9	75	0.37

Effluent Data (Spray Irrigation)

Month	Flow	$CBOD_5$	$CBOD_5$	TSS	TSS	Total Phos
2002-2003	MGD	mg/L	lb/d	mg/L	lb/d	mg/L
June	1.08	14.1	114	34.0	275	2.95
July	0.97	8.0	64	29.5	235	2.48
August	0.86	6.3	50	30.8	247	3.44
September	0.76	6.3	51	25.9	210	3.21
October	0.76	5.5	47	18.6	156	2.66
May	0.99					
June	0.88					
July	0.89					
August	0.95					
September	0.95					
Average	0.91	8.1	65	27.8	225	2.95

Effluent Data (Infiltration)

Month	Flow
2002-2003	MGD
May	0.98
June	1.03
July	1.02
August	
September	0.91
Average	0.99

Table 2.5.1.D: Performance; Percent Removal

(Willow Street Plant)

Month	$CBOD_5$	TSS	Total Phos
2002-2003			
October	89.0%	89.1%	11.4%
November	91.2%	88.0%	14.7%
December	79.8%	85.2%	27.2%
January	85.1%	88.3%	30.7%
February	81.4%	83.2%	39.4%
March	82.5%	85.8%	31.9%
April	85.1%	88.9%	13.7%
May	86.7%	87.6%	13.3%
June	88.5%	70.0%	7.5%
July	93.5%	89.4%	15.6%
August	93.9%	90.1%	23.9%
September	94.5%	92.0%	21.2%
Average	87.6%	86.5%	20.9%

(Chemical Precipitation)

Month	$CBOD_5$	TSS
2002-2003		
January	47.3%	47.8%
February	32.6%	61.3%
March	28.1%	44.0%
January	64.9%	69.1%
February	66.4%	71.1%
March	69.6%	87.4%
April	53.0%	71.7%
Average	51.7%	64.6%

Table 2.5.1.E: Probability Analysis

	Influent			Effluent		
% Occurrence(1)	TSS	BOD	TP	TSS	BOD	TP
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
10%	104	141	4.1	8.5	8.0	2.9
50%	164	182	5.5	17	18	4.2
90%	229	227	7.7	34	36	5.2

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter

APPENDIX 2.6.1

FARIBAULT WWTF

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Appendix 2.6.1

Faribault WWTF

Summary of Plant Data

Table 2.6.1.A - Plant Design Parameters

Parameter	Value	Units
1. Plant Loadings		
Flow		
Design Flow	7.0	MGD
Annual Average Flow	4.1	MGD
% Industrial	25%	
BOD		
Design	10,000	lb/day
Annual Average	11,673	lb/day
% Industrial	83%	
TSS		
Design	7,200	lb/day
Annual Average	8,112	lb/day
% Industrial	72%	
2. Treatment Unit Sizes		
Preaeration	1	
Volume	38,640	gallons
Depth	9	feet
Area	574	sq. feet
Detention time(1)	0.13	hours
Primary Clarifier	4	
Volume	106,370	gallons
Depth	7	feet
Diameter	49	feet
Area	1,923	sq. feet
Overflow Rate(1)	380	gpd/ft^2
Detention time(1)	1.46	hours
Tricking Filter		
Volume	359,064	gallons
Depth	16	feet
Area	3,017	sq. feet
Overflow Rate(1)	40	gpm/sq ft
Detention time(1)	1.23	hours
Aeration Tank	2	
Volume	435,180	gallons
Depth	15	feet
Area	4,012	sq. feet
Detention time(1)	3.0	hours
Final Clarifier	4	
Volume	333,750	gallons
Depth	12	feet
Diameter	70	feet
Area	3,846	sq. feet
Overflow Rate(1)	455	gpd/ft^2
Detention time(1)	2.29	hours
Cl$_2$ Contact Tank		
Volume	51,160	gallons
Depth	8	feet
Area	855	sq. feet
Detention time(1)	0.18	hours
3. Sludge Handling		
Sludge Thickening	Gravity	
Digestion		
Primary Digestors	2	
Volume	319,320	gallons
Secondary Digestor	1	
Volume	537,510	gallons
Sludge Storage	Lagoons	
Sludge Dewatering	None	
Sludge Disposal	Land Application	

(1) - based on design flow

Table 2.6.1.B: NPDES Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Ammonia	Monitor	mg/L	Monthly Avg	Jan - Dec	1/month	24 hr comp
$CBOD_5$	25	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
$CBOD_5$	40	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp
Fecal Coliform	200	#/100 mL	Monthly Geo Mean	Jan - Dec	3/week	Grab
Fecal Coliform	400	#/100 mL	Weekly Geo Mean	Jan - Dec	3/week	Grab
Dissolved Oxygen	4.0	mg/L	Monthly Min	Jan - Dec	1/day	Grab
pH	6.5-8.5	SU	Monthly Min/Max	Jan - Dec	1/day	Grab
Total Phosphorus	Monitor	mg/L	Monthly Avg	Jan - Dec	1/week	24 hr comp
Total Suspended Solids	30	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
Total Suspended Solids	45	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp

Table 2.6.1.C: Wastewater Characterization

Influent

Month 2002-2003	Flow MGD	$CBOD_5$ mg/L	$CBOD_5$ lb/d	TSS mg/L	TSS lb/d	Ammonia mg/L	Total Phos mg/L	BOD/P (mg/L)/(mg/L)
September	4.0	350	11,572	265	8,765	11	7.3	48.2
October	4.3	307	10,931	216	7,678	13	6.2	49.3
November	3.9	323	10,565	246	8,032	15	8.5	37.8
December	3.8	258	8,176	246	7,794	16	7.9	32.7
January	4.0	319	10,541	255	8,434	14	7.8	41.1
February	3.8	382	12,204	280	8,941	12	7.0	54.8
March	3.8	394	12,442	253	7,986	16	7.3	54.1
April	3.9	375	12,325	236	7,757	17	8.4	44.5
May	4.5	333	12,470	199	7.450	13	7.2	46.6
June	4.3	349	12,399	218	7,751	16	8.0	43.6
July	4.2	414	14,680	262	9,294	13	8.1	51.5
Average	4.1	345	11,673	241	8,112	15	7.6	45.6

Effluent

Month 2002-2003	Flow MGD	$CBOD_5$ mg/L	$CBOD_5$ lb/d	TSS mg/L	TSS lb/d	Ammonia mg/L	Total Phos mg/L	BOD/P (mg/L)/(mg/L)
September	4.0	9.0	298	16.8	556	2.9	3.8	2.4
October	4.3	6.8	241	14.5	515	1.9	3.8	1.8
November	3.9	7.1	233	13.2	431	6.3	4.5	1.6
December	3.8	7.7	245	13.1	414	5.2	5.4	1.4
January	4.0	11.4	377	18.9	624	11.5	5.0	2.3
February	3.8	13.0	416	17.9	571	13.4	4.8	2.7
March	3.8	7.8	247	11.8	372	4.5	4.6	1.7
April	3.9	7.3	240	17.4	571	12.4	5.7	1.3
May	4.5	6.7	249	11.9	447	11.4	4.2	1.6
June	4.3	10.4	371	22.5	801	1.8	4.2	2.5
July	4.2	9.4	333	18.0	637	9.3	6.3	1.5
Average	4.0	8.8	296	16.0	540	7.3	4.7	1.9

Table 2.6.1.D: Performance; Percent Removal

Month	$CBOD_5$	TSS	Ammonia	Total Phos
2002-2003				
September	97.4%	93.7%	74.6%	48.1%
October	97.8%	93.3%	85.7%	38.8%
November	97.8%	94.6%	56.9%	47.8%
December	97.0%	94.7%	67.6%	31.1%
January	96.4%	92.6%	19.6%	36.2%
February	96.6%	93.6%	-8.5%	30.9%
March	98.0%	95.3%	72.0%	37.2%
April	98.0%	92.6%	27.1%	32.8%
May	98.0%	94.0%	13.0%	41.1%
June	97.0%	89.7%	88.9%	47.2%
July	97.7%	93.1%	29.5%	21.8%
Average	97.4%	93.4%	47.9%	37.6%

Table 2.6.1.E: Probability Analysis

	Influent				Effluent			
%	**TSS**	**BOD**	**TP**	**NH3**	**TSS**	**BOD**	**TP**	**NH3**
Occurrence[(1)]	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
10%	156	258	6.6	11	9	4.0	3.8	0.92
50%	216	346	7.8	14	14	4.3	4.5	4.1
90%	367	445	9.0	17	26	5.0	6.0	15

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter

APPENDIX 2.6.2

MARSHALL WWTF

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Appendix 2.6.2

Marshall WWTF

Summary of Plant Data

Table 2.6.2.A: Plant Design Parameters

Parameter	Value	Units
1. Plant Loadings		
Flow		
Design Capacity	4.3	MGD
Annual Average Flow	2.1	MGD
% Industrial	80%	
BOD	13,863	lb/day
Design	6,867	lb/day
Annual Average		
TSS		
Design	16,302	lb/day
Annual Average	8,173	lb/day
2. Treatment Unit Sizes		
Grit Tank	1	
Diameter	16	feet
Area	201	sq. feet
Primary Clarifier	2	
Volume	211,506	gallons
Depth	10	feet
Diameter	60	feet
Area	2,827	sq. feet
Overflow Rate(1)	1,521	gpd/ft^2
Detention time(1)	2.4	hours
Trickling Filter	2	
Volume	507,615	gallons
Depth	24	feet
Diameter	60	feet
Area	2,827	sq. feet
Detention time(1)	5.7	hours
Equalization Tank	1	
Generally receives any flow in excess of 4 MGD		
Aeration Tank	4	
Volume	269,298	gallons
Depth	15	feet
Area	2,400	sq. feet
Detention time(1)	6.0	hours
Final Clarifier	2	
Volume	345,460	gallons
Depth	12	feet
Diameter	70	feet
Area	3,848	sq. feet
Overflow Rate(1)	1,117	gpd/ft^2
Detention time(1)	3.9	hours
Effluent Traveling Bridge Filter 2		
Volume	15,160	gallons
Depth	1.7	feet
Area	1,216	sq. feet
UV Contact Tank	1	
Volume	3,890	gallons
Depth	4	feet
Area	130	sq. feet
Detention time(1)	6.4	seconds
Effluent Aeration	1	
Volume	67,325	gallons
Depth	15	feet
Area	600	sq. feet
3. Sludge Handling		
Sludge Thickening	None	
Digestion		
Anaerobic Digestors	2	
Sludge Storage	None	
Sludge Dewatering	None	
Sludge Disposal	Land Application	

(1) - based on design flow

Table 2.6.2.B: Effluent Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Ammonia, Total (as N)	1.1	mg/L	Monthly Avg	June - Sept	1/month	24 hr comp
Ammonia, Total (as N)	2.3	mg/L	Monthly Avg	Oct - Nov	1/month	24 hr comp
Ammonia, Total (as N)	9.4	mg/L	Monthly Avg	Dec - March	1/month	24 hr comp
Ammonia, Total (as N)	2.4	mg/L	Monthly Avg	April - May	1/month	24 hr comp
$CBOD_5$	5	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
$CBOD_5$	10	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp
$CBOD_5$	85	% Removal	Monthly Avg	Jan - Dec	3/week	Calculation
Fecal Coliform	200	Orgs/100 mL	Monthly Geo Mean	March - October	3/week	Grab
Dissolved Oxygen	7.5	mg/L	Monthly Min	Jan - Dec	1/day	Grab
pH	6.0-9.0	SU	Monthly Min/Max	Jan - Dec	1/day	Grab
Total Suspended Solids	30	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
Total Suspended Solids	45		Weekly Avg	Jan - Dec	3/week	24 hr comp
Total Suspended Solids	85	% Removal	Monthly Avg	Jan - Dec	3/week	Calculation

Table 2.6.2.C: Wastewater Characterization

Influent

Month	Flow	$CBOD_5$	$CBOD_5$	TSS	TSS	TP	NH_3	BOD:TP
2002-2003	MGD	mg/L	lb/d	mg/L	lb/d	mg/L	mg/L	
December	1.88	399	6,252	372	5,829	18.8	23.5	21
January	1.81	356	5,379	383	5,797	14.2	17.4	25
February	1.93	416	6,711	369	5,950	15.7	19.0	27
March	2.05	355	6,091	399	6,832	7.5	13.0	47
April	2.11	464	8,171	465	8,200	14.3	15.3	33
May	2.42	330	6,667	459	9,253	6.5	13.0	51
June	2.32	361	6,970	567	10,950	15.8	8.2	23
July	2.32	365	7,051	518	10,005	12.8	8.7	29
August	2.19	383	6,987	553	10,085	15.6	8.8	25
September	2.23	390	7,272	565	10,529	13.4	16.0	29
October	2.22	432	7,987	350	6,469	16.3	21.0	27
November	2.03	418	7,063	519	8,764	11.2	11.2	37
Average	2.13	387	6,867	455	8,173	13.7	14.9	28

Effluent

Month	Flow	$CBOD_5$	$CBOD_5$	TSS	TSS	TP	NH_3
2002-2003	MGD	mg/L	lb/d	mg/L	lb/d	mg/L	mg/L
December	1.85	2.2	34	3.5	54	5.1	2.90
January	1.83	2.4	37	3.6	55	3.4	0.18
February	1.92	2.2	35	2.7	43	4.6	0.28
March	2.05	2.0	34	3.5	59	6.7	1.50
April	2.12	2.6	45	4.0	71	5.4	0.14
May	2.31	2.6	50	7.9	153	6.2	0.12
June	2.14	2.2	39	7.5	133	6.6	0.05
July	2.12	3.1	55	5.6	98	7.4	0.12
August	2.10	2.6	46	6.5	114	7.5	0.10
September	2.09	2.4	42	4.8	84	7.3	0.10
October	2.00	2.9	48	2.6	43	4.1	0.80
November	2.03	2.1	36	5.5	93	6.6	0.10
Average	2.05	2.5	42	4.7	83	5.8	0.57

NOTE: Average %TVSS from January 2002 - September 2003 = 80%

NOTE: Average NH_3 from January 2002 - September 2003 = 17.15 mg/L

Table 2.6.2.D: Percent Removal

Month 2002-2003	$CBOD_5$	TSS	NH_3
December	99.4%	99.1%	87.7%
January	99.3%	99.1%	99.0%
February	99.5%	99.3%	98.5%
March	99.4%	99.1%	88.5%
April	99.4%	99.1%	99.1%
May	99.2%	98.3%	99.1%
June	99.4%	98.7%	99.4%
July	99.2%	98.9%	98.7%
August	99.3%	98.8%	98.9%
September	99.4%	99.1%	99.4%
October	99.3%	99.3%	96.2%
November	99.5%	98.9%	99.1%
Average	99.4%	99.0%	96.8%

Table 2.6.2.E: Probability Analysis

	Influent				Effluent			
% Occurrence(1)	TSS mg/L	BOD mg/L	NH_3 mg/L	TP mg/L	TSS mg/L	BOD mg/L	NH_3 mg/L	TP mg/L
10%	245	2.3	8.5	10	2.0	1.5	0.05	4.2
50%	410	367	15	14	3.9	2.4	0.14	6.5
90%	690	552	22	16	8.8	4.0	1.59	8.0

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter

APPENDIX 2.6.3

GLENCOE WWTF

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Appendix 2.6.3

Glencoe WWTF

Summary of Plant Data

Table 2.6.3.A: Plant Design Parameters

Parameter	Value	Units
1. Plant Loadings		
Flow		
Design Flow	1.60	MGD
Annual Average Flow	0.80	MGD
BOD		
Design	4,235	lb/day
Annual Average	2,019	lb/day
TSS		
Design	4,660	lb/day
Annual Average	2,279	lb/day
2. Treatment Unit Sizes		
Packed Tower Trickling Filter		1
Volume	237,944	gallons
Depth	20	feet
Diameter	45	feet
Area	1,590	sq. feet
Detention time(1)	3.6	hours
Rock Trickling Filter	1	
Volume	131,169	gallons
Depth	6	feet
Diameter	61	feet
Area	2,922	sq. feet
Detention time(1)	2.0	hours
Intermediate Clarifier	2	
Volume	51,054	gallons
Depth	6.5	feet
Area	1,050	sq. feet
Overflow Rate(1)	1,524	gpd/ft^2
Detention time(1)	1.5	hours
Aeration Tank	2	
Volume	179,083	gallons
Depth	15	feet
Area	1,596	sq. feet
Detention time(1)	5.4	hours
Final Clarifiers	4	
Volume	112,803	gallons
Depth	12	feet
Diameter	40	feet
Area	1,257	sq. feet
Overflow Rate(1)	1,273	gpd/ft^2
Detention time(1)	6.8	hours
Effluent Filters	4	
Area	80	sq. feet
Chlorine Contact Tank	1	
Volume	85,577	gallons
Depth	11	feet
Area	1,040	sq. feet
Detention time(1)	1.3	hours
3. Sludge Handling		
Sludge Thickening		
Dissolved Air Flotation	1	
Volume	15,799	gallons
Depth	11	feet
Area	192	sq. feet
Digestion		
Primary Digester	1	
Volume	261,739	gallons
Depth	22	feet
Diameter	45	feet
Area	1,590	sq. feet
Secondary Digester	1	
Volume	227,663	gallons
Depth	15.5	feet
Diameter	50	feet
Area	1,963	sq. feet
Storage		
Tank	2	
Volume	370,285	gallons
Depth	15	feet
Area	3,300	sq. feet
Sludge Dewatering	None	
Sludge Disposal	Land Application	

(1) - based on design flow

Table 2.6.3.B: NPDES Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Ammonia, Total (as N)	7.7	mg/L	Monthly Avg	Dec - Mar	2/month	Grab
Ammonia, Total (as N)	4.0	mg/L	Monthly Avg	April - May	2/month	Grab
Ammonia, Total (as N)	1.0	mg/L	Monthly Avg	Jun - Sept	2/month	Grab
Ammonia, Total (as N)	4.3	mg/L	Monthly Avg	Oct - Nov	2/month	Grab
$CBOD_5$	25	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
$CBOD_5$	40	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp
$CBOD_5$	85	% Removal	Monthly Avg	Jan - Dec	3/week	Calculation
Total Residual Chlorine	0.038	mg/L	Monthly Max	April - Oct	1/day	Grab
Fecal Coliform	200	#/100 mL	Monthly Geo Mean	April - Oct	3/week	Grab
Dissolved Oxygen	5	mg/L	Monthly Min	Jan - Dec	1/day	Grab
pH	6.0-9.0	SU	Monthly Min/Max	Jan - Dec	1/day	Grab
Total Phosphorus	Monitor	mg/L	Monthly Avg	Jan - Dec	2/month	24 hr comp
Total Suspended Solids	30	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
Total Suspended Solids	45	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp
Total Suspended Solids	85	% Removal	Monthly Avg	Jan - Dec	3/week	Calculation

Table 2.6.3.C: Biological Secondary Treatment Process Design Information

Month 2002-2003	RASS mg/L	WAS gallons/day	SRT days	F/M lb/lb	MLSS mg/L	MLVSS mg/L
September	6,572	26,983	15	0.165	4,367	4,073
October	4,616	12,006	20	0.223	2,570	1,901
November	4,938	9,276	46	0.398	2,971	2,285
December	7,582	12,919	23	0.175	4,728	3,736
January	10,302	21,384	12	0.138	6,709	5,343
February	8,883	21,261	14	0.157	6,260	4,815
March	12,086	23,253	12	0.076	8,227	6,267
April	10,653	24,400	11	0.099	7,015	5,284
May	8,530	24,293	10	0.112	5,388	4,037
June	5,969	25,393	11	0.129	4,271	3,278
July	4,351	18,432	22	0.224	3,156	2,412
August	3,612	14,032	21	0.214	2,658	2,053
Average	7,341	19,470	18	0.176	4,860	3,790

Table 2.6.3.D: Wastewater Characterization

Influent

Month 2002-2003	Flow MGD	CBOD$_5$ mg/L	CBOD$_5$ lb/d	TSS mg/L	TSS lb/d	TP mg/L
September	0.87	239	1,734	318	2,307	15.6
October	0.83	227	1,578	207	1,443	12.5
November	0.75	324	2,025	225	1,406	10.1
December	0.69	435	2,519	334	1,932	15.6
January	0.68	534	3,010	548	3,087	22.4
February	0.68	384	2,196	485	2,767	23.0
March	0.67	364	2,022	596	3,312	23.1
April	0.97	216	1,749	380	3,083	14.7
May	1.22	186	1,884	286	2,898	11.9
June	0.86	234	1,685	307	2,208	10.8
July	0.73	345	2,093	249	1,510	11.4
August	0.65	321	1,738	257	1,390	9.6
Average	0.80	317	2,019	349	2,279	15.1

Effluent

Month 2002-2003	Flow MGD	CBOD$_5$ mg/L	CBOD$_5$ lb/d	TSS mg/L	TSS lb/d	TP mg/L	Total NH$_3$-N mg/L
September	0.87	1.2	8	2.4	18	9.4	0.40
October	0.83	2.7	19	4.6	32	8.1	0.21
November	0.75	2.7	17	2.4	15	7.9	5.79
December	0.69	1.2	7	1.5	9	11.8	0.08
January	0.68	2.8	16	4.0	23	12.8	0.55
February	0.68	2.6	15	4.1	23	10.4	0.08
March	0.67	3.4	19	6.5	36	10.7	0.08
April	0.97	4.8	39	5.2	42	8.3	1.11
May	1.22	2.5	25	6.4	65	6.1	0.08
June	0.86	2.4	17	6.4	46	8.0	0.08
July	0.73	3.5	21	6.5	40	8.4	0.08
August	0.66	4.5	25	5.0	27	8.4	0.34
Average	0.8	2.9	19	4.6	31	9.2	0.74

NOTE: Based on 2002 Draft Evaluation Report the plant treats an average of 695 lbs/day of TKN.

Table 2.6.3.E: Percent Removal

Month	$CBOD_5$	TSS	TP
2002-2003			
September	99.5%	99.2%	39.7%
October	98.8%	97.8%	35.2%
November	99.2%	98.9%	21.8%
December	99.7%	99.5%	24.4%
January	99.5%	99.3%	42.9%
February	99.3%	99.2%	54.8%
March	99.1%	98.9%	53.7%
April	97.8%	98.6%	43.5%
May	98.7%	97.8%	48.7%
June	99.0%	97.9%	25.9%
July	99.0%	97.4%	26.3%
August	98.6%	98.1%	12.5%
Average	99.0%	98.5%	35.8%

Table 2.6.3.F: Probability Analysis

	Influent			Effluent			
% Occurrence[1]	TSS mg/L	BOD mg/L	TP mg/L	TSS mg/L	BOD mg/L	NH3 mg/L	TP mg/L
10%	184	144	10	1.0	1.0	0.08	7
50%	313	286	13	4.0	2.0	0.08	8
90%	204	553	23	9.0	5.0	0.89	12

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter

Note: Total Phosphorus data based on monthly averages

APPENDIX 2.6.4

LITTLE FALLS WWTP

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Appendix 2.6.4

Little Falls WWTP

Summary of Plant Data

Table 2.6.4.A: Plant Design Parameters

Parameter	Value	Units
Flow		
Design Flow	2.4	MGD
Annual Average Flow	1.5	MGD
BOD		
Design	2,671	lb/day
Annual Average	1,516	lb/day
TSS		lb/day
Design	3,407	lb/day
Annual Average	1,970	lb/day
2. Treatment Unit Sizes		
Wet Weather Holding Basin		
Volume	254,000	gallons
Depth	12	feet
Area	2,827	sq. feet
Diameter	60	feet
Primary Clarifier	2	
Volume per tank	103,000	gallons
Depth	11	feet
Area	1,257	sq. feet
Diameter	40	feet
Overflow Rate(1)	580	gpd/ft^2
Detention time(1)	2.1	hours
Fixed Growth Contactor		
Redwood Pellets	Downflow; no air added	
Avg. Organic Loading Rate	118	lb/day/1000 ft^3
Avg. Hydraulic Loading Rate	3.0	gpm/ft^2
Volume per tank	80,425 (media)	gallons
Depth	14 (media)	feet
Area	768	sq. feet
Aeration Tanks	2	
Length	36	ft
Width	18	ft
Sidewater Depth	14	ft
Total Volume	138,000	gallons
Detention time(1)	1.4	hours
Aeration Blowers (number)	3	
Aeration Blowers (capacity)	810	scfm
Final Clarifier	2	
Volume per tank	176,000	gallons
Depth	12	feet
Area	1,963	sq. feet
Diameter	50	feet
Overflow Rate(1)	371	gpd/ft^2
Detention time(1)	3.5	hours
Cl_2 Contact Tank	1	
Volume per tank	39,800	gallons
Depth	8	feet
Diameter	750	feet
Detention time(1)	0.40	hours
3. Sludge Handling		
Gravity Thickening	321,000	gallons
Digestion	None	
Storage		
Tank	84,500	gallons
Sludge Drying Bed	11,000	ft^2
Sludge Disposal		
Land Application		

(1) Based on design flow

Table 2.6.4.B: NPDES Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Total Chromium	Monitor	ug/L	Single Value	Jan - Dec	1/quarter	Grab
Total Copper	Monitor	ug/L	Single Value	Jan - Dec	1/quarter	Grab
Ammonia	Monitor	mg/L	Monthly Avg	Jan - Dec	1/month	24 hr comp
$CBOD_5$	25	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
$CBOD_5$	40	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp
$CBOD_5$	85	% Removal	Monthly Avg	Jan - Dec	3/week	24 hr comp
Total Residual Chlorine	0.038	mg/L	Monthly Max	Jan - Dec	1/day	Grab
Fecal Coliform	200	#/100 mL	Monthly Geo Mean	April - Oct	3/week	Grab
Total Mercury	Monitor	ng/L	Single Value	Mar, Jun, Sep, Dec	1/month	Grab
Dissolved Oxygen	Monitor	mg/L	Monthly Min	Jan - Dec	1/day	Grab
pH	6.0-9.0	SU	Monthly Min/Max	Jan - Dec	1/day	Grab
Total Phosphorus	Monitor	mg/L	Monthly Avg	Jan - Dec	1/week	24 hr comp
Total Suspended Solids	30	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
Total Suspended Solids	45	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp
Total Suspended Solids	85	% Removal	Monthly Avg	Jan - Dec	3/week	24 hr comp

Table 2.6.4.C: Biological Secondary Treatment Process Design Information

Month	RAS	WAS	SRT	F/M	MLSS
2002-2003	GPD	GPD	days	lb BOD/lb MLSS	mg/L
September	Typically 750 gpd; Can be up to 500 1000 gpd	29,832	4 - 5 days	0.42	3,458
October		26,148		0.59	3,616
November		8,100		0.05	41,182
December		23,917		0.61	4,045
January		33,604		1.15	3,003
February		38,499		1.29	3,441
March		32,967			
April		31,320			
May		26,090		0.89	2,722
June		22,815		0.81	3,220
July		31,393		0.78	3,207
August		28,296		0.55	4,425
Average		27,748		0.71	3,460

Table 2.6.4.D: Wastewater Characterization

Influent

Month 2002-2003	Flow MGD	CBOD$_5$ mg/L	CBOD$_5$ lb/d	TSS mg/L	TSS lb/d	Ammonia mg/L	Total P mg/L	BOD:P
September	1.4	70	824	127	1,500	10.00	2.58	27
October	1.9	77	1,219	125	1,974	34.20	3.64	21
November	1.4	97	1,132	135	1,581	16.50	3.98	24
December	1.3	124	1,393	158	1,779	18.60	3.71	33
January	1.1	211	1,966	215	2,006	25.80	4.74	44
February	1.2	243	2,511	220	2,270	21.10	4.94	49
March	1.1	215	2,006	351	3,278	105	4.25	51
April	1.2	148	1,490	162	1,631	37.00	3.80	39
May	1.4	115	1,379	136	1,630	19.30	3.55	33
June	1.9	91	1,479	155	2,516	12.10	2.46	37
July	2.1	81	1,414	107	1,866	3.50	1.78	45
August	1.3	130	1,382	152	1,614	13.30	2.34	56
Average	1.5	133	1,516	170	1,970	26.37	3.48	38

Effluent

Month 2002-2003	Flow MGD	CBOD$_5$ mg/L	CBOD$_5$ lb/d	TSS mg/L	TSS lb/d	Ammonia mg/L	Total P mg/L	BOD:P
September	1.4	4.0	47	10.7	127	0.95	1.34	3
October	1.9	5.9	93	12.9	204	16.75	3.46	2
November	1.4	6.6	77	13.4	157	0.30	2.52	3
December	1.3	9.0	101	18.1	204	7.26	0.58	15
January	1.1	16.5	154	25.3	236	18.20	2.29	7
February	1.2	14.8	153	17.0	176	12.90	3.38	4
March	1.1	16.2	151	20.2	188	29.40	3.20	5
April	1.2	15.4	155	13.9	141	7.00	2.99	5
May	1.4	12.3	147	11.1	133	20.50	1.84	7
June	1.9	11.1	180	14.2	231	8.78	1.17	9
July	2.1	6.4	111	13.2	230	3.40	1.98	3
August	1.3	7.5	79	18.3	194	11.71	1.69	4
Average	1.5	10.5	121	15.7	185	11.43	2.20	6

Table 2.6.4.E: Plant Performance - Percent Removal

Month	$CBOD_5$	TSS
2002-2003		
September	94.3%	91.5%
October	92.4%	89.6%
November	93.2%	90.1%
December	92.8%	88.5%
January	92.1%	88.2%
February	93.9%	92.3%
March	92.5%	94.3%
April	89.6%	91.4%
May	89.3%	91.9%
June	87.8%	90.8%
July	92.1%	87.7%
August	94.3%	88.0%
Average	92.0%	90.4%

Table 2.6.4.F: Probability Analysis

	Influent				Effluent			
% Occurrence[1]	TSS mg/L	BOD mg/L	TP mg/L	Ammonia mg/L	TSS mg/L	BOD mg/L	TP mg/L	Ammonia mg/L
10%	103	55	1.9	10	6.8	4.3	0.6	0.3
50%	138	106	3.2	19	13.2	7.7	2.2	7.3
90%	255	200	5.0	36	25	15.0	3.8	19.6

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter

APPENDIX 2.7.1

REDWOOD FALLS WWTP

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Appendix 2.7.1

Redwood Falls WWTP

Summary of Plant Data

Table 2.7.1.A: Plant Design Parameters

Parameter	Value	Units
1. Plant Loadings		
Flow		
Design Capacity	1.32	MGD
Annual Average	0.76	MGD
Industrial input	30	MG/year
BOD		
Design	2,202	lb/day
Annual Average	1,162	lb/day
TSS		
Design	3,270	lb/day
Annual Average	1,736	lb/day
2. Treatment Unit Sizes		
Aerated Ponds		
Redwood Falls Ponds	3	
Total Area	14	Acres
Total Volume	32	MG
Aerator Type: Static Tube		
Regional Ponds	3	
Total Area	5.7	Acres
Total Volume	17.3	MG
Aerator Type: Floating		
3. Sludge Handling	None - Pond Facility	

Table 2.7.1.B: NPDES Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Ammonia	7.5	mg/L	Monthly Avg	June - Sept	2/month	24 hr comp
Ammonia	9.7	mg/L	Monthly Avg	Oct - Nov	2/month	24 hr comp
Ammonia	94	mg/L	Monthly Avg	Dec - March	2/month	24 hr comp
Ammonia	64	mg/L	Monthly Avg	April - May	2/month	24 hr comp
Un-ionized Ammonia	1	mg/L	Monthly Avg	Jan - Dec	2/month	24 hr comp
$CBOD_5$	25	mg/L	Monthly Avg	Jan - Dec	2/month	24 hr comp
$CBOD_5$	40	mg/L	Weekly Avg	Jan - Dec	2/month	24 hr comp
$CBOD_5$	85	% Removal	Monthly Avg	Monthly Avg	2/month	24 hr comp
Chlorides	873	mg/L	Monthly Avg	Monthly Avg	2/month	24 hr comp
Fecal Coliform	200	#/100 mL	Monthly Geo Mean	April - Oct	2/month	Grab
Dissolved Oxygen	Monitor	mg/L	Monthly Min	Jan - Dec	2/month	Grab
pH	6.0-9.0	SU	Monthly Min/Max	Jan - Dec	2/month	Grab
Total Suspended Solids	65	mg/L	Weekly Avg	Jan - Dec	2/month	24 hr comp
Total Suspended Solids	85	% Removal	Monthly Avg	Jan - Dec	2/month	24 hr comp

Table 2.7.1.C: Wastewater Characterization

Influent

Month	Flow	CBOD$_5$	CBOD$_5$	TSS	TSS
2002-2003	MGD	mg/L	lb/d	mg/L	lb/d
October	0.78	181	1,177	214	1,392
November	0.79	242	1,594	290	1,911
December	0.70	189	1,105	315	1,842
January	0.68	346	1,948	300	1,689
February	0.58	228	1,103	413	1,998
March	0.63	184	965	260	1,364
April	0.72	258	1,556	549	3,310
May	0.83	124	855	320	2,215
June	0.73	149	908	264	1,611
July	0.67	146	816	194	1,084
August	0.66	170	936	220	1,211
September	0.64	184	979	226	1,203
Average	0.70	200	1,162	297	1,736

Effluent

Month	Flow	CBOD$_5$	CBOD$_5$	TSS	TSS	Total Ammonia	Un-Ionized Ammonia	Total Phosphorus
2002-2003	MGD	mg/L	lb/d	mg/L	lb/d	mg/L	mg/L	mg/L
October	0.84	9.0	63	26	182	0.08	0.02	0.73
November	0.87	9.5	69	12	83	0.08	0.02	0.77
December	0.71	6.5	38	26	154	16.20	1.39	5.4
January	0.62	11.0	57	26	135	14.00	0.28	3.8
February	0.63	7.5	39	20	105	15.30	0.18	3.8
March	0.64	6.5	35	15	81	16.50	0.16	3.9
April	0.78	10.5	68	48	309	7.80	0.38	3.0
May	0.93	9.1	71	84	654	16.54	0.26	4.3
June	0.79	9.0	59	45	297	0.08	0.02	1.5
July	0.89	7.5	56	34	253	0.08	0.02	1.2
August	0.65	5.0	27	26	141	0.08	0.02	
September	0.77	9.0	57	32	201	0.08	0.02	
Average	0.76	8.3	53	33	216	7.24	0.23	2.85

Table 2.7.1.D: Percent Removal

Month **2002-2003**	**CBOD5**	**TSS**
October	95.0%	87.9%
November	96.1%	96.0%
December	96.6%	91.7%
January	96.8%	91.3%
February	96.7%	95.2%
March	96.5%	94.2%
April	95.9%	91.3%
May	92.6%	73.8%
June	93.9%	82.9%
July	94.9%	82.5%
August	97.1%	88.2%
September	95.1%	86.1%
Average	95.6%	88.4%

Table 2.7.1.E: Probability Analysis

	Influent		Effluent				
% Occurrence[1]	TSS mg/L	BOD mg/L	TSS mg/L	BOD mg/L	Ammonia mg/L	Un-Ionized Ammonia mg/L	TP mg/L
10%	215	146	14.1	6.0	0.08	0.02	0.73
50%	277	184	27.0	8.5	0.1	0.02	2.2
90%	404	256	51	14.3	16.1	0.27	4.6

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter

APPENDIX 2.7.2

THIEF RIVER FALLS WWTP

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Appendix 2.7.2

Thief River Falls WWTP

Summary of Plant Data

Table 2.7.2.A: Plant Design Parameters

Parameter	Value	Units
1. Plant Loadings		
Flow		
Design Capacity	2.57	MGD
Annual Average	1.24	MGD
Industrial input	0.41	MGD
BOD		
Design	5,578	lb/day
Annual Average	2,569	lb/day
Industrial Contribution	50	%
TSS		
Design	4,442	lb/day
Annual Average	2,263	lb/day
2. Treatment Unit Sizes		
Aerated Ponds		
Primary Ponds	2	
Volume (each)	256	MG
Depth	6	feet
Area (each)	131	acres
Detention time (each)	373	days
Secondary Pond	1	
Volume (each)	172	MG
Depth	6	feet
Area (each)	88	acres
Detention time (each)	125	days
3. Sludge Handling	None - Pond Facility	

Table 2.7.2.B: NPDES Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Ammonia	Monitor	mg/L	Monthly Min	Jan - Dec	1/month	Grab
$CBOD_5$	15	mg/L	Monthly Avg	Jan - Dec	2/week	Grab
$CBOD_5$	25	mg/L	Weekly Avg	Jan - Dec	2/week	Grab
Fecal Coliform	200	#/100 mL	Monthly Geo Mean	April - Oct	2/week	Grab
Total Mercury	Monitor	mg/L	Monthly Min	Jan - Dec	1/month	Grab
Dissolved Oxygen	Monitor	mg/L	Monthly Min	Jan - Dec	2/week	Grab
pH	6.0-9.0	su	Monthly Min/Max	Jan - Dec	2/week	Grab
Total Phosphorus	Monitor	mg/L	Monthly Min	Jan - Dec	2/week	Grab
Total Suspended Solids	45	mg/L	Monthly Avg	Jan - Dec	2/week	Grab
Total Suspended Solids	65	mg/L	Weekly Avg	Jan - Dec	2/week	Grab

Table 2.7.2.C: Wastewater Characterization

Influent

Month 2002 - 2003	Flow MGD	$CBOD_5$ mg/L	$CBOD_5$ lb/d	TSS mg/L	TSS lb/d	TP mg/L	BOD:P
September	1.02					41	
December	1.08	304	2,743	215	1,940	14	23
March		325		199		8.0	41
May	1.53						
June	1.34	215	2,396	232	2,585	11	20
September		197		183		6.6	30
Average	1.24	260	2,569	207	2,263	15.8	28

Effluent

Month 2002 - 2003	Flow MGD	$CBOD_5$ mg/L	$CBOD_5$ lb/d	TSS mg/L	TSS lb/d	NH_4-N Total mg/L	TP mg/L
September	6.83						0.6
December							
March							
May	8.63	6.0	432	14	1,007	6.5	3.0
June	7.74	6.0	387	32	2,065	5.6	5.0
September	5.73	5.0	239	27	1,291	0.2	1.0
Average	7.23	5.7	353	24	1,455	4.1	2.4

Table 2.7.2.D: Plant Performance - Percent Removal (CBOD5)

Month	$CBOD_5$
2002-2003	
September	
December	
March	
May	
June	97.2%
September	97.5%
Average	97.3%

Table 2.7.2.E: Probability Analysis

	Influent			Effluent			
% Occurrence[1]	TSS mg/L	BOD mg/L	TP mg/L	TSS mg/L	BOD mg/L	NH_3 (T) mg/L	TP mg/L
10%	188	202	3.7	20.0	5.0	1.3	0.96
50%	207	260	6.8	29.5	6.0	5.6	3.0
90%	227	319	17	40	6.0	6.3	4.3

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter

APPENDIX 2.8.1

BRAINERD AND BAXTER WWTP
(BRAINERD AREA)

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Appendix 2.8.1

Brainerd and Baxter WWTP

Summary of Plant Data

Table 2.8.1.A: Plant Design Parameters

Parameter	Value	Units
1. Plant Loadings		
Flow		
Design Flow	3.13	MGD
Annual Average Flow	2.61	MGD
BOD		
Design	5,456	lb/day
Annual Average	3,619	lb/day
TSS		
Design	8,000	lb/day
Annual Average	3,303	lb/day
2. Treatment Unit Sizes		
Primary Clarifier	2	
Volume per tank	149,610	gallons
Depth	10	feet
Area	2,000	sq. feet
Overflow Rate(1)	783	gpd/ft^2
Detention time(1)	1.12 - 2.83	hours
Rotating Biological Contactors		12
# of Baffles	3	per unit
Total Surface Area	1,200,000	sq. ft per unit
Diameter	12	feet
Hydraulic Loading Rate(1)	2.80 - 5.23	gpd/ft^2
Detention time(1)	1.5 minimum	hours
Final Clarifier	2	
Volume per tank	260,637	gallons
Depth	11	feet
Diameter	65	feet
Area	3,318	sq. feet
Overflow Rate(1)	472	gpd/ft^2
Detention time(1)	1.81 - 4.47	hours
Cl_2 Contact Tank	2	
Volume per tank	35,345	gallons
Depth	8	feet
Area	630	sq. feet
Detention time(1)	approx 0.5	hours
3. Sludge Handling		
Thickening	Gravity	
Digestion	Anaerobic	
Storage	None	
Dewatering	None	
Sludge Disposal		
Agricultural Application		

(1) - based on design dry weather flow

Table 2.8.1.B: NPDES Permit Limits

Parameter	Limit	Units	Limit Type	Period	Frequency	Type
Ammonia	Monitor	mg/L	Monthly Avg	Jan - Dec	1/month	24 hr comp
$CBOD_5$	25	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
$CBOD_5$	40	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp
Fecal Coliform	200	#/100 mL	Monthly Geo Mean	Jan - Dec	3/week	Grab
Fecal Coliform	400	#/100 mL	Weekly Geo Mean	Jan - Dec	3/week	Grab
Dissolved Oxygen	2.8	mg/L	Monthly Min	Jan - Dec	1/day	Grab
Chlorine Residual	0.038	mg/L	Monthly Min	Jan - Dec	1/day	Grab
pH	6.0-9.0	SU	Monthly Min/Max	Jan - Dec	1/day	Grab
Total Phosphorus	Monitor	mg/L	Monthly Avg	Jan - Dec	1/month	24 hr comp
Total Suspended Solids	30	mg/L	Monthly Avg	Jan - Dec	3/week	24 hr comp
Total Suspended Solids	45	mg/L	Weekly Avg	Jan - Dec	3/week	24 hr comp

Table 2.8.1.C: Wastewater Characterization

Influent

Month 2002-2003	Flow MGD	BOD_5 mg/L	BOD_5 lb/d	TSS mg/L	TSS lb/d	Total Phos mg/L	BOD/P (mg/L)/(mg/L)
October	2.64	151	3,311	143	3,135	3.2	47.1
November	2.40	160	3,194	139	2,777	5.9	27.1
December	2.34	177	3,454	157	3,056	7.1	24.9
January	2.25	162	3,046	149	2,790	7.0	23.2
February	2.43	188	3,803	179	3,626	6.0	31.3
March	2.43	207	4,197	165	3,346	6.1	34.0
April	2.71	177	3,991	152	3,425	5.6	31.5
May	2.95	140	3,451	130	3,197	5.4	26.0
June	3.00	153	3,826	152	3,795	3.8	40.8
July	3.06	176	4,493	161	4,119	7.6	23.3
August	2.64	133	2,923	123	2,711	4.6	28.9
September	2.50	179	3,734	175	3,655	4.8	37.2
Average	2.61	167	3,619	152	3,303	5.6	31.3

Effluent

Month 2002-2003	Flow MGD	BOD_5 mg/L	BOD_5 lb/d	TSS mg/L	TSS lb/d	Ammonia mg/L	Total Phos mg/L
October	2.64	9.0	198	7.9	173	18.1	3.3
November	2.40	10.5	210	9.5	190	19.2	3.7
December	2.34	11.7	228	9.0	176	16.8	3.1
January	2.25	12.1	228	8.9	166	8.7	2.5
February	2.43	11.4	231	8.9	180	17.4	2.5
March	2.43	13.0	263	10.8	219	24.5	3.6
April	2.71	12.6	286	7.5	170	20.2	2.5
May	2.95	12.6	311	8.2	201	17.3	2.9
June	3.00	11.8	294	7.5	188	23.3	3.1
July	3.06	12.3	315	8.0	204	12.6	2.7
August	2.64	8.8	193	5.8	127	11.40	1.7
September	2.50	10.4	217	6.7	140	23.3	3.6
Average	2.61	11.4	248	8.2	178	17.7	2.9

Table 2.8.1.D: Plant Performance - Percent Removal (CBOD5, TSS, Total Phosphorus)

Month	$CBOD_5$	TSS	Total Phos
2002-2003			
October	94.0%	94.5%	
November	93.4%	93.2%	37.3%
December	93.4%	94.3%	56.3%
January	92.5%	94.0%	64.3%
February	93.9%	95.0%	58.3%
March	93.7%	93.4%	41.0%
April	92.8%	95.0%	55.4%
May	91.0%	93.7%	45.4%
June	92.3%	95.1%	17.9%
July	93.0%	95.0%	63.9%
August	93.4%	95.3%	62.3%
September	94.2%	96.2%	25.0%
Average	93.1%	94.6%	47.9%

Table 2.8.1.E: Probability Analysis

	Influent			Effluent			
%	TSS	BOD	TP	TSS	BOD	TP	NH_3-N
Occurrence(1)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
10%	103	117	3.9	5.0	7.0	1.7	11
50%	157	165	5.6	8.0	11.0	2.7	18
90%	217	211	7.1	14	16.0	3.7	25

(1) Percent of samples with concentrations less than the concentration specified
Based on the development of percent occurrence/probability plots for each parameter