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# LCMR 2003 Work Program

**Date of Report:** **June 30, 2005**
**LCMR Final Work Program Report**

**Date of Work Program Approval:** June 26, 2003

**Project Completion Date:** June 30, 2005

## I. PROJECT TITLE: Wastewater Phosphorus Control and Reduction Initiative

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**Total Biennial LCMR Project Budget:**
**LCMR Appropriation:** $ 296,000.00
**Minus Amount Spent:** $ 295,990.92
**Equal Balance:** $ 9.08

**Legal Citation:** ML 2003, Chap. 128, Art. 1, Sec. 9, Subd. 07(e)

**Appropriation Language:**

7(e) Wastewater Phosphorus Control and Reduction Initiative

"$392,000 the first year and $148,000 the second year are from the trust fund to the commissioner of the pollution control agency to study human causes of excess phosphorus and for cooperation and an agreement with the Minnesota environmental science and economic review board to assess phosphorus reduction techniques at wastewater treatment plants."

## II. and III. FINAL PROJECT SUMMARY

The technical approach to evaluate phosphorus removal retrofit options for the seventeen (17) selected MESERB wastewater treatment plants was based on the following objectives: 1) select cost effective treatment systems; 2) meet an effluent phosphorus target concentration of 1 mg/L (the most stringent effluent concentration specified in current MPCA regulations); and 3) 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.

Key conclusions drawn from this study included the following: 1) chemical treatment is the recommended phosphorus removal alternative for plants using trickling filters, rotating biological contactors or lagoons for secondary treatment; and 2) 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.

The findings from this study were presented in a MESERB report entitled "Wastewater Phosphorus Control and Reduction Initiative" which can be found on the MESERB website at www.meserb.org and at the Legislative Reference Library. Two technology transfer seminars were presented at New Ulm and Brainerd discussing the results of the evaluation of phosphorus removal alternatives.

## IV. OUTLINE OF PROJECT RESULTS:

### **Result 1:** Facility Examination and Data Review

**Description:**

MESERB retained HydroQual, Inc., a national engineering and consulting firm, and Professor H. David Stensel, Ph.D., M.E., of the University of Washington, a national expert in biological phosphorus treatment. The experts, with MESERB's assistance, examined actual and potential phosphorus reduction techniques at the seventeen selected wastewater treatment facilities, according to a work plan and systematic review and analysis protocol developed by the experts.

The examination of the 17 facilities included a review of NPDES permits, plant operation logs, process flow sheets, instrumentation data, and plant blueprints; discussions with city engineers and staff; and facility tours. The project team analyzed the data collected to assess which techniques would produce the most significant and cost-effective phosphorus reduction.

The site selection criteria for specific plant evaluations considered the range of possible treatment processes, effluent requirements, the amount and type of data available, laboratory ability, and plant size and capacity. One of the goals was to determine if any plants were very similar so that the project team could focus on only one of those facilities.

Key information items identified for initial plant screening included the following:

1. Plant design capacity (flow and loadings)
2. Present flow and loadings
3. Present permit effluent levels (e.g. biochemical oxygen demand (BOD), phosphorus (P), nitrogen (N))
4. Receiving water and degree of dilution
5. Process description
    - Primary
    - Secondary process
    - Tertiary such as effluent filtration
6. Sludge processing description and disposal/reuse methods
7. Sample monthly reporting form
8. Plant staffing
9. Laboratory ability (list analytical capability) and whether laboratory is certified
10. Whether influent is sampled and analyzed - if yes, how often and whether sample is a grab or composite
11. Presence of any significant industrial contributions to the plant loading
12. Whether the collection system is separate or involves combined sewers

The seventeen sites were visited in September and October of FY2003 (see Item IX, "Location" and the attached map with the 23 sites in the original proposal). Analysis of treatment plant data and evaluation of effective phosphorus removal techniques were conducted in FY 2004 and FY 2005. The report preparation and the two educational seminars occurred in FY 2005.

**Amendment Request:** There was a balance of $430.85 in the Result 1 budget for the contract with Dr. Stensel. Of this balance, $425.00 would be used to offset additional labor charges incurred by Dr. Stensel for editing and corrections to the Result 2 report.

**Summary Budget Information for Result 1:** **LCMR Budget** ~~$ 208,704.00~~ $ 208,279.00
**Balance** $ 8.32

**Completion Date:** December 2004

**Summary of Results 1 Analyses**

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 ($Al_2(SO_4)_3 \bullet 18H_20$), 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 bio-solids 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.

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 - 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.

A summary of the general plant information and preliminary treatment process data collected from the screening forms is presented in Tables 1 and 2, respectively, for the selected plants. These data were used specifically for the selection and grouping of the treatment plants. 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 the report appendices.

Table 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 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). This breakdown of biological treatment process is illustrated in

Table 1. The data on the table 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,

# Table 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)<br>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 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

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 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 bio-solids.

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 were summarized.

In this study, a critical step in the evaluation of effective phosphorus removal alternatives was the development of a protocol for evaluating phosphorus removal alternatives for the representative wastewater treatment facilities. The protocol was 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 applied to evaluate phosphorus removal for each facility in a systematic and consistent fashion. The protocol is presented on Figure 1. The conceptual designs considered the wastewater characteristics, the plant layout and sizing of

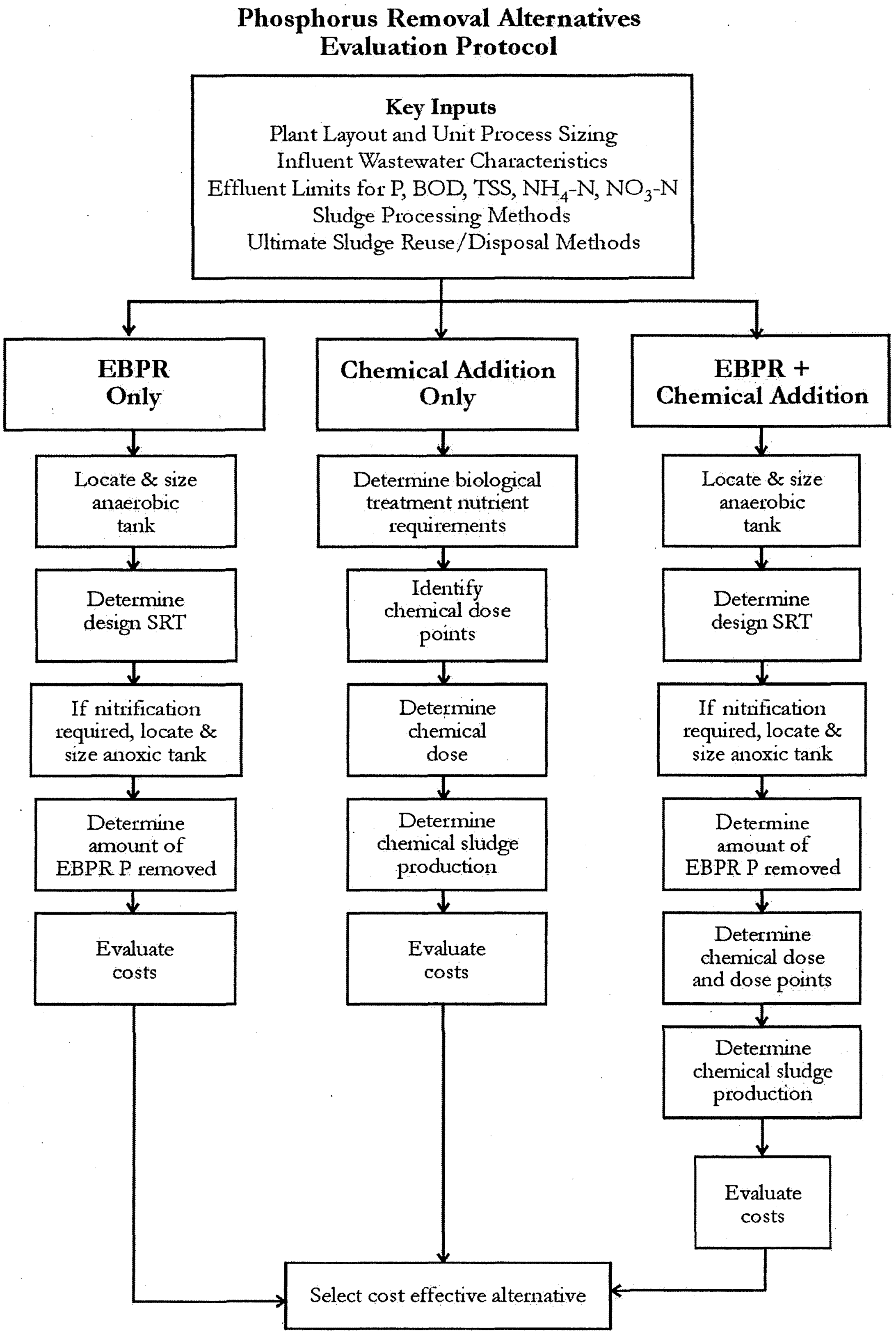

Figure 1 – Phosphorus Removal Alternatives Evaluation Protocol

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 defining biological treatment nutrient requirements, identifying chemical dose points, and determining chemical dose and 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.

The basis for the preliminary planning level costs was 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.

**Result 2:** Report with Best Practices Recommendations

**Description:**

With MESERB's assistance, HydroQual and Professor Stensel used the findings from data review and facility examinations to develop recommendations on low-cost, high-benefit strategies that were most effective for facilities of various sizes and types, in various regions of the state. This information was compiled into a project report, designed to assist wastewater operators in identifying and implementing effective phosphorus removal techniques. This report was available in paper format and on the Internet.

**Amendment Request:** MESERB is requesting an amendment to the project budget, to accommodate additional Result 1 and Result 2 labor costs not anticipated at the time of our last work program update on March 29, 2005. The requested changes are as follows:

- There was a balance of $8,428.18 remaining in the Result 2 budget. The budget balances for Results 2 and 3 are proposed to be modified as follows:
- $5,308.96 from the Result 2 balance would be used to offset held labor charges for additional engineering analysis and report preparation required to complete Result 2.

- Of the remaining balance of $3,119.22 in the Result 2 budget, $3,118.46 would be used to offset additional expenses incurred for the seminars in Result 3.

- The $3,118.46 from Result 2 was moved to Result 3.

- There was a balance of $430.85 in the Result 1 budget for the contract with Dr. Stensel. Of this balance, $425.00 would be used to offset additional labor charges incurred by Dr. Stensel for editing and corrections to the Result 2 report.

| | | | |
|---|---|---|---|
| **Summary Budget Information for Result 2:** | **LCMR Budget** | ~~$65,486.00~~ | $ 62,367.54 |
| | **Balance** | ~~$3,119.22~~ | $ 0.76 |

**Completion Date:** March 2005

**Summary of Results 2 Analyses**

Conceptual designs were developed for each facility so that the performance of possible phosphorus removal alternatives 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.

For each type of wastewater treatment plant identified for this study, all reasonable phosphorus removal technologies were identified 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.

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 comparison for individual sites was 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.

A summary of the results of the evaluation is presented in Table 3. 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

## Table 3. Summary of the Phosphorus Reduction/Removal Evaluation

| | | Available Phosphorus Removal Treatment Alternatives | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | EBPR | | | | | | |
| Biological Treatment Process (BTP) Plant Name | Report Section | Nitrification Required | Phosphorus 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**

**<u>Notes:</u>**

(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**

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.

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. The comparison is summarized in Table 4. 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

## Table 4 - Comparison of Selected Phosphorus Removal Alternative to Approximate Influent BOD/P Ratio to Activated Sludge Process

| *Biological Treatment Process*<br>Plant Name | Selected Alternative | Activated Sludge Feed ~BOD/P | Comments |
|---|---|---|---|
| ***Activated Sludge*** | | | |
| Alexandria Lake WWTF | (Chemical) | 27 | |
| New Ulm WWTF | EBPR + | 23 | |
| Grand Rapids WWTF | (Biomass Synthesis) | >100 | *Phosphorus limited, Source control* |
| | | | |
| ***Biological Nutrient Removal*** | | | |
| St. Cloud WWTF | EBPR + | 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 + | 46 | |
| | | | |
| ***High Purity Oxygen*** | | | |
| Moorhead WWTF | EBPR | 32 | |
| Rochester WRP | (Chemical) | 30 | |
| | | | |
| ***Trickling Filter/Activated*** | | | |
| 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<br>1) w/o dairy operation<br>2) with dairy operation | EBPR<br>Chemical | 40<br>10 | *Includes bypassing the trickling filter. Excess nitrogen and insufficient tankage for BNR* |
| Little Falls WWTF | Chemical | 36 | *Highly loaded trickling filters* |

(....) parenthesis in the Selected Alternative Column indicates process already in use.

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 bio-solids, 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 one 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.

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. This analysis is summarized in Tables 5 and 6 for EBPR and chemical addition processes, respectfully. 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.

## Table 5. – 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, $lb/d\text{-}ft^2$ | 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 |

**Table 6. 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 |

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.

## 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°C and 20°C, 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.

## 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.

The development of the protocol, the evaluation of alternatives using the protocol and the results of the comparison of phosphorus removal alternatives are discussed in detail in the MESERB report, entitled "Wastewater Phosphorus Control and Reduction Initiative." The report is available on MESERB website www.meserb.org and at the Legislative Reference Library.

**Result 3:** Wastewater Treatment Best Practices Seminars

**Description:**

Once the recommendations and report were completed, MESERB hosted two educational seminars at New Ulm (for southern cities) and Brainerd (for northern cities). These seminars were partially funded by the grant to keep attendance costs nominal. At each seminar, the report was distributed and discussed, and attendees were encouraged to review the findings and conclusions when developing plant specific phosphorus removal options. A follow-up data collection and monitoring strategy and implementation report, although not currently anticipated in this funding phase, can be built into the plan as a second phase for application to the LCMR in the 2006 funding cycle.

**Amendment Request:** The corrected budget figure below reflects a shift of $3,118.46 from the Result 2 budget.

**Summary Budget Information for Result 3:** **LCMR Budget** ~~$21,810.00~~ $ 24,928.46
**Balance** ~~$-3,118.46~~ $ 0.00

**Completion Date:** June 2005

**Summary of Results 3 Requirements**

Phosphorus removal strategies seminars were conducted at New Ulm on May 25th and at Brainerd on June 8th. The Agenda for these seminars are presented on the attached exhibit (Figure 2 – Phosphorus Removal Strategies Seminar). There were four presentations at each seminar; Project Overview, Retrofit Evaluations Protocol and Key Process Considerations, Retrofit of Activated Sludge Facilities for Phosphorus Control and Retrofit of Fixed Film, Combined Processes and Lagoons for Phosphorus Research. Details of the presentations are highlighted on Figure 2. Copies of the presentations can be found on MESERB website at www.meserb.org.

## V. TOTAL LCMR PROJECT BUDGET:

| | | |
|---|---|---|
| **All Results:** | **Personnel:** | **$269,431** |
| **All Results:** | **Equipment:** | **$0** |
| **All Results:** | **Development:** | **$0** |
| **All Results:** | **Acquisition:** | **$0** |
| **All Results:** | **Printing:** | **$11,000** |
| **All Results:** | **Advertising:** | **$1,000** |
| **All Results:** | **Communication:** | **$2,514** |
| **All Results:** | **Travel:** | **$12,055** |
| **All Results:** | **Other** | **$0** |

**TOTAL LCMR PROJECT BUDGET: $ 296,000**

**Explanation of Capital Expenditures Greater Than $3,500:**

# TECHNOLOGY TRANSFER SEMINAR SERIES

## Wastewater Phosphorus Control and Reduction Initiative
## Phosphorus Removal Strategies Seminar

*Co-sponsored by the*
**Minnesota Environmental Science and Economic Review Board (MESERB) and HydroQual, Inc.**
*in association with*
**H. David Stensel, Ph.D., P.E.**
**University of Washington**

**May 25th – New Ulm**
Turner Hall
102 South State Street
New Ulm, MN
507-354-4916

**June 8th – Brainerd**
address 2k

### AGENDA

| | |
|---|---|
| 10:00 to 10:15 | **Introduction and Opening Remarks** |
| 10:15 to 10:45 | **Project Overview**<br>Project Objectives and approach<br>Type of facilities evaluated to demonstrate retrofit designs for phosphorus removal<br>Phosphorus removal technologies and their requirements |
| 10:45 to 11:45 | **Retrofit Evaluation Protocol and Key Process Considerations**<br>Key design inputs and evaluation steps<br>Process factors for chemical treatment<br>Process factors for enhanced biological phosphorus removal (EBPR) |
| 11:45 to 12:45 | **Lunch** |
| 12:45 to 1:30 | **Retrofit of Activated Sludge Facilities for Phosphorus Removal**<br>Conventional, BNR, oxidation ditch, and HPO facilities case histories<br>Lessons learned – key factors affecting EBPR and/or chemical treatment |
| 1:30 to 2:15 | **Retrofit of Fixed Film, Combined Processes, and Lagoons for Phosphorus Removal**<br>Trickling filters, trickling filter/activated sludge, lagoon facilities and rotating biological contractors case histories<br>Lessons learned – key factors affecting EBPR and/or chemical treatment |
| 2:15 to 2:30 | **Discussion and Closing Remarks** |

*Seminar will count as 3 direct contact hours.*

**MESERB**
Minnesota Environmental Science and Economic Review Board

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

HydroQual
Environmental Engineers & Scientists

*For additional copies of HydroQual's report, please visit the MESERB website at www.meserb.org*

### REGISTRATION

(one registration form per attendee)

Name:______________________________

Affiliation:______________________________

Address:______________________________

______________________________

Phone Number:______________________________

Email:______________________________

I will attend the seminar at (select one): ___ New Ulm ___ Brainerd

Cost: $15.00 Options for billing: ___Pay at seminar ___ Bill me

**Figure 2. Phosphorus Removal Strategies Seminar Agenda**

## VI. PAST, PRESENT AND FUTURE SPENDING:

### A. Past Spending:

| | |
|---|---|
| $ 39,653 | Voluntary assessment from MESERB, December 2001 to present |
| Unknown | Amounts spent by individual facilities to treat phosphorus up to July 1, 2003. To our knowledge, these amounts have not been fully documented. |

### B. Current Spending:

| | |
|---|---|
| In-Kind | Contributions from MESERB, such as use of facilities and equipment, city personnel time, monitoring data, etc. |

### C. Required Match (if applicable): No match required

### D. Future Spending:

Cities may spend funds to implement best practices recommendations; however the amount that may be spent by whom is unknown and is outside the context of this project.

## VII. PROJECT PARTNERS:

### A. Partners Receiving LCMR Funds:

See Appendix A, Tab 1.
Dr. David Stensel is an employee of the University of Washington
Dr. George J. Kehrberger and the other positions listed in Tab A are employees of HydroQual, Inc.

### B. Project Cooperators:

Ken Robinson, Public Utilities Director, City of St. Cloud – MESERB Northern Representative and LCMR Project Manager
Christopher M. Hood, Attorney – Flaherty & Hood, P.A., representing MESERB
Steven W. Nyhus, Associate Attorney – Flaherty & Hood, P.A., representing MESERB

MESERB in cooperation with Flaherty & Hood, P.A. will contribute some additional administrative services in-kind as well as other services based on a past voluntary $39,653 contribution from cities participating in the project, which was collected in 2002 and used to proceed through the LCMR funding process and project development.

## VIII. DISSEMINATION:

Results 2 description indicated that the field investigation and analysis of the plants was summarized in a report. The report was available to the public and to the wastewater treatment plant operators. The report was also handed out at the two seminars. Results 3 description indicated that the results were presented at two educational seminars. The seminars were held at New Ulm on May 25th and at Brainerd on June 8th.

## IX. LOCATION:

Statewide. Participants receiving facility tours include the Alexandria Lake Area Sanitary District, Brainerd, Detroit Lakes, the Dover Eyota St. Charles Sanitary District, Faribault, Fergus Falls, Glencoe, Grand Rapids, Little Falls, Marshall, Moorhead, New Ulm, Redwood Falls, Rochester, St. Cloud, Thief River Falls, and Wadena.

## X. REPORTING REQUIREMENTS:

Periodic work program progress reports were submitted in May 2004, October 2004, December 2004 and March 2005.

This document constitutes the final work program report.

**Attachment A: Budget Detail for 2003 Projects - Summary and a Budget page for each partner (June 24, 2005, Replacement Attachment A (1), (2), (3) & (4))**

**Project Title:** *Wastewater Phosphorus Control and Reduction Initiative, 07e*

**Project Manager Name:** *Ken Robinson, Public Utilities Director, City of St. Cloud for Minnesots Environmental Science and Economic Review Board (MESERB)*

**LCMR Requested Dollars:** *$296,000*

| **2003 LCMR Proposal Budget** | **Result 1 Budget:** | **Amount Spent** *(6/24/05)* | **Balance** *(6/24/05)* | **Result 2 Budget:** | **Amount Spent** *(6/24/05)* | **Balance** *(6/24/05)* | **Result 3 Budget:** | **Amount Spent** *(6/24/05)* | **Balance** *(6/24/05)* | | **Total Spent** | **Total Balance** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **BUDGET ITEM** *(Budget costs rounded to nearest dollar. Actual costs in Tabs 1, 2, 3.* | *Facility Examination and Data Review* | | | *Report with Best Practices Recommendations* | | | *Wastewater Treatment Best Practices Seminar* | | | **TOTAL FOR BUDGET ITEM** | | |
| **PERSONNEL: Staff Expenses, wages, salaries** *(see Tab 1 for combined rate/cost)* | 165,281.79 | 165,368.03 | -86.24 | 40,598.57 | 45,703.73 | -5,105.16 | 10,077.12 | 9,950.95 | 126.17 | 215,957.48 | 221,022.71 | -5,065.23 |
| Dr. David Stensel | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Dr. George J. Kehrberger | 50,232.45 | 53,740.48 | -3,508.03 | 12,391.52 | 16,498.44 | -4,106.92 | 7,688.64 | 5,045.67 | 2,642.97 | 70,312.61 | 75,284.59 | -4,971.98 |
| Gary M. Grey | 28,960.32 | 21,272.40 | 7,687.92 | 13,148.58 | 8,285.04 | 4,863.54 | 2,388.48 | 4,179.84 | -1,791.36 | 44,497.38 | 33,737.28 | 10,760.10 |
| Dennis E. Scannell | 29,803.20 | 32,517.42 | -2,714.22 | 13,624.32 | 14,156.52 | -532.20 | 0.00 | 106.44 | -106.44 | 43,427.52 | 46,780.38 | -3,352.86 |
| John G. Sondey | 0.00 | 79.87 | -79.87 | 1,436.40 | 2,316.25 | -879.85 | 0.00 | 619.00 | -619.00 | 1,436.40 | 3,015.12 | -1,578.72 |
| Melissa E. Morrone | 45,944.32 | 47,539.00 | -1,594.68 | 0.00 | 4,418.25 | -4,418.25 | 0.00 | 0.00 | 0.00 | 45,944.32 | 51,957.25 | -6,012.93 |
| Barry J. Cheney | 1,002.55 | 947.20 | 55.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1,002.55 | 947.20 | 55.35 |
| Emely C. Scheible | 795.00 | 795.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 795.00 | 795.00 | 0.00 |
| Kristin Munoz | 8,541.00 | 8,476.57 | 64.43 | 0.00 | 29.23 | -29.23 | 0.00 | 0.00 | 0.00 | 8,541.00 | 8,505.80 | 35.20 |
| **PERSONNEL: Staff fringe benefits** *(see Tab 2 for benefit rate/cost)* | 8,677.21 | 8,625.37 | 51.84 | 2,373.43 | 2,577.23 | -203.80 | 422.88 | 499.42 | -76.54 | 11,473.52 | 11,702.02 | -228.50 |
| Dr. David Stensel | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Dr. George J. Kehrberger | 1,825.15 | 1,952.65 | -127.50 | 450.24 | 599.41 | -149.17 | 279.36 | 286.49 | -7.13 | 2,554.75 | 2,838.55 | -283.80 |
| Gary M. Grey | 1,740.18 | 1,278.24 | 461.94 | 790.08 | 497.84 | 292.24 | 143.52 | 148.01 | -4.49 | 2,673.78 | 1,924.09 | 749.69 |
| Dennis E. Scannell | 2,186.80 | 2,385.97 | -199.17 | 999.68 | 1,038.74 | -39.06 | 0.00 | 7.81 | -7.81 | 3,186.48 | 3,432.52 | -246.04 |
| John G. Sondey | 0.00 | 7.37 | -7.37 | 132.66 | 213.74 | -81.08 | 0.00 | 57.11 | -57.11 | 132.66 | 278.22 | -145.56 |
| Melissa E. Morrone | 2,347.52 | 2,429.00 | -81.48 | 0.00 | 225.75 | -225.75 | 0.00 | 0.00 | 0.00 | 2,347.52 | 2,654.75 | -307.23 |
| Barry J. Cheney | 39.56 | 37.64 | 1.92 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.56 | 37.64 | 1.92 |
| Emely C. Scheible | 27.00 | 27.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 27.00 | 27.00 | 0.00 |
| Kristin Mumford | 511.00 | 507.50 | 3.50 | 0.00 | 1.75 | -1.75 | 0.00 | 0.00 | 0.00 | 511.00 | 509.25 | 1.75 |
| **Total Labor Budget** *(see Tab 3 for total labor rate/cost)* | 173,959.00 | 173,993.40 | -34.40 | 48,280.96 | 48,280.96 | 0.00 | 10,500.00 | 10,450.37 | 49.63 | 232,739.96 | 232,724.73 | 15.23 |
| **Contracts** | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Professional/technical** *(with whom?, for what?)* | 24,000.00 | 23,994.15 | 5.85 | 12,000.00 | 12,000.00 | 0.00 | 6,000.00 | 6,000.00 | 0.00 | 42,000.00 | 41,994.15 | 5.85 |
| **Other contracts** *(with whom?, for what?) list out: personnel, equipment, etc.* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Space rental: NOT ALLOWED** | X | X | X | X | X | X | X | X | X | X | | |
| **Other direct operating costs** *(for what? – be specific)* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Equipment / Tools** *(what equipment? Give a* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Office equipment & computers** *(be specific)* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Other Capital equipment** *(list specific items)* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Land acquisition** *(how many acres)* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Land rights acquisition** *(less than fee)* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Printing** | 0.00 | 0.00 | 0.00 | 1,575.05 | 1,574.29 | 0.76 | 1,000.00 | 1,542.75 | -542.75 | 2,575.05 | 3,117.04 | -541.99 |
| **Advertising** (for 2 seminars in Result 3) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1,832.54 | 1,971.60 | -139.06 | 1,832.54 | 1,971.60 | -139.06 |
| **Communications, telephone, mail, etc.** | 1,000.00 | 1,396.34 | -396.34 | 511.53 | 511.53 | 0.00 | 1,000.00 | 972.15 | 27.85 | 2,511.53 | 2,880.02 | -368.49 |
| **Office Supplies** *(list specific categories)* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Other Supplies** *(list specific categories)* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Travel expenses in Minnesota** *(see Tab 4 for breakdown of travel costs)* | 4,945.00 | 4,879.79 | 65.21 | 0.00 | 0.00 | 0.00 | 1,210.00 | 605.67 | 604.33 | 6,155.00 | 5,485.46 | 669.54 |
| **Travel outside Minnesota (Airfare from NJ to Minnesota & from Washington to Minnesota)** *(see Tab 4 for breakdown of travel costs)* | 4,800.00 | 4,432.00 | 368.00 | 0.00 | 0.00 | 0.00 | 3,385.92 | 3,385.92 | 0.00 | 8,185.92 | 7,817.92 | 368.00 |
| **Construction** *(for what?)* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Other land improvement** *(for what?)* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Other** *(Describe the activity and cost)* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **COLUMN TOTAL** | 208,704.00 | 208,695.68 | 8.32 | 62,367.54 | 62,366.78 | 0.76 | 24,928.46 | 24,928.46 | 0.00 | 296,000.00 | 295,990.92 | 9.08 |

(1) #6 From K. Robinson Letter - See Next Page ( June 30, 2004 LCMR Work Program Report).

(2) Redistribution of Allocated time for Results 1 and 2, (October 29, 2004 LCMR Work Program Report).

(3) Redistribution of time for Results 1 and 2

(4) Redistribution of time and expenses for Results 2 and 3

Footnote (1): Item 6 from Ken Robinson's letter of April 28, 2004 to John Velin, Executive Director, LCMR.

HydroQual, Inc made a number of staff changes, although the overall Phase 1, 2 and 3 budgets did not change. Sergey Shpits worked on the project for a time and he has now been replaced. HydroQual also added Barry Cheney, Emely Scheible and Kristin Mumford. Time and budget allotted to Mr. Shpits was allocated to these individuals. Additional time for Mr. Shpits was also allocated to Melissa Morrone and George Kehrberger. HydroQual, Inc also moved Professor Stensel to the Professional/Technical Contracts category to be consistent with monthly reimbursement summaries. Only the revised Attachment A Budget Detail is included because the changes are identified here, and a mark-up of the attachment itself proved too confusing to be readable.

Footnote (2):

HydroQual has revised the time and budget for George Kehrberger, Gary Grey, Melissa Morrone and Kristin Mumford. Additional time was allocated to George Kehrberger from time originally allocated to Gary Grey. Additional time was also allocated to Melissa Morrone from time originally allocated to Kristin Mumford. The overall budgets for Results 1, 2 and 3 did not change.

Footnote (3):

HydroQual added John Sondey to the project team for Phase 2 work on the Report with Best Management Practices. Budget balances in Phase 1, Facility Examination and Data Review, show time spent by members of the project team exceeding their estimated budgets, offset by reduced Phase 1 effort by Gary Grey.

Footnote (4):

HydroQual has redistributed time and expenses for the Results 2 and Results 3 Budgets. There was a balance of $8,428.18 remaining in the Results 2 Budget. This balance was used to offset held labor charge of $5,308.96 for additional engineering analysis and report preparation required to complete Results 2. The remaining balance of $3,119.22 in the Results 2 Budget was used to offset the additional expenses of $3,118.46 required for the seminars in Results 3. Also, there was a labor charge held of $425 for Dr. Stensel that was required for report editing and corrections. This held charge was included with the remaining labor budget of $430.85 for Dr. David Stensel in the Results 1 Budget. The LCMR grant of $296,000 was not exceeded. The total balance at the end of this project was $9.08.

## Tab 1: Combined Cost

| Result 1 | | | | |
|---|---|---|---|---|
| | Combined Rate | Total Days | Personnel Cost | % of Total Hours |
| Dr. David Stensel | $950.00 | 24 | $22,800 | 10.47% |
| Dr. George J. Kehrberger | $1,281.44 | 39.2 | $50,232.45 | 17.11% |
| Gary M. Grey | $1,194.24 | 24.25 | $28,960.32 | 10.58% |
| Dennis E. Scannell | $851.52 | 35 | $29,803.20 | 15.27% |
| John G. Sondey | $638.40 | 0 | $0.00 | 0.00% |
| Melissa E. Morrone | $548.00 | 83.84 | $45,944.32 | 36.59% |
| Barry J. Cheney | $1,165.76 | 0.86 | $1,002.55 | 0.38% |
| Emely C. Scheible | $212.00 | 3.75 | $795.00 | 1.64% |
| Kristin M. Mumford | $468.00 | 18.25 | $8,541.00 | 7.96% |
| TOTAL RESULT 1 | | 229.15 | $188,079.73 | |

| Result 2 | | | | |
|---|---|---|---|---|
| | Combined Rate | Total Days | Personnel Cost | % of Total Hours |
| Dr. David Stensel | $950.00 | 12 | $11,400.00 | 23.56% |
| Dr. George J. Kehrberger | $1,281.44 | 9.67 | $12,391.52 | 18.99% |
| Gary M. Grey | $1,194.24 | 11.01 | $13,148.58 | 21.62% |
| Dennis E. Scannell | $851.52 | 16 | $13,624.32 | 31.42% |
| John G. Sondey | $638.40 | 2.25 | $1,436.40 | 4.42% |
| Kristin M. Mumford | $468.00 | 0 | $0.00 | 0.00% |
| Melissa E. Morrone | $548.00 | 0 | $0.00 | 0.00% |
| TOTAL RESULT 2 | | 50.93 | $52,000.83 | |

| Result 3 | | | | |
|---|---|---|---|---|
| | Combined Rate | Total Days | Personnel Cost | % of Total Hours |
| Dr. David Stensel | $950.00 | 6 | $5,700.00 | 42.86% |
| Dr. George J. Kehrberger | $1,281.44 | 6 | $7,688.64 | 42.86% |
| Gary M. Grey | $1,194.24 | 2 | $2,388.48 | 14.29% |
| Dennis E. Scannell | $851.52 | 0 | $0.00 | 0.00% |
| John G. Sondey | $638.40 | 0 | $0.00 | 0.00% |
| Kristin M. Mumford | $468.00 | 0 | $0.00 | 0.00% |
| Melissa E. Morrone | $548.00 | 0 | $0.00 | 0.00% |
| TOTAL RESULT 3 | | 14 | $15,777.12 | |

*NOTE: Rates are in $/day*

## Tab 2: Fringe Benefits Cost

| Result 1 | | | | |
|---|---|---|---|---|
| | Fringe Benefits Rate | Total Days | Personnel Cost | % of Total Hours |
| **Dr. David Stensel** | $50.00 | 24 | $1,200.00 | 10.47% |
| **Dr. George J. Kehrberger** | $46.56 | 39.2 | $1,825.15 | 17.11% |
| **Gary M. Grey** | $71.76 | 24.25 | $1,740.18 | 10.58% |
| **Dennis E. Scannell** | $62.48 | 35 | $2,186.80 | 15.27% |
| **John G. Sondey** | $58.96 | 0 | $0.00 | 0.00% |
| **Melissa E. Morrone** | $28.00 | 83.84 | $2,347.52 | 36.59% |
| **Barry J. Cheney** | $46.00 | 0.86 | $39.56 | 0.38% |
| **Emely C. Scheible** | $7.20 | 3.75 | $27.00 | 1.64% |
| **Kristin M. Mumford** | $28.00 | 18.25 | $511.00 | 7.96% |
| **TOTAL RESULT 1** | | 229.15 | $9,877.21 | |

| Result 2 | | | | |
|---|---|---|---|---|
| | Fringe Benefits Rate | Total Days | Cost | % of Total Hours |
| **Dr. David Stensel** | $50.00 | 12 | $600.00 | 23.56% |
| **Dr. George J. Kehrberger** | $46.56 | 9.67 | $450.24 | 18.99% |
| **Gary M. Grey** | $71.76 | 11.01 | $790.08 | 21.62% |
| **Dennis E. Scannell** | $62.48 | 16 | $999.68 | 31.42% |
| **John G. Sondey** | $58.96 | 2.25 | $132.66 | 4.42% |
| **Kristin M. Mumford** | $28.00 | 0 | $0.00 | 0.00% |
| **Melissa E. Morrone** | $28.00 | 0 | $0.00 | 0.00% |
| **TOTAL RESULT 2** | | 50.93 | $2,972.65 | |

| Result 3 | | | | |
|---|---|---|---|---|
| | Fringe Benefits Rate | Total Days | Cost | % of Total Hours |
| **Dr. David Stensel** | $50.00 | 6 | $300.00 | 42.86% |
| **Dr. George J. Kehrberger** | $46.56 | 6 | $279.36 | 42.86% |
| **Gary M. Grey** | $71.76 | 2 | $143.52 | 14.29% |
| **Dennis E. Scannell** | $62.48 | 0 | $0.00 | 0.00% |
| **John G. Sondey** | $58.96 | 0 | $0.00 | 0.00% |
| **Kristin M. Mumford** | $28.00 | 0 | $0.00 | 0.00% |
| **Melissa E. Morrone** | $28.00 | 0 | $0.00 | 0.00% |
| **TOTAL RESULT 3** | | 14 | $722.88 | |

*NOTE: Rates are in $/day*

## Tab 3: Total Labor Cost

| Result 1 | | | | |
|---|---|---|---|---|
| | Billing Rate | Total Days | Cost | % of Total Hours |
| Dr. David Stensel | $1,000.00 | 24 | $24,000.00 | 10.47% |
| Dr. George J. Kehrberger | $1,328.00 | 39.2 | $52,057.60 | 17.11% |
| Gary M. Grey | $1,266.00 | 24.25 | $30,700.50 | 10.58% |
| Dennis E. Scannell | $914.00 | 35 | $31,990.00 | 15.27% |
| John G. Sondey | $697.92 | 0 | $0.00 | 0.00% |
| Melissa E. Morrone | $576.00 | 83.84 | $48,291.84 | 36.59% |
| Barry J. Cheney | $1,211.76 | 0.86 | $1,042.11 | 0.38% |
| Emily C. Scheible | $219.20 | 3.75 | $822.00 | 1.64% |
| Kristin M. Mumford | $496.00 | 18.25 | $9,052.00 | 7.96% |
| TOTAL RESULT 1 | | 229.15 | $197,956.94 | |

| Result 2 | | | | |
|---|---|---|---|---|
| | Billing Rate | Total Days | Cost | % of Total Hours |
| Dr. David Stensel | $1,000.00 | 12 | $12,000.00 | 23.56% |
| Dr. George J. Kehrberger | $1,328.00 | 9.67 | $12,841.76 | 18.99% |
| Gary M. Grey | $1,266.00 | 11.01 | $13,938.66 | 21.62% |
| Dennis E. Scannell | $914.00 | 16 | $14,624.00 | 31.42% |
| John G. Sondey | $697.92 | 2.25 | $1,570.32 | 4.42% |
| Kristin M. Mumford | $496.00 | 0 | $0.00 | 0.00% |
| Melissa E. Morrone | $576.00 | 0 | $0.00 | 0.00% |
| TOTAL RESULT 2 | | 50.93 | $54,972.00 | |

| Result 3 | | | | |
|---|---|---|---|---|
| | Billing Rate | Total Days | Cost | % of Total Hours |
| Dr. David Stensel | $1,000.00 | 6 | $6,000.00 | 42.86% |
| Dr. George J. Kehrberger | $1,328.00 | 6 | $7,968.00 | 42.86% |
| Gary M. Grey | $1,266.00 | 2 | $2,532.00 | 14.29% |
| Dennis E. Scannell | $914.00 | 0 | $0.00 | 0.00% |
| John G. Sondey | $697.92 | 0 | $0.00 | 0.00% |
| Kristin M. Mumford | $496.00 | 0 | $0.00 | 0.00% |
| Melissa E. Morrone | $576.00 | 0 | $0.00 | 0.00% |
| TOTAL RESULT 3 | | 14 | $16,500.00 | |

*NOTE: Rates are in $/day*

## Tab 4: Travel Expenses

| Basis of Expenses: | | |
|---|---|---|
| | $450 | Airfare Round Trip From Seattle to Minneapolis/St. Paul |
| | $650 | Airfare Round Trip From Newark to Minneapolis/St. Paul |
| | $65 | Car Rental ($/day) |
| | $84 | Hotel Stay ($/day) |
| | $31 | Meals ($/day) |

### Travel Expenses: Result 1

| | | |
|---|---|---|
| Trip 1 | Dave Stensel and One HQI Person (5 Days) | 5 Day Trip |
| Trip 2 | Dave Stensel (2 Days), 2 HQI Persons (5Days), One HQI Person (2days) | 5 Day Trip |
| Trip 3 | Two HQI Persons (4 Days Each) | 4 Day Trip |

Estimated Expenses -

| | Trip 1 (5 Days) | | Trip 2 (2 Days) | | Trips 2 & 3 (8days) | | Totals By Expense |
|---|---|---|---|---|---|---|---|
| | DS | HQI | DS | HQI | 2 HQI X 2 | | |
| Airfare | $450 | $650 | $450 | $650 | 4 X | $2,600 | $4,800 |
| Car Rental | $325 | | $130 | | 2 X 8 | $1,040 | $1,495 |
| Hotel | $420 | $420 | $168 | $168 | 2 X 8 | $1,344 | $2,520 |
| Meals | $155 | $155 | $62 | $62 | 2 X 8 | $496 | $930 |
| | $1,350 | $1,225 | $810 | $880 | | $5,480 | $9,745 |

| Summary of Travel and Living Expenses | |
|---|---|
| Travel Expenses in Minnesota | $4,945 |
| Travel outside of Minnesota | $4,800 |
| TOTAL | $9,745 |

### Travel Expenses: Result 3

Dave Stensel and One HQI Person (2 1/2 Days) for 2 seminar presentation

Estimated Expenses - estimated 4 travel days

| | Trip 4 days | | Totals By Expense |
|---|---|---|---|
| | DS | HQI | |
| Airfare | $450 | $650 | $1,100 |
| Car Rental | $290 | | $290 |
| Hotel | $336 | $336 | $672 |
| Meals | $124 | $124 | $248 |
| | $1,200 | $1,110 | $2,310 |

| Summary of Travel and Living Expenses | |
|---|---|
| Travel Expenses in Minnesota | $1,210 |
| Travel outside of Minnesota | $1,100 |
| TOTAL | $2,310 |

### Travel Expenses: Results 1& 3

| Summary of Travel and Living Expenses | |
|---|---|
| Travel Expenses in Minnesota | $6,155 |
| Travel outside of Minnesota | $5,900 |
| TOTAL | $12,055 |