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Feasibility Study
Glenna Property – Balsam Lake

Prepared for:

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Balsam Lake, Wisconsin

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Executive Summary

Introduction and Background

Mead and Hunt, Inc., has completed a feasibility study on the Glenna Property, an 80-acre parcel of land upstream of Balsam Lake in Polk County, Wisconsin. The study's main goal was to determine a feasible alternative to improve the lake's water quality by treating the water in Rice Creek, a major tributary of the lake. Steady development near the lake has increased its sediment and nutrient loadings, encouraging algal bloom growth and causing a noticeable decrease in water clarity beginning in the early 1980s.

Since then, water quality studies have shown that the lake's excessive weeds and poor water clarity in the summer are due to high inflows of phosphorus from Rice Creek and the Milltown Sanitary Treatment Plant (WDNR, 1991). Based on those studies, the Balsam Lake Protection and Rehabilitation District, the Wisconsin Department of Natural Resources, and the Polk County Land Conservation District have taken steps to improve Balsam Lake water quality by reducing the phosphorus content. The WDNR established the Balsam Lake watershed as a *Priority Watershed Project* and has also constructed wetland demonstration projects to treat nonpoint source pollution within the lake's watershed. Polk County has plans to construct erosion control and water pollution control devices on agricultural land within the watershed and sediment basins on Rice Lake tributaries upstream of Rice Creek, and also plans to purchase a buffer around Rice Lake. The WDNR has also recently attempted to stabilize the lake bed by reestablishing wild rice there. Although those attempts have been unsuccessful so far, in 1998 Polk County hopes to reestablish wild rice on the lake bed after first consolidating it by an extended lake drawdown.

Using a grant from the WDNR *Lake Protection Program*, the Balsam Lake Protection and Rehabilitation District purchased the Glenna property to construct water quality improvements on the site for treating phosphorus-laden water in Rice Creek. The District retained Mead & Hunt, Inc., of Madison, Wisconsin, and Enviroscience of Eden Park, Minnesota, to assist in planning, designing, and constructing those improvements. This report documents the feasibility and assumptions of various alternatives on this site to improve Balsam Lake water quality.

Appendices A and B contain site location maps of Balsam Lake and the surrounding area and the Glenna property.

Phosphorus Removal Objective

The primary study goal was to analyze phosphorus removal structural practices along Rice Creek as it flows through the Glenna site that would remove at least 50 percent of the phosphorus loading into Balsam Lake from Rice Creek.

Data Analysis

The existing data were analyzed to determine the phosphorus loading rate into Little Balsam Bay from Rice Creek. The average streamflow rate was determined to be 4.4 cubic feet per

In this comparison, the most feasible three alternatives from economic and engineering perspectives are (in descending order):

- Sediment basin
- Chemical precipitation
- Dissolved air flotation

However, this report only considered the use of water quality improvement alternatives acting independently of the others. Based on our analysis, the *most* feasible alternative is a combination of a sediment basin with chemical precipitation that drains into a wetland, combining the two most feasible options with the low-cost wetland option. Using a sediment basin *in conjunction with wetlands* will, together, remove over 50 percent of the phosphorus.

The next step in the design process is to participate in the WDNR priority watershed program for Balsam Lake to obtain financing for design and construction of the recommended improvements. The application for funding grants is due June 1, 1996. Design will start on January 1, 1997, if priority watershed funding can be obtained.

Mead & Hunt recommends that the BLPRD pursue the following activities in the order listed:

- Participate in the Balsam Lake Priority Watershed Program.
- Undertake a detailed design project.
- Apply for construction permits.
- Construct the water quality improvement.
- Routinely maintain the structure once construction ends.

second (cfs), and phosphorus concentrations in Rice Creek were calculated to be about 1,500 pounds per year. To meet the 50 percent phosphorus removal goal, Mead & Hunt determined that the water quality structural improvement should remove 750 pounds of phosphorus annually.

Existing Site Conditions

The Glenna site topography is rolling hilltops with a wide valley that narrows from west to east. Rice Creek flows easterly for approximately 4,000 feet through the site. The Rice Creek drainage area calculated from the U.S. Geological Survey topographic map at the property (upstream of Otter Creek) is approximately 4.5 square miles.

Enviroscience gathered the field data, which, together with the creek profile, show that Rice Creek's channel slope and configuration is divided into three major segments as it flows through the Glenna property (see Appendix C and Figures 1, 2, and 3). Wetlands fall into three categories on the site's western, central, and eastern areas; the wetland delineation report is presented in Appendix D.

Soil borings were taken at six locations throughout the site to determine ground water levels and soil type (see Appendix E). The site is primarily sand overlain with organic materials, which are ideal for phosphorus removal.

Summary of Alternatives, Recommendations, and Future Activities

The alternatives discussed in this report were selected because of their very promising phosphorus removal rates. The WDNR is considering these alternatives and is interested in funding construction; permitting issues will be addressed early in the design phase.

Figures 4 – 12 in the report detail the alternatives considered in this study. The following briefly summarizes their cost and feasibility.

Alternative	Cost ($)	Negatives	Feasibility
Sedimentation basin	384,000	requires maintenance	feasible
Modified wetland	120,000	inadequate peat wetland area	infeasible individually
Wahnbach process	750,000–1 million	high construction and O & M costs	feasible engineering infeasible economically
Dissolved air flotation	300,000–400,000	requires manpower, O & M costs, and new technology	feasible (tentative)
Chemical precipitation into settling basin	446,400	high construction costs	feasible

Feasibility Study
Glenna Property - Balsam Lake

I. Introduction

Mead and Hunt, Inc., has completed a feasibility study on the Glenna Property to determine the feasibility of various alternatives to improve the water quality in Rice Creek, a major tributary to Balsam Lake. Funded by the Balsam Lake Protection and Rehabilitation District (BLPR) and the Wisconsin Department of Natural Resources (WDNR) *Lake Planning Grant Program*, the study's primary objective is to determine a feasible alternative to improve Balsam Lake water quality by treating the water upstream in Rice Creek.

Balsam Lake, the largest in Polk County, Wisconsin, is a three-basin, 1,900-acre lake that receives flow from two main tributaries, Rice and Harder Creeks. Harder Creek begins upstream of Half-Moon Lake and flows through and discharges to the main basin of Balsam Lake. Rice Creek begins upstream of Rice Lake and flows through and discharges to Little Balsam Lake. The only outflow from Balsam Lake is through Balsam Branch. Appendix A contains a site location map of Balsam Lake and the surrounding area (U.S. Geological Survey [USGS], 1993). Balsam Lake is primarily used for recreational purposes, with increasing population over the past 10 years. This increase has brought additional development around the lake, which increased the amount of sediment and nutrients (phosphorus and nitrogen) into the lake. The increased sediment and nutrients caused an increase in the lake's algal blooms and a notable decrease in water clarity in the early 1980s.

II. Background

Several studies have been done since the early 1980s to determine the water quality and nutrient and sediment loadings in Balsam Lake. A summary of the studies and their conclusions can be found in Mead & Hunt's *Summary of Reports – Balsam Lake (1995)*.

Past reports show that the two main problems in Balsam Lake, both of which are caused by excessive phosphorus input into the lake, are:

- Extreme variation in water clarity, with poor conditions during much of the summer

- Excessive weeds in select areas that receive heavy recreational usage

High inflows of total phosphorus are due to erosion of particles from slopes with easily erodible soils. Agricultural and domestic wastes deliver phosphorus to water bodies that is later released and made available to algae when the bottom sediment of a stream becomes anaerobic, causing water quality problems and eventually the eutrophication of a lake.[1]

Rice Creek is a major water and nutrient source to Balsam Lake (USGS, 1993). Even during drought years, 1987–1989, Rice Creek carried 90 percent of phosphorus received by Little Balsam Lake and 60 percent received by the entire Balsam Lake. Most nutrients came from Rice Lake and the Milltown sewage treatment plant (WDNR, 1991). Nutrient loadings to Rice Creek and Balsam Lake would increase in wet years because of greater nutrient release from the lake and surrounding areas. Therefore, removing phosphorus from the water will aid in reducing the algal blooms and in improving Rice Creek and Balsam Lake water quality.

Based on the findings in past studies and reports, the BLPR, the WDNR, and the Polk County Land Conservation District (LCD) have taken steps to improve the water quality in Balsam and Rice Lake by reducing the phosphorus content. The WDNR has established the Balsam Lake watershed as a *Priority Watershed Project* through the Wisconsin *Nonpoint Source Water Pollution Abatement Program* in 1992, which provides financial and technical assistance to landowners and local government to reduce nonpoint source pollution. The Balsam Lake watershed plan, which contains lake problems, hydrologic data, proposed goals, eligible cost-sharing improvements, and schedules, was finalized in June 1995. The WDNR has also constructed several demonstration projects consisting of constructed wetlands to treat nonpoint source pollution within the Balsam Lake watershed.

As part of the Priority Watershed, Polk County also has plans to construct water quality improvements within the Rice Lake watershed. The county is now working with farmers who own agricultural lands within the watershed to construct erosion control and water pollution control devices on the land. Jeff Timmons, Polk County director of land conservation, said that the county plans to construct several sediment basins on Rice Lake tributaries upstream of Rice Creek. Polk County also has plans to purchase a 100- to 200-foot buffer around Rice Lake to prevent nonpoint pollution from discharging directly into the lake.

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[1] Eutrophication is the process by which a water body becomes excessively rich in dissolved nutrients, which eventually leads to a seasonal deficiency in dissolved oxygen.

The sediment in Rice Lake contains excessive phosphorus due to loading from the Milltown Sanitary Treatment Plant (WDNR, 1991). The WDNR has recently attempted to stabilize the lake bed by reestablishing wild rice there. These attempts have been unsuccessful due to the murky, semisolid lake bottom condition and the wind fetch of the lake, which act to prevent the wild rice seeds from germinating. Recently, Polk County has indicated that another attempt to reestablish rice vegetation on the lake bottom is planned. The lake would be drawn down so that little or no water remained in the lake.[2] Rice Lake would be left at a low elevation for several months, during which time the bottom would consolidate. The lake would eventually be filled to a level 1 to 1.5 feet lower than its current elevation, and wild rice would be established on the consolidated lake bottom.

The drawdown of Rice Lake is a tentative idea at this time; permitting issues, environmental impact studies, and financial resources must be obtained first. Jeff Timmons estimates that this drawdown may occur in 1998 if all issues get resolved.

Using a grant from the WDNR *Lake Protection Program*, the BLPR has purchased an 80-acre parcel of land—the Glenna property, upstream of Balsam Lake along Rice Creek—on which to construct water quality improvements for treating phosphorus-laden water in Rice Creek. BLPR hired Mead & Hunt, Inc., of Madison, Wisconsin, and Enviroscience of Eden Park, Minnesota, to assist in planning, designing, and constructing those improvements. The first step in this process was to gather site data to address the feasibility of implementing the improvements on the property. This report documents the feasibility and assumptions of various alternatives on this site to improve Balsam Lake water quality. Appendix B contains a site location map of the Glenna property.

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[2] The drawdown would occur either by piping flow from the bottom of Rice Lake or by excavating the Rice Creek channel to allow for increased drainage.

III. Phosphorus Removal Objective

The primary objective of this feasibility study is to analyze phosphorus removal structural practices along Rice Creek as it flows through the 80-acre Glenna property. Due to the other phosphorus control practices described in *Section II*, the objective was to remove at least 50 percent of the phosphorus loading into Balsam Lake from Rice Creek.

IV. Existing Data Analysis

The existing data were analyzed to determine the phosphorus loading rate into Little Balsam Bay from Rice Creek. To calculate a phosphorus loading rate in pounds per year (lbs/yr), the average flow rate and phosphorus concentration of Rice Creek needed to be determined. Due to the large amount of data collected, the water quality data were researched from past studies on Balsam and Rice Lakes to determine accurate values. Table 1 summarizes the data gathered.

TABLE 1
Phosphorus-level Data

Year	Report	Phosphorus Level	Location
1988	USGS, 1987–1989	692 lbs	Mouth of Little Balsam Lake
1989		1144 lbs	
1991	Restoring Rice Lake at Milltown, Wisconsin	0.2 ± 0.1 mg/L	Outlet of Rice Lake to Rice Creek
1991	USGS Annual Data Reports	0.21-0.43 mg/L	Balsam Lake off Little Narrows
1992		0.014-0.03 mg/L	
1993		<0.02-0.027 mg/L	
1994		0.015-0.028 mg/L	
1995	Miscellaneous Data from Rice Lake (1995)	0.143 mg/L	Deepest spot of Rice Lake

The average streamflow on Rice Creek was 4.0 cubic feet per second (cfs) during the drought years of 1987-89 (USGS, 1993). This value corresponds to a 1995 calculation of streamflow in Rice Creek of 4.4 cfs (Miscellaneous Data, 1995). Because these values agree closely, an average streamflow of 4.4 cfs was used for the phosphorus loading calculation.

Several assumptions were made in selecting the phosphorus concentration value in Rice Creek:

- The 1987-1989 data were assumed low, because sampling took place during drought years. Because precipitation—and therefore runoff—was lower during this period, phosphorus loadings were lower.

- The 1991-1994 USGS phosphorus concentration data were assumed low, because sampling occurred in Balsam Lake, where phosphorus concentrations would already be diluted.

- The 1991 and 1995 Rice Lake phosphorus concentration data were used as a range for phosphorus levels, based on the assumption that there is minimal difference in phosphorus concentrations from Rice Lake to Rice Creek.

Using these assumptions, phosphorus concentrations in Rice Creek typically range between 0.15 mg/L and 0.2 mg/L. Using these concentrations and an average flow of 4.4 cfs, the average annual phosphorus loading into Little Balsam Bay from Rice Creek is:

Loading Rate (LR) = Phosphorus Concentration * Average Flow * Conversion Factor

LR = 0.15-0.2 mg/L * 4.4 cfs * 1,968.4

LR = 1,300-1,730 lbs/yr Approximately 1,500 lbs/yr

The phosphorus loading rate will be one of the criteria to consider when addressing the feasibility of Rice Creek water quality improvements. To meet the project objective of 50 percent phosphorus removal, the improvement should remove 750 lbs/year of phosphorus.

V. Existing Site Conditions

The 80-acre Glenna property is located in the NE1/4, NW1/4, and NE1/4, Section 28, T35 N., R17 W. Town of Milltown. The site topography is rolling hilltops with a wide valley that narrows from west to east. Rice Creek flows easterly for approximately 4,000 feet through the site. The Rice Creek drainage area calculated from the USGS topographic map at the property (upstream of Otter Creek) is approximately 4.5 square miles.

Enviroscience gathered the field data, which included soil borings, a wetland delineation, and a survey of cross sections of Rice Creek at 100-foot intervals on the Glenna property. The field survey data and the creek profile show that Rice Creek's channel slope and configuration is divided into three major segments as it flows through the Glenna property (see Appendix C).

- The first segment, which extends from the northwest corner of the property (Station 0+00) to the 155th Street road crossing (Station 23+00), is characterized by flat channel slopes of .0008 to .0003 ft/ft. The 20- to 40-foot-wide channel cross section in this reach has a relatively steep north bank of 10:1 (horizontal to vertical) side slope. The south side slope is very flat (50:1) as it extends into the existing wetland bordering the creek. Photographs of the first segment of Rice Creek are shown in Figure 1.

- The second segment, which extends from the 155th Street road crossing (Station 23+00) to the Glenna Barn (second segment Station 27+00), is characterized by a much steeper channel slope of .0038 ft/ft (vertical to horizontal). The channel cross section is still 20 to 40 feet wide, but both channel banks have relatively steep side slopes that range from 10:1 to 20:1. Photographs of the second segment are shown in Figure 2.

- The third segment, which extends from the Glenna Barn (Station 27+00) to the east edge of the property (Station 41+00), is characterized by an even steeper channel slope of .0068 ft/ft. The cross section in this segment is more confined than in the other two, with an average width of 10 to 20 feet and side slopes of 10:1 or greater. Photographs of the third segment are shown in Figure 3.

The wetland delineation report, which is presented in Appendix D, states that the wetland area on the property can be divided into three wetland areas - the western, central, and eastern areas. The western area contains organic soils and is dominated by cattails (*Typha latifolia*) and sedge (*Carex sp.*). The central area contains Seeleyville muck and has two distinct plant communities, emergent species and shrubs and trees. A few wetland species on-site are sedge (*Carex sp.*), softstem bulrush (*Scirpus validus*) and cattail (*Typha latifolia*). Some of the trees and shrubs in the area include black ash (*Fraxinus nigra*), box elder (*Acer negundo*), and buckthorn (*Rhamnus cathartica*). The eastern area contains soils that cannot be described by the Soil Conservation Service (SCS) series level due to their variation in color, texture, and thickness. The eastern area's vegetative communities are similar to those in the central area.

Figure 1 - Rice Creek
Station 0+00 (West property edge) to Station 23+00 (155th Street)

Figure 2 - Rice Creek
Station 23+00 (155th Street) to Station 27+00 (Glenna Barn)

Figure 3 - Rice Creek
Station 27+00 (Glenna Barn) to Station 41+00 (East property edge)

Soil borings were taken at six locations throughout the site to determine ground water levels and soil type. The soil boring logs and location map are shown in Appendix E. The site is primarily sand overlain with organic materials. Peat material also exists in the wetland area south of the creek and west of 155th Street.

The soil conditions on the Glenna property are ideal for phosphorus removal. The high porosity of the sandy soils allows for easy infiltration and corresponding filtering of the water. In addition, the high organic content of the soils will remove much of the phosphorus from the water.

Several water quality improvement alternatives that control phosphorus were considered for the Glenna property and Rice Creek. The following sections summarize the alternatives considered and include the following for each alternative:

- General alternative descriptions, including the phosphorus removal mechanism and expected removal rate
- Feasibility analyses, given the site conditions
- Cost estimates and site layouts

VI. Sedimentation Basin

A. Description

As shown in Figure 4, the use of a sediment detention basin to trap and remove particulates and corresponding phosphorus is a possible treatment alternative for the Glenna property along Rice Creek. Sediment basins act to decrease the velocity of the incoming water and allow the settling out of suspended water-borne sediments and phosphorus.

Wet detention basins have the capacity to remove 40 percent to 70 percent of the incoming phosphorus. A wet basin has a permanent water level between 3 to 6 feet deep in which most settling occurs. Biological and chemical activity from vegetative material in the sediment basin also contribute to phosphorus removal.

Due to the base flow in Rice Creek, an on-line system was considered in which the entire flow will be detained and treated. An off-line system, in which only a portion of the flow is diverted into the basin, would not provide a sufficient level of treatment to meet the project objective.

B. Feasibility Analysis

Feasibility criteria considered for the sediment basin were:

Pond surface – The surface area (SA) of the pond is critical to achieve the needed detention time to allow efficient particle removal rates. The WDNR recommends a surface area of:

> SA (square feet) = 625 * Drainage Area (in acres)
> (page C.4.2 in WDNR Construction Site BMP Handbook)
>
> SA (acres) = .002 (60% removal) to .006 (80% removal) * Drainage Areas (in acres) (page 4-23 in WDNR Wisconsin Stormwater Manual, Part Two, Technical Design Guidelines for BMP – 10/1/95 draft)

The direct contributing watershed is 4.5 square miles into the Glenna property. Using this value, the required surface area of the pond should be 41 acres (using the first criterion) or between 5.79 and 17.4 acres (using the second criterion). The first value may be high, because it is based on the entire upstream area being disturbed. Therefore, a surface area of 5.8 acres meets the WDNR's feasibility criteria for a sediment basin to remove 60 percent of the particulates.

Releasable water – The WDNR has established criteria under administrative rule NR 333 governing the release of water below a dam. Assuming the dam height will be less than 6 feet, the 7-day, 10-year low flow must be released, which is approximately 25 percent of the natural low flow. As described above, the natural low flow was measured during the drought years of 1988 and 1989 to be 4.0 cfs.

Therefore, a releasable rate of 1 cfs will be required below the proposed sediment basin.

Groundwater level – The sediment basin should have a minimum of 4 feet of depth between the basin's bottom and the groundwater level. This depth allows for adequate filtration and reduces the possibility of groundwater contamination with phosphorus-laden water. Due to the high groundwater table around Rice Creek, the sediment basin should be located in the area with the lowest groundwater elevation to achieve good phosphorus removal rates.

Channel slope – To minimize excavation below the existing channel elevation, the basin was assumed to be built up from the channel bottom. A berm would be placed across the channel backing the water up into a basin. However, the channel slope must drop off enough so that the water is not backed up upstream of the site onto adjoining property. As described above, the upper portion of the stream is exceedingly flat. The basin should therefore be located in the eastern portion of the property.

In summary, a 5.8-acre pond located in an area with maximum depth to groundwater on the eastern section of the property would be feasible to achieve a 50 percent phosphorus removal rate.

C. Cost Estimate and Site Layout

Figure 5 details the features and layout of a typical wet detention basin. Based on the feasibility analysis above, a sediment basin could be constructed on the eastern section of the property as shown in Figure 4. The basin bottom shown in Figure 4 would be set at elevation 1176 feet with 4 to 1 side slopes[3]. The basin could be created by moving the creek banks out. The soil borings indicate a groundwater depth of 1168.5 feet (Boring No. 4) at the northern limits of the pond. Using this groundwater elevation, an infiltration depth of 7.5 feet can be achieved.

The basin would be 6 feet deep, of which 3 feet would be continuously wet. The outlet would consist of an earthen berm lined with riprap placed in the existing channel. A low-flow pipe would be sized to release the 1 cfs required under NR 333.

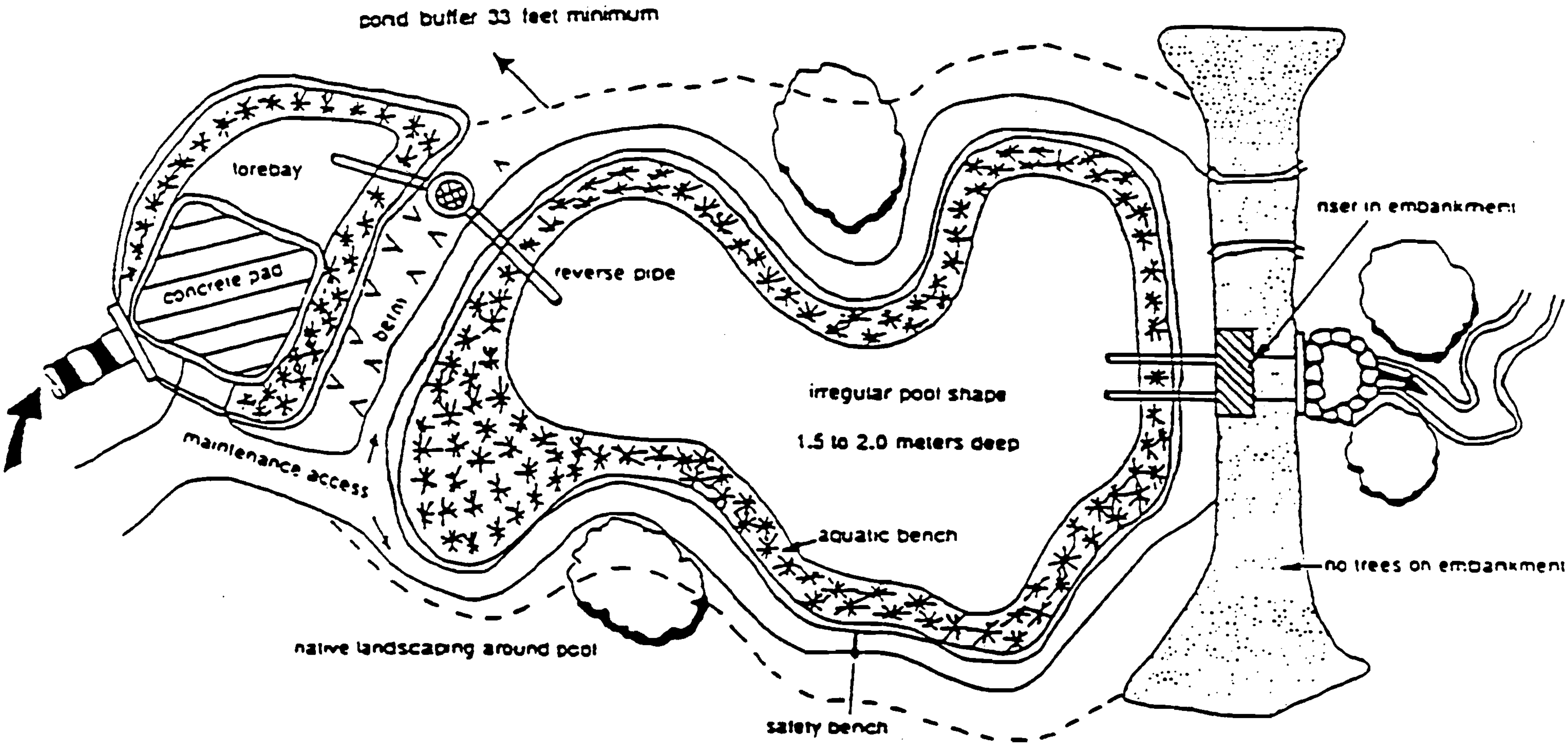
Table 2 is a preliminary cost estimate for the sedimentation basin.

[3] Elevations throughout this report are referenced to National Geodetic Vertical Datum.

TABLE 2
Sediment Basin Cost Estimate

Description	**Cost ($)**
Excavation	260,000
Outlet Structure	10,000
Erosion Control (including riprap)	50,000
Subtotal	320,000
Engineering & Contingencies	64,000
Total	384,000

Schematic Design of an Enhanced Wet Pond System



Source: Schueler, 1991.

Figure 5

VII. Modified Wetland

A. Description

Great potential exists for the natural wetland system surrounding Rice Creek to be used to treat the phosphorus from Rice Lake. Wetlands can provide water quality improvements that not only benefit the water, but nourish the wetland as well. Existing, natural wetlands growing on organic or mineral soils of relatively high permeability can be used for nutrient uptake and polishing of effluent waters (EPA, 1993). A common and simple method uses emergent wetlands growing on peat soils as ready-made free water surface treatment cells. This system uses a surface discharge pipe with multiple perforations along its length to maximize the contact of untreated waters with the wetland vegetation and rooting zone, such as that used by the Houghton Lake Sewer Authority at Houghton Lake, Michigan (EPA, 1993, pp 19-34).

Conceptually, this type of system relies on the very high cation exchange capacity of peat and other soils with high organic matter content, which immobilize nutrients due to their high fraction of organic colloidal complexes (Isirimah and Keeney, 1973). Treatment efficiency relies on flow-path length, hydraulic retention time, and degree of effluent contact with the organic substrate. Unsaturated layers that may seasonally occur in peatlands provide the best opportunity for treatment, because the available fraction of the pore space can function as a treatment filter as long as gradients and flow path lengths can accommodate the necessary volume of water for effective treatment.

In designing a natural wetland treatment system, the estimated areas should generally be increased based on regulatory requirements to protect the biological integrity of the natural wetland ecosystem. To allow for resting periods, to reestablish aerated soil conditions, and propagate woody species, conservative designs should be used. Doubling the area needed for treatment will ensure that at least half of the wetland area will be allowed to renourish itself for continued use (UW Extension, 1995).

A potential drawback to such systems is eutrophication and progressive deterioration of the surrounding plant community, usually resulting in monotypic cattail marshes. However, these results are usually associated with phosphorus loadings many times higher than the concentration in Rice Creek. Lower-level nutrient loadings to mesotrophic sedge meadows can cause a variety of adaptive responses in the vegetation, depending on the ecology of the individual dominant species (Aerts and De Caluwe, 1994).

B. Feasibility Analysis

Sedge meadow peatlands such as those adjacent to Rice Creek occur on glacial outwash plains, lake terraces and river bottoms. These peatlands can be the most effective natural wetland treatment systems, because they have favorable gradients and are commonly subjected to midsummer dry periods due to high evapotranspiration and depression of the regional water table (Trudell, 1985). Sedge meadow peatlands are also usually of moderate-to-high trophic status and so are less sensitive to nutrient-induced effects.

The phosphorus concentration in the water discharged from the modified wetland system is estimated using the following equation:[4]

$$C_o = C^* + (C_i - C^*) \exp(-kA/0.0365Q)$$

where:

where:	C_o	=	Outflow concentration (mg/L)
	C^*	=	Wetland background concentration limit (mg/L)
	C_i	=	Influent concentration (mg/L)
	k	=	Areal rate constant (m/year)
	A	=	Wetland area (hectares)
	Q	=	Flow rate (m^3/day)

The wetland background concentration is the concentration below which the water in a wetland never drops, due to the equilibrium between plant and soil uptake and release. This value has been reported to be between 0.015 and 0.005 mg/L for phosphorus. For this report, an intermediate value of 0.01 mg/L was used. The areal rate constant is a measure of how quickly a nutrient will be removed from the water. Kadlec and Knight recommend a k value of 12 meters per year for submerged-flow wetland systems. The site survey and wetland delineation indicated the suitable wetland area along the creek is 8 acres (3.2 hectares). The effluent phosphorus concentration was calculated for various influent phosphorus concentrations and flow rates that may be encountered at the Balsam Lake site. The actual phosphorus removal during the first year of operation may be higher than predicted by this equation, due to the adsorption of phosphorus to the wetland soils.

If 4.0 cfs of water from Rice Creek was pumped to the 8-acre wetland area with an influent phosphorus concentration of 0.2 mg/L, the computer program calculates that the phosphorus concentration as the water reenters Rice Creek would be 0.18 mg/L—a 10 percent removal rate during the 2- to 3-month season when water could be diverted to the wetland for treatment. If the flow rate discharged to the 8-acre wetland was reduced to 2.0 cfs, and the influent phosphorus concentration remained at 0.2 mg/L, the calculated outflow phosphorus concentration would be 0.16 mg/L. This would be a removal rate of 20 percent for the water applied to the wetland but would remain as 10 percent removal of the total phosphorus load in Rice Creek.

To calculate how much wetland area would be required to achieve the targeted 50 percent phosphorus reduction, the computer program was rewritten. Using an influent phosphorus concentration of 0.2 mg/L and a flow of 4.0 cfs, the wetland area required to reduce the outflow phosphorus concentration to 0.1 mg/L is 55 acres.

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[4] Dr. Robert H. Kadlec, professor of chemical engineering at the University of Michigan and Dr. Robert L. Knight, director of wetland technologies at CH2M Hill Consulting Engineers developed this equation and presented it along with supporting data at a University of Wisconsin seminar, *Creating and Using Wetlands for Wastewater and Water Quality Improvement*, April 24–26, 1995.

This is over six times the wetland area of the proposed wetland treatment system along Rice Creek on the Glenna property. The results of the computer program runs are shown in Appendix F.

Several additional computer runs, also shown in Appendix F, were done to test the sensitivity of the input data used to predict the phosphorus removal rates. The following variables were analyzed:

- *Influent phosphorus concentration.* Using an influent concentration of 0.15 mg/L, the area required to reduce the phosphorus concentration by 50 percent was calculated to be 56 acres, or nearly the same as if the influent concentration was 0.2 mg/L.

- *Background phosphorus concentration, C^*.* Using the lowest C^* value reported in the literature, 0.005 mg/L, the area required to reduce the influent phosphorus concentration of 50 percent was 53 acres.

- *Areal rate constant, k.* The area required to reduce the phosphorus concentration by 50 percent using the highest reported areal rate constant, 18 m/year, was calculated to be 37 acres.

These results indicate that the area required to reduce the phosphorus concentration by 50 percent does not change much over the range of influent concentrations and C^* values tested; even using the most favorable rate of phosphorus removal report still requires over four times the wetland area of the proposed wetland treatment system along Rice Creek on the Glenna property.

C. Cost Estimate and Site Layout

The 8-acre wetland parcel that could be used as the modified wetland is shown in Figure 6. The site would require metered three-phase electrical service to pump the water through the diversion pipe to the perforated pipe. The water would then filter through the wetland and be returned to the creek.

Table 3 is a preliminary cost estimate for the modified wetland alternative.

TABLE 3
Modified Wetland Cost Estimate

Description	Cost ($)
Piping	35,000
Pump	65,000
Subtotal	100,000
Engineering & Contingencies	20,000
Total	120,000

D. Maintenance

Maintenance of the wetland discharge system would depend mainly on the inputs of sediment. If algae or suspended mineral sediments are contained in the discharge waters, infrequent dredging or cleanup of deposited material may be required, possibly once every 10 years. This could be largely avoided through the use of a combined system with a sediment basin outside the wetland treatment area to remove suspended particles. However, even without pretreatment, the lake basin would function to a certain degree as a sediment trap, since the water withdrawal is at the lower end. Sediment loading and dynamics would be an important issue in the final design, in order to protect against excessive eutrophication and degradation of the wetland treatment area.

Dissolved phosphorous in itself would not represent a significant mass loading to the wetland. The absorption capacity of the wetland would be determined by the acidity (pH) of the peat, and the depth of the aerated layer during the middle of the growing season. Increasing acidity and mid-summer depth to the water table increases the absorptive capacity (cation exchange capacity) of the peat. Once absorbed, the dissolved phosphorous is permanently neutralized in the form of insoluble iron compounds and no maintenance would be required.

VIII. Chemical Precipitation – Wahnbach Process

A. Description

To reduce phosphorus levels in sediments and decrease the late-summer algal blooms in Balsam Lake, the water in Rice Creek could be withdrawn, the phosphorus removed in a water treatment plant, and the clean water recycled back to the creek. This process, known as the "Wahnbach process," is now being tested by the WDNR and Mead & Hunt at Devil's Lake in Baraboo, Wisconsin.

This process is designed after a German treatment plant that removes phosphorus from a river flowing into a drinking water reservoir near Bonn. The process entails pumping the water from the creek to aerate it and adding iron salts, thereby creating insoluble iron compounds with a very strong capacity for binding phosphorus. A chemical (an anionic polyelectrolyte) is then added to increase the size of the iron-phosphorus particles, the water flows through a mixed-media filter bed that traps the particles, and the water is returned to the stream. The filter bed is periodically backwashed to collect the iron-phosphorus sludge for disposal. Removal efficiency for phosphorus can range from 90 percent to 95 percent. A schematic of the Wahnbach process plant used at Devil's Lake is shown in Figure 7.

B. Feasibility Analysis

The Wahnbach process is a feasible alternative for the Glenna site. The base flow of the creek could be diverted through the treatment facility and clean water returned to the creek. Preliminary calculations show that with diverting the entire flow, 4.0 cfs, the Wahnbach process could attain a minimum 50 percent reduction in the creek's total phosphorus load. Since capital costs of treatment facilities are directly proportional to flow rates, we would recommend a reduced creek diversion of 2.2 cfs through the Wahnbach process. Preliminary calculations show that a maximum 90 percent removal rate could be expected for the treatment process, resulting in a maximum 50 percent reduction in the creek's total phosphorus load.

C. Cost Estimate and Site Layout

The treatment facility's estimated 3.0-acre site shown in Figure 8 would be located on the Glenna property. Components of the facility would consist of a creek diversion/intake structure, influent pumping system, process/filtration building, and sludge storage tanks. The site would require a metered three-phase electrical service and an access road to maintain and operate the treatment facility. The existing barn on the site could be used to house the structures needed for this process. The estimated schedule of operation for the treatment facility would be from March through October. This schedule is subject to change pending seasonal stormwater occurrences and first-flush events contributing to high phosphorus loading to Balsam Creek. This system requires an operator to check the site and operation daily through its seasonal use.

The opinion of probable construction cost for the Wahnbach treatment facility on the Glenna property ranges from $750,000 to $1 million. The annual operation and maintenance costs associated with power, chemical usage, and sludge handling would be approximately $35,000 to $45,000.

IX. Dissolved Air Flotation Process

A. Description

Dissolved air flotation (DAF) is a flow-through process that removes phosphorus by adding a flocculent to form a precipitate, which is then pushed upward by air being forced through the water. Additional removal efficiency can be obtained by directing the outflow from the DAF process through a sand filtration system. The DAF process is a new technique that is now being tested; laboratory results show that phosphorus removal ranges form 85 percent to 99 percent. Costs of this system are extremely variable, due to the minimal testing that has been done on it to date.

The DAF process has been applied for municipal and industrial wastewater projects, but is a new technique being considered for lake restoration projects. Recent laboratory results of lake water treated with the process show that phosphorus removal rates range from 85 percent to 99 percent. The WDNR, Bureau of Research, is tentatively scheduling a pilot study of this process at Devil's Lake in late summer 1996.

A DAF unit is shown in Figure 9.

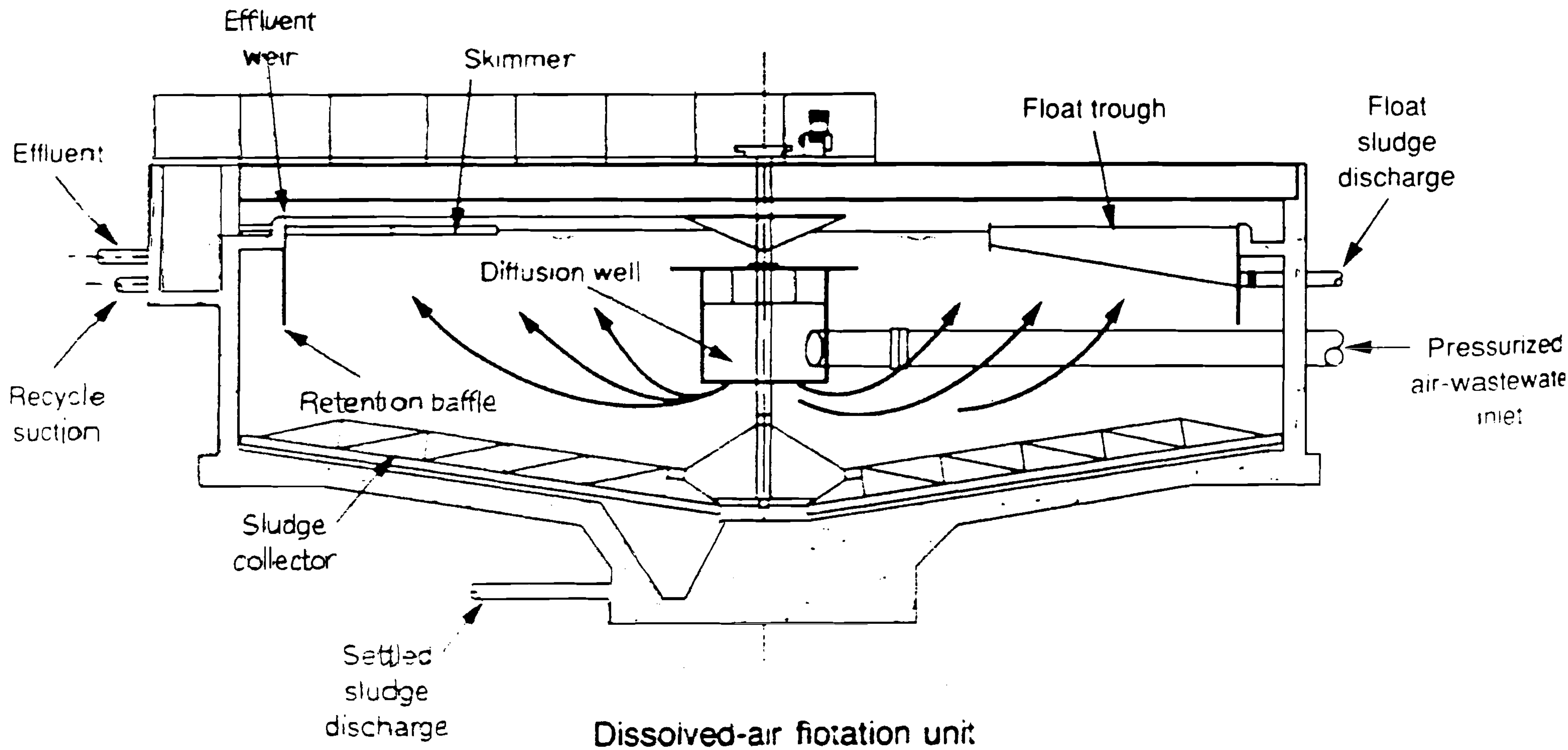
B. Feasibility Analysis

The DAF process is another feasible alternative for this site. The base flow of Balsam Creek could be diverted through the DAF treatment facility, similar to the Wahnbach process, and clean water would be returned to the creek. Preliminary calculations based on laboratory test results show that with diverting approximately 58.8 percent of the creek's total flow, or 2.35 cfs, the DAF process could attain a minimum 50 percent reduction of the creek's total phosphorus load.

C. Cost Estimate and Site Layout

The treatment facility's estimated 2.0-acre site shown in Figure 10 would be located on the Glenna property. The DAF facility area requirements would be smaller than the Wahnbach facility due to the compact size of the DAF equipment. The DAF facility would consist of a creek diversion/intake structure, influent pumping system, DAF process building, and sludge storage tanks. Some or all of the structures needed could be housed in the existing barn. The site would require a metered three-phase electrical service and an access road to maintain and operate the treatment facility. The estimated operation schedule for the DAF treatment facility is identical to the Wahnbach facility, i.e., March through October pending seasonal stormwater changes.

The construction cost for the DAF treatment facility on the Glenna property is difficult to determine, due to the lack of actual pilot and full-scale projects. However, based on preliminary cost information obtained on a planned 3.9-cfs facility scheduled for 1996 construction in Maryland, our opinion of probable construction cost is between $300,000 to $400,000. Annual operation and maintenance costs associated with power, chemical usage, and sludge handling is estimated to be between $35,000 to $45,000, similar to the cost of operating the Wahnbach treatment facility.



Dissolved-air flotation unit
Figure 9

X. Chemical Precipitation in a Settling Basin

A. Description

This process involves an off-line sediment basin in which the flow from the stream is diverted. A flocculent, such as ionic forms of aluminum, iron, and calcium, is added to remove the phosphorus from the water by precipitation. These metallic ions react with the orthophosphate in the water to form insoluble phosphate precipitates that settle to the bottom while clean water flows through the outlet structure of the sediment basin.

Alum, $Al_2(SO_4)_3$, is the precipitant commonly used, because phosphorus binds tightly to its floc over a wide range of ecological conditions including low or zero dissolved oxygen. Aluminum hydroxide, a brownish flocculent, is the precipitate that forms during the aluminum precipitation process. This flocculent rapidly grows in size as it binds both inorganic and organic forms of phosphorus to it. The flocculent eventually grows large enough that it settles out onto the bottom of the basin, usually within hours or days. After the flocculent settles out, the water is very clear.

B. Feasibility Analysis

Chemical precipitation can be effective in reducing the phosphorus concentration with typical removal rates of up to 80 percent. Adding these flocculents may decrease the pH of the water that can cause a problem in receiving waters. The pH and alkalinity of the Rice Creek water should be measured before treatment is implemented. At a pH below 6, a toxic form of aluminum may form causing fish mortality downstream. Balsam Lake is a hard water lake with a total alkalinity of 202 mg/L calcium carbonate ($CaCO_3$). This hard water will limit the extent of pH falling below the threshold of 6.

Recent studies in Edmonton, Canada, have shown 80 percent phosphorus removal rates using a combination of lime, $Ca(OH_2)$, and alum applied to surface waters. The combination of lime and alum keeps the pH between 6 and 9 and removes both filamentous algae and macrophytes, which are common in Balsam Lake.

Flocculation will also clarify the water by removing much of the suspended sediment in the flocculate. This phenomenon may have a negative effect by allowing a weed infestation to spread to deeper waters.

Laboratory experimentation using alum injections for phosphorus removal indicates dosage rates from 6 mg/L to 25 mg/L may be necessary for coagulation. Field tests on Lake Iroquois, however, indicate alum concentrations in excess of 100 mg/L have the greatest potential to remove phosphorus from the water table (Vermont Department of Water Resources and Environmental Engineering, Undated). The chemical injection rate is determined by two factors—flow rate and chemical concentration values. A jar test should be conducted during the design phase of this project to determine the site-specific ideal application rate.

Coagulant application can be either continuous or applied as a shock treatment to the surface of the standing water. Shock treatment applications can range in frequency from monthly to annual.

The accumulation of sludge in the bottom of the basin is a concern. Accumulations of 6 inch/year in a 1-acre detention basin draining a 100-acre basin have been reported for a dosage rate of 10 mg/L. Periodic cleaning out of the basin should be addressed as part of the design process.

C. Cost Estimate and Site Layout

The injection system consists of a pump, chemical holding tank, flow measurement device, feed hose and various fittings. Chemicals are pumped out of the holding tank through a connecting hose and introduced into the diverted Rice Creek water at a constant rate. The lime or aluminum needs to be mixed with Rice Creek water in a slurry maker as shown in Figure 11 and applied to the surface of the water. A typical layout for this alternative is shown in Figure 12.

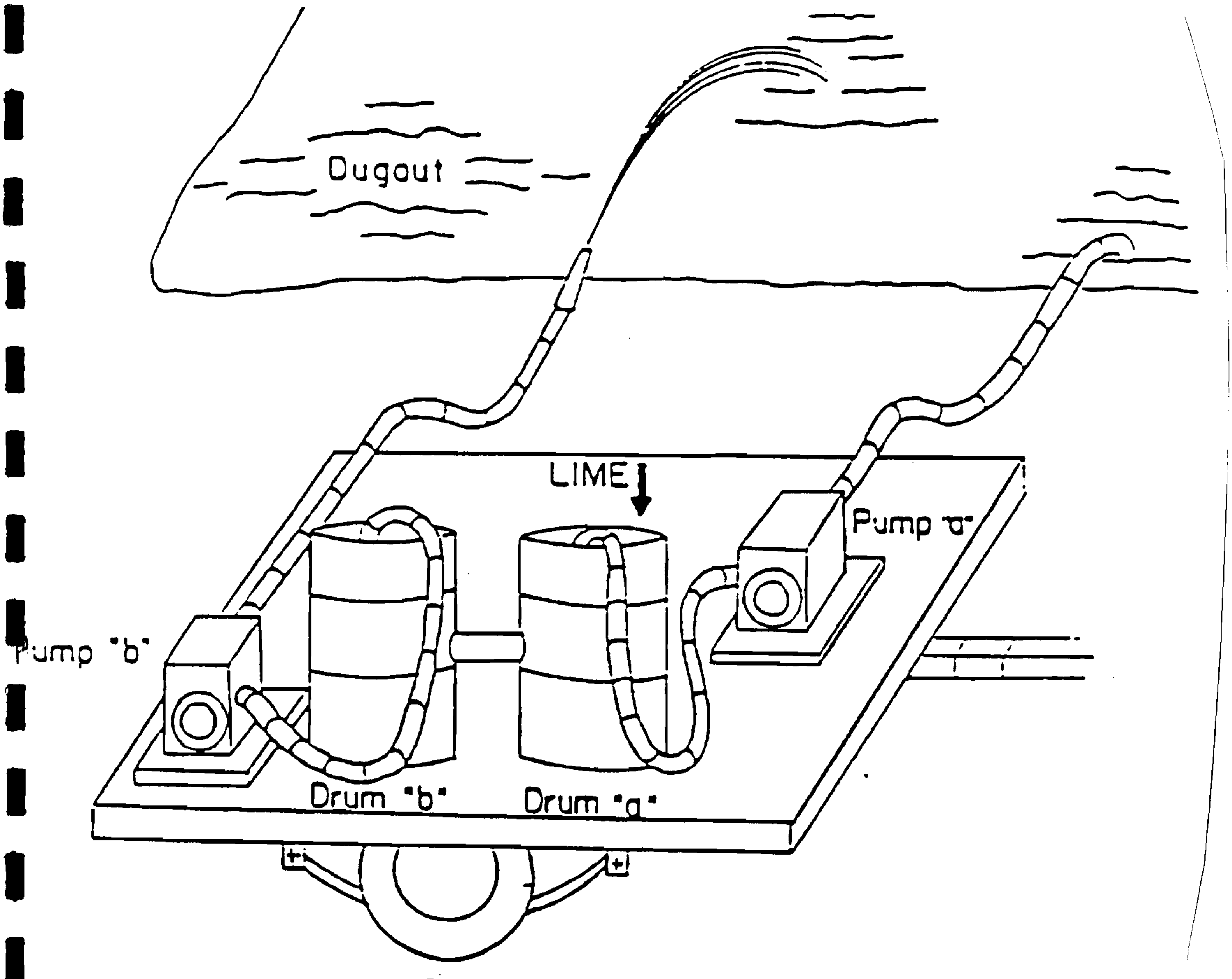
Table 4 is a preliminary cost estimate for this alternative.

TABLE 4
Chemical Precipitation Cost Estimate

Description	Cost ($)
Chemical feed equipment	52,000
Sedimentation Basin	320,000
Subtotal	372,000
Engineering & Contingencies	74,400
Total	446,400

The annual operating and maintenance cost for this alternative is $36,000.

Figure 11



Slurry maker and trailer.

XI. Recommendations and Future Activities

The five alternatives described in this report were selected from the many options available because of their very promising phosphorus removal rates. According to Dick Lathrop of the WDNR, the WDNR is considering these phosphorus removal alternatives and is interested in funding construction. The five alternatives require placing fill material in a wetland, which will require a 404 permit from the U.S. Army Corps of Engineers (COE) and subsequent WDNR permits. Wetland fill permits for construction projects are generally either Nationwide or Individual permits. Nationwide permits are available for a variety of small-scale projects conforming to a project-type description or requiring less than 50-cubic-yards of fill material in wetlands. Nationwide permits are not subject to public notice requirements. Projects not meeting the description of any Nationwide permit require an Individual permit which must be supported by an analysis of non-wetland alternatives. Individual permits require a public notice period and take longer to acquire. Permitting issues will be addressed early in the design phase. If wetland impacts are a necessary feature of the project, the impacts will be avoided, minimized, and compensated for, in accordance with Section 404 requirements during the detail design phase.

The feasibility of the five alternatives is summarized as follows:

1. **Sediment Basin** – A sediment basin is a feasible alternative for this site. The project objective of 50 percent phosphorus removal can be met with a 5.8-acre basin with 3 feet of standing water. The primary expense to building a basin involves grading and earth movement to shape it. An extra positive benefit is that a basin is a "passive" system, which does not require human intervention or electricity. A negative consequence is the maintenance that is needed on a sediment basin.

2. **Modified Wetland** – As described above, a modified wetland is a low-cost alternative in which Rice Creek water is rerouted to flow through the wetland to the south of the creek. The absorptive capacity of the peat acts to greatly reduce phosphorus in the water. While this alternative is attractive because of its low cost and simplicity, our engineering analysis shows that 50 acres of wetland are needed to remove 50 percent of the phosphorus. Our wetland delineation shows only 8 acres of peat wetland on the Glenna property, thus making this alternative infeasible.

3. **Wahnbach Process** – The Wahnbach Process is feasible at the Glenna site. This process has been tested experimentally by Mead & Hunt and the WDNR on Devil's Lake in Baraboo, Wisconsin, with phosphorus removals in excess of 90 percent to 95 percent. The main drawback is the high cost of constructing the storage tanks, chemicals, and filters needed for this process. In addition, the installation would require manpower to operate (one person per day to visit the site). Although feasible from the engineering perspective, the high cost of installation and maintenance makes this process economically infeasible.

4. **Dissolved Air Flotation** – The Dissolved Air Flotation (DAF) process is also a feasible alternative for the site. The cost to install this alternative is substantially less than the Wahnbach Process. However, similar to the Wahnbach process, daily manpower and a relatively high operation and maintenance cost is required. DAF is a newer

technology than the Wahnbach process and has not been tested as thoroughly. The WDNR is interested in funding the full-scale testing of this process. Because of its high operation and maintenance expense and its lack of testing, the DAF process is less feasible than the sediment basin alternative.

5. **Chemical Precipitation** – Chemical precipitation is a feasible alternative for this site. Chemical precipitation will remove over 50 percent of the phosphorus in Rice Creek. The cost is primarily due to creating a sediment basin to settle out the particulates. Our analysis assumed the basin size would be similar to the size of sediment basin used in Alternative 1. However, a smaller sized basin and corresponding reduced cost may be possible. The actual size of the basin, dosage rate, and dredging period will be addressed in the design phase.

This report has only considered the use of water quality improvement alternatives acting alone. In this comparison, the most feasible three alternatives from both an economic and engineering perspective are (in descending order):

- Sediment basin
- Chemical precipitation
- Dissolved air flotation

However, the *most* feasible alternative might well be a combination of these alternatives. Based on our analysis, the most feasible combination of alternatives is a sediment basin with chemical precipitation that drains into a wetland. This combines the two most feasible options with the low-cost wetland option. BLPRD has expressed sensitivity to the use of chemicals in a tributary to Balsam Lake. For this reason, we recommend a sediment basin/wetland combination without chemical precipitation. As mentioned above, there is not enough wetland area on the Glenna property to remove 50 percent of the phosphorus. However, using a sediment basin *in conjunction with wetlands* will, together, remove over 50 percent of the phosphorus.

We also recommend that Rice Creek monitoring be conducted semi-annually for total and dissolved phosphorus, both at the inlet and outlent from our treatment alternative. This monitoring will establish the phosphorus removal efficiency of our treatment system. Chemical precipitation can be considered as a future enhancement to our system if phosphorus removal rates are below 50 percent.

The next step in the design process will be to participate in the WDNR priority watershed program for Balsam Lake to obtain financing for the design and construction of the recommended improvements. The application for funding grants is due June 1, 1996. Design will start on January 1, 1997, if priority watershed funding can be obtained.

Mead & Hunt recommends the following future activities for BLPRD to pursue in sequential order:

- **The BLPRD should participate in the Balsam Lake Priority Watershed Program** – Mead & Hunt will assist BLPRD in filling out the grant application and fulfilling the WDNR requirements to participate in this program. We will present these requirements and discuss the priority program at a spring BLPRD meeting. Both the design and construction costs are funded either at 100 percent or 70-30 percent through this program.

- **A detailed design project should be undertaken** – The detailed design phase will address the size and actual expected phosphorus removal of the recommended "combination alternative." This detailed design phase will use the wetland delineation, soil borings, and survey data from this feasibility study to prepare final plans and specifications suitable for bidding purposes.

- **Needed construction permits should be applied for** – A COE 404 permit may be needed to place fill within a wetland adjacent to both sides of the creek. Due to the lengthy time to procure such a permit, we recommend that the permitting issues be identified early in the design process, and the necessary permits applied for as soon as possible to avoid construction delays.

- **The water quality improvement should be constructed** – Construction of the water quality improvement is scheduled for the summer of 1997. The priority watershed application submitted in June of 1996 should cover both design and construction of this process.

- **The structure should be routinely maintained once construction ends** – The maintenance of the structure is a critical element that is often overlooked. Periodic dredging must occur for the sediment basin to function properly. Periodic inspections of the outfall structure and overflow spillway should also occur to ensure that they are in good operating condition. Mead & Hunt will develop a maintenance plan for the structure as part of the design process in which scheduled maintenance will be detailed.

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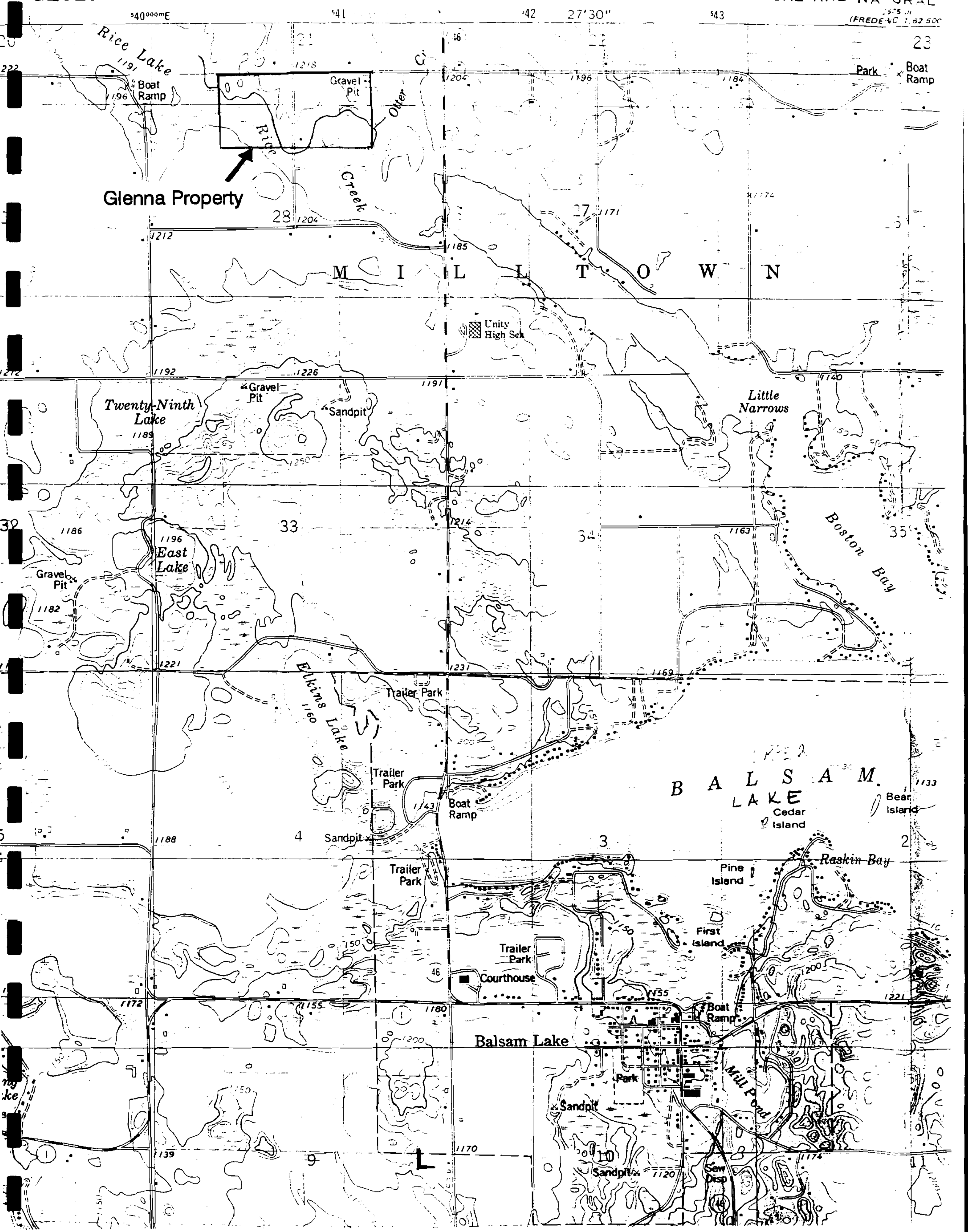
Glenna Property
Rice Lake
Boat Ramp
Gravel Pit
Otter
Ridge
Creek
Park
Boat Ramp
M I L L T O W N
Unity High Sch
Twenty-Ninth Lake
Gravel Pit
Sandpit
Little Narrows
East Lake
Gravel Pit
Boston Bay
Elkins Lake
Trailer Park
Trailer Park
Boat Ramp
B A L S A M
LAKE
Cedar Island
Bear Island
Sandpit
Trailer Park
Pine Island
Raskin Bay
First Island
Trailer Park
Courthouse
Boat Ramp
Balsam Lake
Park
Mill Pond
Sandpit
Sandpit
Sew Disp

Appendix D. Wetland Delineation Report

Introduction

This wetland delineation report was prepared in conjunction with the on-going Balsam Lake Water Quality Improvement Feasibility Study being conducted for the Balsam Lake Lake District by the consulting team of Mead & Hunt and Enviroscience. A jurisdictional wetland delineation was conducted on October 30, 1995 on the 80 - acre parcel owned by the Lake District (Glenna Site) as part of the feasibility study to identify and define the boundaries of on-site wetlands. The property location is NE 1/4, NW1/4 and NW 1/4, NE 1/4, Section 28, T35N, R17W, Town of Milltown.

Methods

Prior to the field investigation, background information was evaluated on potential wetland areas lying within the Glenna Site. Information sources included U.S.G.S. topographic and Wisconsin Wetland Inventory maps, aerial photographs and the USDA - SCS Soil Survey of Polk County, Wisconsin (1979).

Wetland boundaries were determined using the routine on-site delineation method outlined in the 1987 Army Corps of Engineers (ACOE) Wetland Delineation Manual. For an area to be classified as a wetland, three essential characteristics must be present:

1. wetland hydrology;
2. hydric soils; and
3. a predominance of hydrophytic vegetation.

Hydrology and hydrologic indicators and hydric soil indicators were evaluated within the on-site wetland areas. Primary indicators of hydrology included inundated or saturated soil conditions with secondary indicators consisting of water marks on trees, drift lines, drainage patterns, and sediment deposits. Soils were evaluated by excavating soil pits using a tile spade to a depth of 18 to 24 inches. Soil characteristics including matrix color and soil texture along with hydric soil indicators such as mottling, gleying and water table depth were recorded. Soil color was described according to the Munsell Soil Color Charts (1992 Revised Edition).

Where plant species have been referenced in the text, we have cited the common name, scientific name, and wetland indicator status according to the *National List of Plant Species that Occur in Wetlands, North Central (Region 3)* (USFWS Biological Report 88/26.3; May 1988). A plus or minus sign attached to a species' indicator status means that the species falls in the high or low end of the wetland frequency range for its classification, respectively. The various indicator categories are as follows:

Obligate Wetland (OBL): Species occur almost always (estimated probability >99 percent) in wetlands under natural conditions.

Facultative Wetland (FACW): Species usually occur in wetlands (estimated probability 67 to 99 percent) but occasionally found in non-wetlands.

Facultative (FAC): Species equally likely to occur in wetlands and non-wetlands (estimated probability 34 to 66 percent).

Facultative Upland (FACU): Species usually occur in non-wetlands (estimated probability 67 to 99 percent) but occasionally found in wetlands (estimated probability 1 to 33 percent).

Obligate Upland (UPL): Species occur in wetlands in another region but, under natural conditions, occur almost always (estimated probability >99 percent) in non-wetlands within the region specified.

Species that do not occur in wetlands in any region are not found on the National List.

No Indicator Status (NI): Insufficient information available to establish indicator status.

For an area to be considered a jurisdictional wetland, more than 50 percent of the composition of the dominant species from all strata (e.g. tree, shrub and herbaceous) must be OBL, FACW and/or FAC.

Based on the results of the assessment of the three wetland criteria, wetland boundaries were flagged and/or staked to be surveyed at a later date.

Results

Background Review

The review of background information indicated that a contiguous wetland complex was present but restricted to the western two-thirds of the property along Rice Creek, based on the Wisconsin Wetland Inventory classification and SCS soil descriptions. The eastern third of the property was not classified on the Wisconsin Wetland Inventory as wetland; however, SCS soil classification for this portion of the property indicated that wetlands could be present. The section of the property along Rice Creek was divided into three distinct wetland areas (Figure 1), the western, central, and eastern, which were distinguished by the major soil classifications. Forested and emergent wetland types were identified by the Wisconsin Wetland Inventory in the western and central wetland areas on the property. The western wetland area was classified as having deciduous forested and palustrine, persistent, narrow-leaved emergent wetland cover types (T1/E2H). The SCS had classified soils within this area as Rifle muck. The Rifle series is described as a histisol and is listed on the National and Wisconsin hydric soils lists. The central wetland area was classified as having a palustrine, persistent narrow-leaved emergent wetland cover type (E2H). The SCS had classified soils within this area as Seeleyville muck. The Seelyville series is described as a histisol and is listed on the National and Wisconsin hydric soils lists.

Field Investigation

The topography of the Glenna Site is rolling flat hilltops and a wide valley which narrows west to east across the site. Rice Creek flows easterly through the site and along the valley floor. Wetlands identified on the site were located adjacent to Rice Creek along the entire course through the property. The results of the field investigation confirmed that the western and central wetland complex consisted of forested and emergent wetlands; however, the wetland complex continues along the creek and is contiguous to similar wetland types off the property to the west and east. (Appendix A)

Western Wetland Area

Most of the western wetland area was inundated with as much as two to three feet of water. Near the northern and eastern edges, depth to water was within 12 inches of the surface in the soil pits, or oxidized root zones were observed.

Rifle soils comprised the bulk of this wetland area. Rifle soils are deep, very poorly drained, moderately rapidly permeable, organic soils formed from herbaceous plant material. Soil color within areas of the Rifle series had a matrix of black N 2.5/. Soil texture was characterized as sapric material (muck) to depth. The wetland edges were characterized as sandy loam to loam soils with a matrix color of very dark grayish brown 10YR 3/2 with few to common, prominent, yellowish red 5YR 4/6 mottles within the upper 12 inches of the soil profile.

The western wetland area was dominated by cattail (Typha latifolia, OBL) and sedge (Carex sp.) with the shoreline edges consisting of a mixture of tree species including black willow (Salix nigra, OBL) and box elder (Acer negundo, FACW-) and shrubs including sandbar willow (Salix exigua, OBL). Other hydrophytic species observed included: sedge (Carex sp.), blue vervain (Verbena hastata, FACW+), hummock sedge (Carex stricta, OBL) and reed canarygrass (Phalaris arundinacea, FACW+). A small group (approx. 200 feet in diameter) of dead trees was observed within the east end of this wetland area. The vegetation surrounding this wetland area to the north and south was mixed hardwood forest and to the east was pastureland or fallow fields.

Central Wetland Area

The central wetland area was located in the south central section of the site. Most of this wetland area was not inundated at the time of the field investigation with the exception of an approximately 3-6 foot zone adjacent to the creek which was inundated with several inches of water. The water table was evident in the soil pits to be within 12 inches of the soil surface.

The majority of the soils comprising the central wetlands area were Seeleyville muck. The Seelyville series consists of deep, very poorly drained, moderately rapidly permeable, organic soils. These soils formed in organic material derived from herbaceous plants. Soil color within areas of the Seelyville series had a matrix of black N 2.5/. Soil texture was characterized as sapric material (muck) to depth.

The central wetland area consisted of two distinct plant community types, the western half being comprised of a mix of emergent species and the eastern half, shrubs and trees. Emergent wetland species included sedge (Carex sp.), softstem bulrush (Scirpus validus, OBL), cattail (Typha latifolia, OBL), marsh milkweed (Asclepias incarnata, OBL), blue vervain (Verbena hastata, FACW+), and reed canarygrass (Phalaris arundinacea, FACW+). The tree and shrub species included black ash (Fraxinus nigra, FACW+), box elder (Acer negundo, FACW-), and buckthorn (Rhamnus cathartica, NI). The vegetation surrounding this wetland area was pastureland to the north, cropland to the west and south and mixed hardwood forest to the east.

Eastern Wetland Area

The eastern third of the site was not classified on the Wisconsin Wetland Inventory Map as wetland, however, wetland areas were delineated along this reach of the creek, thus making the wetlands on the site contiguous as described earlier in this report.

The eastern wetland area was not inundated during the time of the field investigation however, the water table was observed within 12 inches of the surface in the soil pits excavated in this wetland area. Additionally, the wetlands along the north side of the creek toward the eastern boundary of the property were elevated approximately 1-2 feet above the creek surface, yet the water table was within a few inches of the surface. These wetland areas are bounded to the north by a steep slope.

The SCS had classified soils within this area as fluvaquents which cannot be described on the series level because of wide variations in color, texture and thickness of individual layers. The soils within the eastern wetland area were quite variable in color and texture with both mineral and organic soils being present. Matrix color within the mineral soils varied from black 10YR 2/1 to very dark grayish brown 10YR 3/2. Mottles were observed in the mineral soils were prominent and common to abundant with colors of dark red 2.5Y 3/6, red 2.5Y 4/8 and yellowish red 5YR 4/6. Oxidized root zones were observed in several of the soil pits. The soil texture included sandy loam, loamy sand, silt, and fine to coarse sand and gravel. Organic soils were present at one location along the south central section of the creek. This soil consisted of sapric material to depth and was similar to the Rifle or Seelyville soils. The matrix color was black N 2.5/.

The eastern wetland area was similar to the central wetland area by having two distinct vegetative communities. An emergent wetland community dominated by sedge (Carex Sp.) and reed canary grass (Phalaris arundinacea, FACW+). The shrub community was dominated by speckled alder (Alnus rugosa, OBL). The eastern wetland area is surrounded by pastureland to the north, west and south and by mixed hardwood and pine forest to the east.