LAKE FRANCIS

DIAGNOSTIC-FEASIBILITY STUDY

(Clean Water Partnership Project #3371)

Prepared For

Minnesota Pollution Control Agency
On Behalf Of

ISANTI COUNTY
Government Center
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PREFACE

This document is based on brief historical lake and watershed data combined with part time water quality data. It represents the 1999-2000 trophic status of the lakes as well as the predicted or potential status using remedial alternatives.

Eutrophication is a dynamic process influenced by many internal and external forces. In using this document it is important to keep in mind the shortcomings inherent in making predictions and remedial recommendations.

Water Research & Management, Inc. would like to acknowledge Mark DeMuth, (Isanti County Soil and Water Conservation District), Roger Ramthun (Minnesota Pollution Control Agency), and Roger Hugill (Minnesota Department of Natural Resources, Department of Fisheries) for their time, effort, and information that enhanced the quality and technical accuracy of this study. It is with gratitude that we acknowledge the Lake Francis Improvement Association volunteers, and especially Don Quaintance and Robbie Thum who contributed their time and effort towards lake and stream monitoring, lake clean-up projects and many hours of meetings for the project. The volunteers conducted in-lake and streamflow water quality monitoring, maintained automated recorders, stream water level readings and velocities, storm event runoff samples, precipitation readings, and water levels. Their efforts and support were invaluable to the success of the project.

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CONVERSION TABLE

	Multiply By	To Obtain
Centimeters	0.3937	Inches
Hectometers	1000	Meters
Cubic Hectometers/Year	2.22	Acre-Feet/Day
Cubic Hectometers/Year	1.12	Cubic Feet/Second
Cubic Meters	35.31	Cubic Feet
Cubic Meters	264.2	Gallons
Hectares	2.471	Acres
Kilograms	2.205	Pounds
Kilograms	0 001102	Tons
Kilograms/Hectare	0.8924	Pounds/Acre
Kilometers	3281	Feet
Kilometers	0.6241	Miles
Meters	39.37	Inches
Meters	3.281	Feet
Square Kilometers	247.1	Acres

Non-Technical Summary

Isanti County, the Minnesota Pollution Control Agency (MPCA), and the Lake Francis Improvement Association (LFIA) co-funded the study of Lake Francis. The objectives of the study were to understand the current conditions in the lake and make recommendations for improving the water quality. Isanti County and LFIA contributed 50% of the study through cash and in-kind services and the remaining 50% was funded through the MPCA Clean Water Partnership Program (CWP).

Periodically, from October 1999 to May 2001, water samples were collected from the lake, its inlet and outlet. Water samples were analyzed for nutrients (phosphorus and nitrogen) and a variety of other chemical parameters, such as dissolved oxygen, selected to indicate various aspects of the water quality. Samples were collected of microscopic plants (algae) in the lakes and the aquatic vegetation. Flows into and leaving the lakes were measured. Finally, other studies conducted in the area were reviewed for information on soils, geology, hydrology, climate, vegetation, population, land use changes, and any other information relevant to the lake.

The following provides a brief summary of the findings from this study. We have attempted to address the major elements of the study and those often asked by interested parties. For further details, the reader should refer to the complete project report.

What is the status of the water quality in Lake Francis?

The lake is experiencing cultural eutrophication (a natural process caused by nutrient enrichment, but accelerated by people). Highly nutrient enriched lakes, such as Lake Francis, typically have abundant growths of aquatic weeds, algae, or both. Lake Francis has such poor water transparency due to wave action from wind and powerboats and bottom-feeding roughfish, that submerged aquatic vegetation is unable to grow. Most lakes in Central Minnesota are phosphorus limited, that is, of the two major growth nutrients, phosphorus and nitrogen, phosphorus is the nutrient that if controlled will most inhibit growth of algae and plants. Lake Francis is nitrogen limited due to the internal recycling of phosphorus. It must be remembered Lake Francis was a wetland and wetlands inherently store nutrients. Most of Lake Francis's available phosphorus is used by algae rather than aquatic vegetation.

What are the major sources of water to the lakes?

We need to know where the sources of water to the lake are in order to understand how we can improve its condition. The vast majority of water enters the lake from CD-10 (partially driven by groundwater) and precipitation (38 percent). Only about 5 percent of the water entering Lake Francis is from local runoff. The primary routes for water exiting the lake are at its outlet and evaporation/transpiration.

Historically what was the lake like and how has it changed?

Lake Francis was a wetland and therefore highly productive. The wetland's hydrologic and nutrient regimes were in balance with its ecological composition. With the routing of CD-10 into the wetland and damning of the outlet the wetland ecosystem was altered. With the rising water levels the existing plant communities began to change, those that could tolerate the increased water levels survived or were replaced by those species that could survive. Additional nutrient and sediment that were pumped in via CD-10 remained in the basin. Essentially the lake is not deep enough to allow for adequate sedimentation and not shallow enough to remain as a viable wetland. Influencing factors, like the bottom sediments being continually disturbed by wind and wave action, boat motors and foraging fish keep the water clarity so poor that submerged vegetation cannot grow and the water is too deep for emergent vegetation without adequate light penetration.

Where are the nutrients entering the lakes?

Lake Francis receives most of its phosphorus from the lake bottom. Phosphorus is recycled from the lake bottom every time the bottom sediments are disturbed. This recycling is known as internal loading. Originally the nutrient, stored in the wetland basin, was re-used by wetland vegetation. The addition of inflow from CD-10 increased the phosphorus load. Other sources of phosphorus include the atmosphere, and groundwater (including septic systems). A small amount comes from lakeshore runoff.

What will happen to the lake if nothing is done?

We developed estimates for what might happen to the lake under various conditions using mathematical models. The results from these models have uncertainty, but they indicate that if nothing is done the lake will remain as it is today and could further decline.

What can be done to improve the condition in the lake?

Water quality in Lake Francis can only be improved if the majority of internal phosphorus loading is halted. The lake is nutrient rich and is too shallow to allow for nutrient burial by sedimentation. Dredging is not an option due to a number of reasons including cost, regulations, and devastating effects on the ecosystem.

The only options are to drastically reduce the internal phosphorus loading by compaction of the sediments during a lake drawdown. During the drawdown (2 years), vegetation will be allowed to grow and the previous fishery population eliminated. Also during the drawdown, some lakeshore owners will be able to get MDNR permits to remove sediment, which will help reduce resuspension of sediment by boat motors once the lake is refilled. A reduction of resuspension of bottom sediments is the key factor in improving water clarity and reducing available phosphorus for algal growth. This effort will also necessitate the County to adopt and enforce a 'No Wake' ordinance and possibly a reduction in allowable horsepower for boat motors. After drawdown, the lake will be stocked with gamefish and managed as a periodic fish hatchery by the Minnesota Department of Natural Resources (MDNR). Maintaining the fishery will also require the addition of aeration during some winters to help prevent fish winterkill.

Along with efforts to reduce the internal nutrient loading, an effort must be made to reduce all other sediment and nutrient inputs to the lake. Septic systems must be brought into compliance, local runoff must be reduced and the sediment and nutrient concentrations in CD-10 must be reduced through best management practices, e.g., buffer strips offered through the Isanti County Soil and Water Conservation District (SWCD) office. Even though all other sources of nutrient are minor in comparison with internal loading, only with the concerted effort of the entire community will the water quality of the lake be improved.

Recommended Alternatives

Education and lake stewardship programs	$2,000
Lake Drawdown	$5,000
Individual septic system repairs and upgrades	$25,000 - $50,000
Adopt Water Craft Limitations	___
CD10 Erosion Control	$5,600
Aeration	$14,000-$28.000
Removal of Lake Sediment	___

How long will it take to see improvements in the lake?

Most of the lake degradation took place during the last 50 years. As sources of nutrient to the lake and within are further reduced, it is anticipated that the lake would improve over the next decade. Improvements after drawdown would be dramatic, but easily reversed if caution is not exercised. Future management of Lake Francis should focus on protection, fishery management, aquatic vegetation management and education.

The following Table represents short and long term goals for the Lake. Values shown are based on eutrophication computer modeling. Goals for Lake Francis are based on restoration alternatives. Theoretically, water quality restoration should take as long as a lake's water residence time, about 1 year, but some restoration alternatives make improvements, both visual and quantitative, quicker than some other alternatives. Short term and long term goals are achievable, but only through an effort by the whole community.

Short and Long Term Water Quality Goals*

	TP** (ug/l)	Chl-*a* (ug/l)	Secchi (m)
1999-2002	394	196	0.15
Short Term 2003 - 2005	100	33	0.4
Long Term 2005 - 2008	60	10	1-2.00

TP + or – 5 ug/l summer surface water average

How much will the proposed plan cost and why should I support it?

The cost of lake restoration depends on the approach eventually selected by the community steering committee. The estimated cost of the project is $ 133,000 for major tasks listed below. Degradation of a community resource can potentially impact everyone in the watershed. The impact might be recreational for one person and aesthetic for another, or financial for someone else. Fixing the problem is too costly for any one person or group, it takes a community effort.

Estimated Phase II Budget

Administration	$ 5,000
Public Meetings and Education	$ 2,000
Monitoring	
Phase II Plans and Meetings	$ 4,000
Field Work	$ 6,000
Laboratory Analysis	$ 5,000
Implementation of Alternatives	$ 88,000
Data Analysis and Assessment	$ 5,000
Annual Reports	$ 3,000
Final Report	$ 5,000
Contingencies	$ 10,000
Total	$133,000

What is the time-line for restoration activities?

The formation of a Steering Committee is the first task. This Committee should be made up of one individual each representing Isanti County, LFIA, farmer and lakeshore residents, MDNR, SWCD/NRCS and MPCA.

During 2002, the Committee, with assistance from natural resource agencies should begin a low-cost education program for the community. The LFIA should also work with the County to review individual septic system compliance and initiate discussions with City and Township planning and zoning to begin working toward an ordinance to establish a 'No Wake' lake to prevent continual resuspension of the lake bottom sediments. The LFIA should assist the Isanti County Soil and Water Conservation District in enrolling all land owners adjacent to CD-10 into the NRCS 10-year land set-aside and begin establishing 100-foot wide buffer strips along the ditch. The MDNR hydrologists and fisheries' department should initiate their plans to manage the lake drawdown, and manage the lake as a fish hatchery. Finally, the Committee should apply for a CWP Phase II grant for funding assistance. Implementation of septic upgrades, buffer strips and "No Wake" ordinance alternatives should begin in 2002 prior to the grant application. Once the Phase II CWP grant is received. Lake drawdown should begin no later than the fall of 2003 and the project should end in 2006.

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DIAGNOSTIC STUDY

Introduction

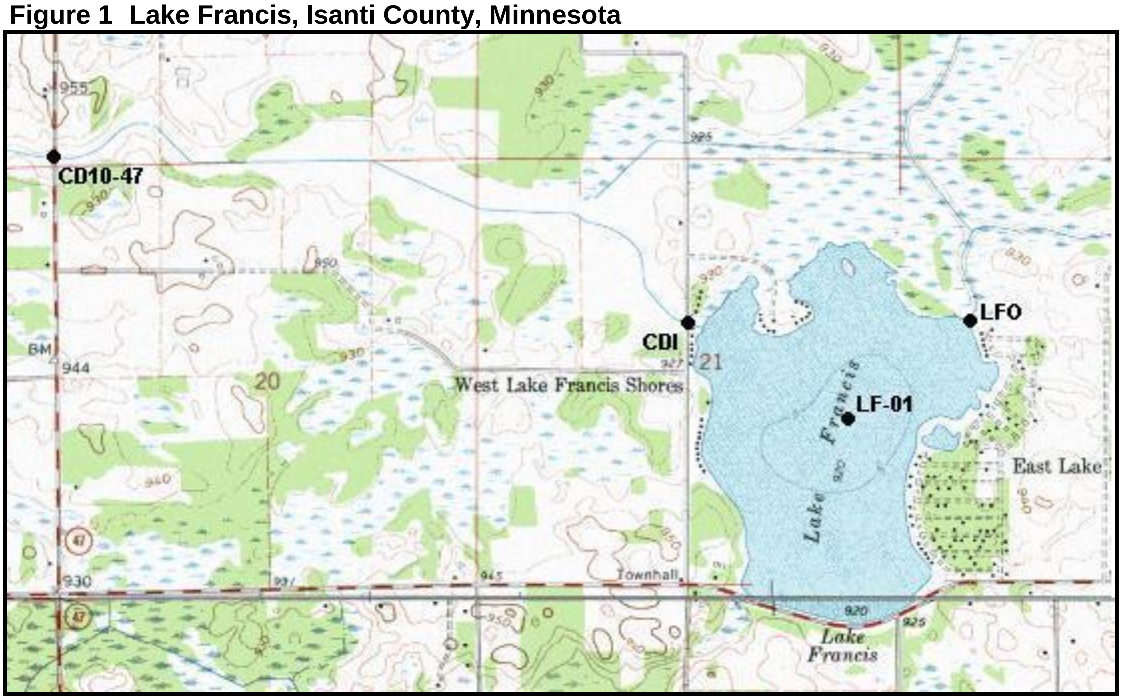
Lake Francis (30-0080) is located in east central Minnesota (Lat. 43°30'00" Long. 93°20'00") near the City of Isanti (Figure 1). Limited historical water quality data is available for the Lake. The Lake Francis watershed consists of County Ditch 10 (CD-10) flowing into the lake from the south, as well as surface runoff and groundwater.

Lake Francis is experiencing cultural eutrophication. Simplistically, eutrophication is the process of changing a water body into a wetland and eventually into dry land. Humans speed this process (cultural eutrophication) by introducing nutrient and sediment from a variety of sources. The lake's average Trophic State Index (TSI) places it in approximately the 0^{th} percentile range (one of the worst) when compared to other lakes in the region. Lake user perception, indicates a reduction in water transparency, an abundance of roughfish, an increase in algae, no aquatic vegetation and little use for recreation. Currently its main value is for wildlife and aesthetics.

The LFIA was formed to address the water quality of the lake. LFIA and Isanti County requested a Phase I grant under the Minnesota Pollution Control Agency, Clean Water Partnership Program. This study is a result of the request.

A major goal of the project is to improve the recreational quality of the lake by reducing the frequency and severity of algal blooms, increasing the water clarity and increasing the fisheries potential. The end goal of the project is to provide the lake stewards, Isanti County and LFIA, with a comprehensive strategy for managing, improving and protecting the water quality of Lake Francis.

Figure 1 Lake Francis, Isanti County, Minnesota



Methods and Materials
The goal of this diagnostic-feasibility study was to provide additional information on which to base an implementation plan for corrective action and future management of Lake Francis and its watershed.

Objectives were two-fold; (1) to gather additional base-line data about the water quality and quantity of Lake Francis and (2) determine the influence of the watershed on surface water quality.

Flowage sampling sites were selected by reviewing topographical maps, conducting a field inspection to determine where major hydrologic inflows occurred and whether or not they could or should be monitored. All inlets contribute to the hydrologic and potential pollutant loading of a water body. The loading influence is dependent on a variable number of factors. Lake studies are relatively expensive. An effort is made to gather as much information as possible from inlets which have hydrologic loads capable of having a significant influence on the lake since they are the inlets which are likely to carry the highest percentage of pollutants. Professional experience and judgement suggests that it is usually not cost effective to study a 3-inch tile when the contribution has relatively minor hydrologic and pollutant loads when compared to large storm drain, ditch, and stream systems. Nor is it usually cost effective to study an isolated road ditch that has occasional inflow. In both of these scenarios the runoff is already being partially treated, either by moving downward through the ground or through vegetation in the ditches. Drainage areas are defined for all major hydrologic inflows and all others are lumped into local runoff. The contribution of pollutant loading from minor runoff outfalls would be negligible, when compared to the remainder of the inflows. Proportionally, sampling all inflows can easily double the cost of sampling and sample analysis while having little influence on hydrologic, nutrient, and pollutant budgets.

Lake Francis has one major hydrologic inflow; County Ditch 10. Since Lake Francis is morphologically a large shallow dish-shaped basin there was only one in-lake sampling site. Lake Francis was sampled at a single station once monthly from January 2000 through September 2000 with a second sampling at the same station monthly from June 2000 through July 2000. County Ditch 10, the only inflow, and the outlet were sampled intermittently from October 1999 to September 2000. Lake Francis was sampled at one outlet station and at two inflow stations (Table 1 and Figure 1).

Field sampling was conducted by LFIA according to the project's Minnesota Pollution Control Agency (MPCA) approved work and monitoring plans (WRM, 1999). The LFIA volunteers underwent field training provided by the MPCA. Sampling equipment was purchased through the grant. The MPCA installed and maintained a continuous stage recorder where CD-10 crosses under Dahlia Road from October 1999 through October 2001.

Minnesota Department of Health Lab, St Paul, MN, did analyses of water quality samples. ZP's Taxonomic Services, Keizer, OR, and Aquatic Analysts, Inc. of Wilsonville, OR, performed zoo- and phytoplankton analyses, respectively. WRM personnel conducted a survey of Lake Francis's aquatic macrophytes during June and August of 2000. A summary of the study, which included a determination of Genera and species, frequency of occurrence, and species abundance is included in this report.

Table 1 Monitoring Sites

Station	Field Code	Flow Station	Lake Station
CD10 at HWY47	CD10-47	X	
CD10 at Dahlia Rd.	CDI	X	
Lake Francis Outlet	LFO	X	
Lake Francis**	LF-01		X

Due to the shallowness of the Lake (2-meters), all in-lake samples were collected as 2-meter composites. Water quality parameters included total phosphorus (TP), ortho-phosphorus (OP), ammonia-nitrogen(NH_3), nitrite+nitrate-nitrogen (NO_2+NO_3), total Kjeldahl nitrogen (TKN), alkalinity, pH, conductivity, total suspended solids (TSS), total volatile solids (TVS) and chlorophyll-*a* (Chl-a). Temperature, dissolved oxygen and Secchi depth were also measured during each sampling.

Zooplankton and phytoplankton samples were obtained from 2-meter composite surface samples during May and August sampling trips.

Hydrologic and nutrient loading budgets were modeled from 1999-2001 data using FLUX. FLUX is a computer model for estimating tributary loading from sample concentration data and flow records (Walker, 1987). The model provides an option to use several different methods of calculation. The option chosen for this study was the flow-weighted concentration method as it is usually the most accurate (Walker, 1987).

Loading, Flow-weighted concentration
Flux = Mean (w) Mean(Q)/Mean(q)
Where
c_i = measured concentration in sample i (mg/m^3)
q_i = measured flow during sample i (hm^3/yr)
w_i = measured flux during sample i = $q_i c_i$ (kg/yr)
Q_j = mean flow on day j (hm^3/yr)

In order to reduce potential bias, reduce the error variance of the mean loading estimate, and adjust for differences in sampled and non sampled flow regimes, data was divided into two groups, or stratified, and loading calculated separately with the above method. FLUX was applied to data from the tributaries and the outlets of each lake. Additional flow regimes for gauged and ungauged streams were estimated for inclusion in BATHTUB model implementation.

Implementation of hydrologic and nutrient balances and eutrophication response in Lake Francis were facilitated by a computer model, BATHTUB (Walker, 1987). BATHTUB implementation included one lake segment, one estimated inflow segment, local runoff, one gauged inflow segment and one outflow segment. Internal loading, precipitation, evaporation and available phosphorus were also factors in the modeling. The model core computes a hydrologic balance, nutrient balance, and eutrophic response.

Hydrologic and Nutrient Balances
Inflows = Outflows + Increase in Storage + Net Loss
Where
Inflows = external; advective; diffusive; atmospheric
Outflow = discharge; advective; diffusive; evaporation

Precipitation during the water year, October 1999 through September 2000, was 0.47.55 meters (18.72 inches) below the 30-year average of 0.72 meters. During the second water year, October 2000 through September 2001, precipitation was higher than the 30-year average at 0.96 meters (28.6 inches). Interestingly, the average precipitation during the two water years was equal to the 30-year average.

Precipitation was monitored at two stations within the watershed, but one station was dropped for lack of consistent data. Values for several missing months during 2001 were taken from the National Weather Service station in Cambridge. The number of precipitation monitoring stations, one per square mile (Holtan, et. al., 1962), was based on a watershed area of just over 2,500 acres. Average annual lake evaporation was estimated from the Minnesota Hydrology Guide (USDA 1975) to be 96.5 cm or 38 inches.

The average atmospheric nutrient loads in kg/km^2/yr were estimated at TP = 30, OP = 15, TN = 1000, and IN = 500 (Walker, 1985). Groundwater and local runoff flow were estimated at 0.3 hm^3 and 0.1 hm^3, respectively. Both Groundwater/Septic TP and local runoff TP concentrations were estimated at 200 ug/. Nutrient contribution from potentially leaking septic systems was included in groundwater.

Modeling options included; second order available phosphorus and nitrogen, mean chlorophyll-*a*, and Secchi depth (Walker, 1987). Second order available phosphorus modeling was chosen because it may be a better representation of what is occurring in the lakes. The phosphorus cycle is a dynamic process. Phosphorus is constantly being used, released, added, and lost. The modeling process increases the phosphorus concentration by about 50% at the start of its in-lake calculations.

Table 2 BATHTUB Definitions

a = Nonalgal Turbidity (1/m) = 1/S - 0.025 B
As= Surface Area of Segment (km^2)
Ac= Cross-Sectional Area of Segment (km*m)
A1= Intercept of Phosphorus Sedimentation Term
B1= Intercept of Nitrogen Sedimentation Term
B = Chlorophyll-*a* Concentration (mg/m^3)
Bp= Phosphorus-Potential Chlorophyll-*a* Concentration (mg/m^3)
CB= Calibration Factor for Chlorophyll-*a* (segment-specific)
C= Calibration Factor for Dispersion (segment-specific)
CN= Calibration Factor for N Decay Rate (segment-specific)
CP= Calibration Factor for P Decay Rate
CS= Calibration Factor for Secchi Depth (segment-specific)
D = Dispersion Rate (km^2/yr)
Dn= Numeric Dispersion Rate (km^2/yr)
E = Diffusive Exchange Rate Between Adjacent Segments (hm^3/yr)
Fs= Summer Flushing Rate = (Inflow-Evaporation)/Volume (yr^{-1})
FD= Dispersion Calibration Factor (applied to all segments)
G = Kinetic Factor Used in Chlorophyll-*a* Model
L = Segment Length (km)
N = Total Nitrogen Concentration (mg/m^3)
N_i= Inflow Total N Concentration (mg/m^3)
N_{iorg}= Inorganic Nitrogen Concentration (mg/m^3)
N_{org}= Organic Nitrogen Concentration (mg/m^3)
P = Total Phosphorus Concentration (mg/m^3)
P_i= Inflow Total P Concentration (mg/m^3)
P_{ortho}= Ortho-Phosphorus Concentration (mg/m^3)
Q = Segment Total Outflow (hm^3/yr)
Qs= Surface Overflow Rate (m/yr)
S = Secchi Depth (m)
T = Hydraulic Residence Time (years)
U = Mean Advective Velocity (km/yr)
V = Total Volume (hm^3)
W= Mean Segment Width (km)
W_p = Total Phosphorus Loading (kg/yr)
W_n= Total Nitrogen Loading (kg/yr)
Z = Mean Total Depth (m)
Z_x= Maximum Total Depth
Z_{mix}= Mean Depth of Mixed Layer (m)

Phosphorus Sedimentation

P=[-1+(1+4 CP A1 P_i T)0.5]/(2 CP A1 T) where
A1 = 0.17 Qs/(Qs+13.3) and Qs= Maximum (Z/T,4)

Nitrogen Sedimentation

N=[-1+(1+4 CN B1 N_i T)0.5]/(2 CN B1 T) where
B1 = 0.0045 Qs/(Qs+7.2) and Qs= Maximum (Z/T,4)

Mean Chlorophyll-*a*

B=CB B_p/[(1+0.025 Bp G) (1+Ga)] where
G =Z_{mix} (0.19+0.0042 Fs) and Bp=P1.37/4.88
N_{inorg}/P_{ortho} > 7 and (N-150)/P > 12

Secchi vs. Chlorophyll-*a* and Turbidity

S= CS/(a + 0.025 B)

Exchange Flows Between Adjacent Model Segments

D = CD FD 100 W2 Z-0.84 Maximum (U, 1)
Dn = U L/2
E= Maximum (D-Dn, 0) Ac/L

Both computer models are rather complex with numerous internal relationships existing. The formulas presented above are presented to indicate options selected for use with the data. It is suggested that readers of this report, who are interested in specifics, refer to the referenced FLUX and BATHTUB publications.

Change in Mass Phosphorus Storage

CM = (P_{mean} • CV) + (C_{mean} • CP) where: CM = Change in Phosphorus Mass
P_{mean} = whole lake volume weighted end minus start
CP = P end - P start
V_{mean} = mean lake volume
CV = Change in lake volume end minus start

Internal Phosphorus Load

((P_{2hypo} - P_{1hypo}) • V) • D where:
P2 = end hypolimnetic phosphorus concentration
P1 = start hypolimnetic phosphorus concentration
V = hypolimnetic volume
D = anaerobic days

Trophic State Indexes are based on mean summer epilimnetic total phosphorus, chlorophyll-*a*, and Secchi transparency and calculated after Carlson (1977) relative to trophic state indicator ranges adopted by the MPCA (1985). TSI values were calculated as follows:

Trophic State Index

Secchi disc TSI = 60 - 14.41 ln (SD)
Total Phosphorus TSI = 14.42 ln (TP) + 4.15
Chlorophyll-a TSI = 9.81 ln (Chl-*a*) + 30.6
Where
SD = Secchi depth in meters
TP = Total phosphorus in ug/l
Chl-*a* = Chlorophyll-*a* in ug/l

Description of the Project Area

Lake Identification

Lake Francis (#30-0080), located approximately three miles northwest of Isanti, in Isanti County Minnesota (Lat. 45 30'00"; Long. 93 20'00"). The lake has a surface area of 301 acres (122 ha), a maximum depth of 7 feet (2 m), 3.6 miles (3.85 km) of shoreline and a fetch and width of 0.9 miles (1.5 km) and 0.5 miles (0.8 km), respectively. The lake's volume is approximately 900 acre-feet (1.2 million cubic meters). All of the lake's surface area is littoral (<5m). The Lake's watershed is approximately 3,840 acres (1,554 ha) (Figure 2).

The lake is located in the North Central Hardwood Forest Ecoregion and has a relatively small watershed compared to its lake area. Lake Francis has a watershed to lake ratio of 12:1.

Geology and Soils

Glacial and postglacial deposits dominate Isanti County's landscape. It is characterized by undulating and rolling morainic hills, outwash sand plains, old glacial lake beds, numerous bogs, lakes, dry stream channels, and barbed streams. Isanti County contains two types of glacial drifts. The middle Wisconsin, or red drift, named for the color of its unweathered material is the older of the two types. The material this drift is composed of was transported from the Lake Superior area by a glacier that moved Southwest.

The newer drift was deposited from the Grantsburg sublobe of the Des Moines lobe, which moved from the Northwest. This material which is deposited from limestone and shale has a gray color, and is commonly called gray drift. Gray drift is finer in texture and less stony than red drift.

The extensive Anoka Sand Plain covers sixty percent of Isanti County and was formed by the Mississippi River as it followed the retreat of the Grantsburg sublobe. The sand plain is a smooth area with scattered dune-like knolls of wind deposited materials with many small isolated wetlands. In most places the sand overlays the gray drift in thicknesses of a few inches to several feet (USDA 1958).
Lake Francis's watershed is located within the Zimmerman-Lino Association, commonly known as the Anoka Sand Plain. A brief description of the soil association follows.

The Zimmerman-Lino soil association consists primarily of Zimmerman and Lino soils with Isanti, Anoka, Braham, and Blomford soils also present. The soils range from nearly level and sloping on plains and terraces to very steep slopes around drainage areas and wetlands. All of the soils in the Zimmerman-Lino Association are acidic. The upland soils are draughty, and low in fertility, but easily worked and respond well to improvement management practices.

Hydrology

Lake Francis is a subwatershed of the Rum River. The lake's immediate watershed resulted from the re-routing of County Ditch 10 into the wetland basin now know as Lake Francis.

There is relatively little local surface runoff into Lake Francis in comparison with direct precipitation on the lakes. As much as 20 percent of the watershed is comprised of depressional wetlands that capture many or the nominal runoff events prior to entering the lake. Only larger precipitation events and those that take place during snowmelt and on frozen soil reach CD-10 and result in streamflow.

Precipitation

LFIA volunteers monitored precipitation within the watershed. The project area received well below average precipitation (47.55cm / 18.72in) between October 1999 to September 2000, but well above average precipitation between October 2000 through September 2001 (96.22cm / 37.88in) (Table 3 and Figure 3). The 30-year precipitation average for the area is about 71.8cm or 28.6in (State Climatology Office - MDNR 1961-1990). The following hydrologic year, October 2000 through September 2001, as measured in Cambridge, was a very wet year with. 96.21cm (37.88 in) of precipitation. Average annual lake evaporation was estimated from the Minnesota Hydrology Guide (USDA 1975) to be 96.5 cm or 38 inches.

Figure 2 Lake Francis Watershed

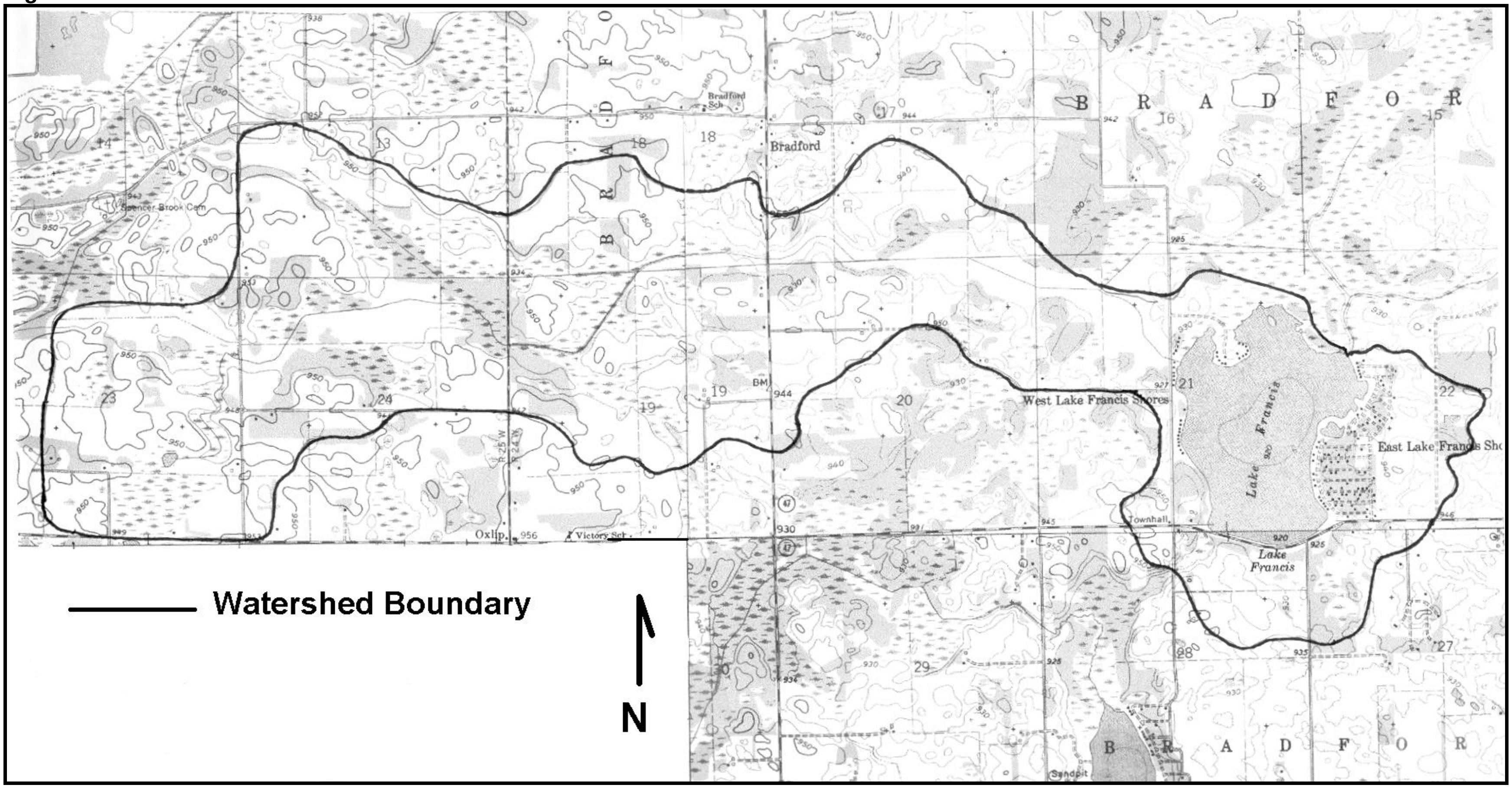
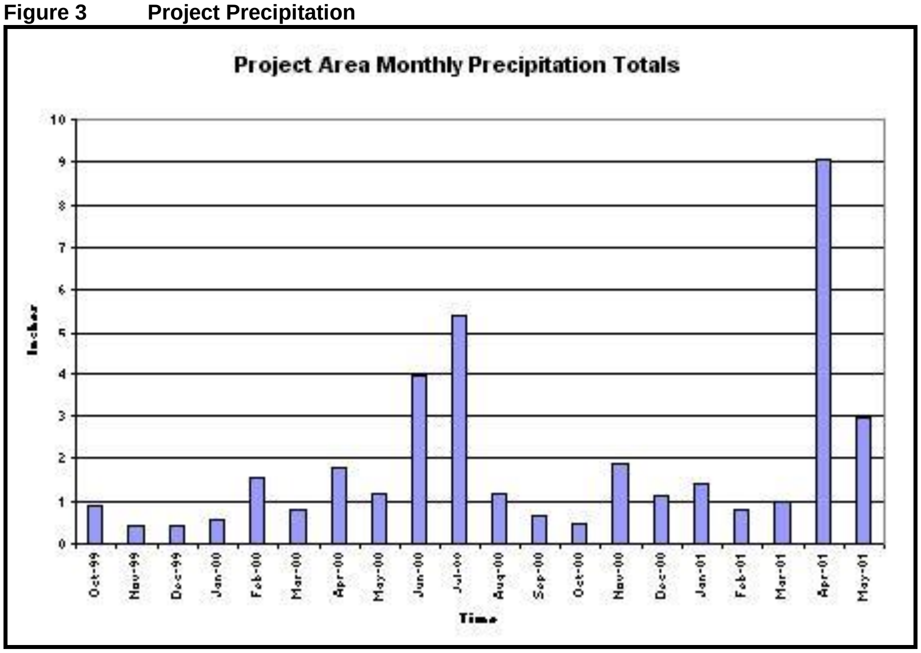


Table 3 Precipitation in the Project Area

Month	Precipitation (inches)	Precipitation (centimeters)	Source
Oct-99	0.91	2.31	LF Watershed
Nov-99	0.40	1.02	LF Watershed
Dec-99	0.40	1.02	LF Watershed
Jan-00	0.54	1.37	Cambridge
Feb-00	1.56	3.96	Cambridge
Mar-00	0.82	2.08	Cambridge
Apr-00	1.78	4.52	LF Watershed
May-00	1.16	2.95	LF Watershed
Jun-00	3.96	10.06	LF Watershed
Jul-00	5.38	13.67	LF Watershed
Aug-00	1.17	2.97	LF Watershed
Sep-00	0.64	1.63	LF Watershed
Oct-00	0.49	1.24	LF Watershed
Nov-00	1.86	4.72	LF Watershed
Dec-00	1.15	2.92	LF Watershed
Jan-01	1.39	3.53	Cambridge
Feb-01	0.81	2.06	Cambridge
Mar-01	0.98	2.49	Cambridge
Apr-01	9.04	22.96	Cambridge
May-01	2.96	7.52	Cambridge

Figure 3 Project Precipitation



Public and Private Lake Access

Lake Francis lies within a region that is urban and residential but surrounded by agriculture and open land/wetland. The lake is midway between State Highways 47 and 65 on County Route 5 and just west of the city of Isanti and east of the towns of Oxlip and Bradford.

There is one public lake access on the southeast side of the lake. The frequency of lake visitations is unknown. There is no official park area.

Permanent Housing

The lakeshore around Lake Francis is heavily developed, with 76 homes or cabins along the east and west lakeshore and approximately 50 houses in the immediate vicinity of the lake, but mostly clustered in East Lake Francis Shores (MDNR1994).

Socio-economic/Population Data

Approximately 9000 people reside within the watershed year round and there are several seasonal residences. Lakeshore property in central Minnesota has an estimated value of $400 per linear foot making the shoreline property of Lake Francis worth about 7 million dollars. Permanent and seasonal homes on the lake have an estimated value of 2 million dollars.

Historical and Current Lake Use

Historically, Lake Francis was a wetland. There has never been much recreational use primarily due to a mean water depth of about three feet.. Occasional use for boating and fishing do occur. Many years of MDNR records have found no ice-fishing occurrences and there is little contact in the way of swimming or personal watercraft due to the depth, turbidity and soft silty bottom.

Specific Impact of Lake Degradation on User Population

There is no known historical information available pertaining to the impact water degradation may have had on recreational use of the lake, mostly because Lake Francis has never been a recreational lake.

The project area lakes are experiencing advancing eutrophication. Complaints of poor water quality in Lake Francis generally pertain to surface scum and debris, a lack of aquatic macrophytes, algal blooms, shallowness of the lake (depth), roughfish, and poor water transparency. These problems, for the most part, are a result of the way the lake was created (flooded wetland), excessive nutrients, predominately phosphorus, and sediments that enter the lakes from runoff during the spring thaws and rainstorms, occasional backing up of the Rum River, winter kill and internal loading.

Point Sources of Pollution

There are two farms, one to the southwest and one to the northeast of the lake, but neither have an impact on the lake (DeMuth, 2002). Most agriculture is taking place on leased land. There are no other known point sources located within the Lake Francis watershed.

Land-Uses in the Watershed

The watershed is characterized as 10 percent forested, 2 percent urban - residential, 33 percent agricultural, 5 percent water, 50 percent wetland (Table 4). The primary use of land in the project area is urban - residential and agricultural activities in the watershed.

Table 4 Watershed Land Use

	Percent
Forested	10
Urban-Residential	2
Agricultural	33
Water	5
Wetlands	50

Source: Minnesota State Planning Office, St. Paul, MN

Fisheries

Species and populations vary depending on the ecological community structure and ecological interactions. The MDNR classifies Lake Francis as a roughfish lake and is managed as such. Roughfish lakes are often without aquatic vegetation, fertile, hardwater lakes and generally have large populations of rough fish.

Lake Francis has had high numbers of yellow perch and black bullhead and low numbers of panfish and other species. Past fish stocking efforts have included bass, sunfish and crappies. Perch, yellow bullheads and carp have been removed from the lake in the past. Lake Francis is prone to winterkill. Low dissolved oxygen concentrations during the winter have been noted many years.

Aquatic Vascular Plants

Aquatic vascular plants in Lake Francis are not particularly diverse. There is no record of prior macrophyte surveys conducted on Lake Francis. The most commonly found macrophytes during 2000 were emergent; submerged macrophytes were all but non-existent.

Historical Water Quality

There is little to no record of water quality in Lake Francis. Over the past several years, watershed residents have observed a continual degradation of the water quality as evidence by severe blue-green algal blooms, unsightly shoreline scum, and diminished water clarity. Several water samples by the MPCA during the mid 1990s indicate elevated TP concentrations as high as 500 ug/l.

RESULTS OF CURRENT DIAGNOSTIC STUDY

Flow Conditions

There were 2 primary flowages measured into and from Lake Francis. Flowages included the lake's inflow (LFI) and its outlet (LFO). A second flow upstream of LFI, CD10 at Highway 47 crossing, was sampled several times, but eliminated as a monitoring site due to the difficulty of sampling and measuring stream flow.

Each of the flowages was measured for instantaneous flow. A continuous stage recorder was installed and in use at LFI from October 1999 through October 2001. Table 6 indicates the degree that the calculated streamflow curves fit the instantaneous flow measurements and stage data. A summary of the relationships can be found on Table 5 and Figures 4 and 5 and in the Appendix.

Stream velocity at all stations ranged from 0.0 (dry or no flow) to 0.8 meters per second (m/s) and streamflow from 0.00 - 0.46 cubic meters per second (m^3/s). Discharge and nutrient loading calculations were performed using FLUX. Streamflow data was stratified, when possible, during calculation to reduce bias. A summary of hydrologic data can be found on Table 6.

Table 5 Streamflow to Stream Stage Relationships

Station	Curve Formula	r^2	(n)
LFI	cfs=-2.377+2.486(H)	0.80	11
LFO	cfs=-1.500+12.415(H)	0.92	15

Note: r^2 = Coefficient of Determination; (n) = number of measurements; cfs = Cubic Feet per Second; H = Depth of Water (inches)

Table 6 Streamflow Summary

Station	Drainage Area (km^2)	Flow Range (cfs)	Flow (hm^3/yr)	Runoff (m/yr)
LFI	0.08	0.00-2.51	0.026	0.004
LFO	9.21	0.12-3.79	1.061	0.115

Flow range and sample number represents instantaneous flows; Runoff and flow in cubic hectometers per year are calculated by modeling.

Figure 4 Lake Francis Inlet Stage to Flow Relationship

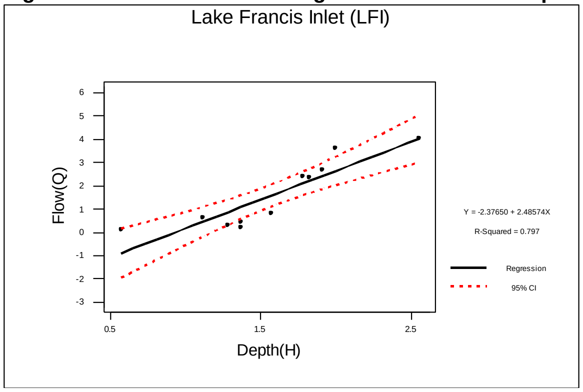
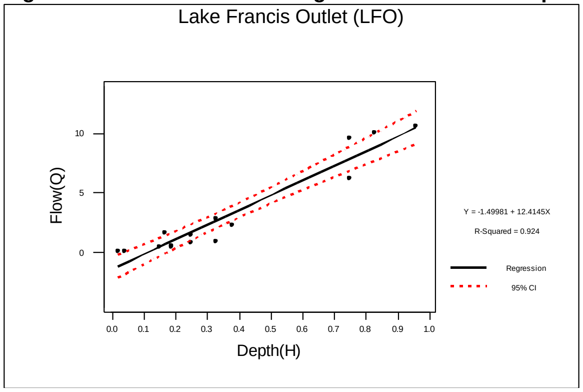


Figure 4 Lake Francis Inlet Stage to Flow Relationship



Discharge Water Quality

Phosphorus and suspended solids are of primary concern in stream water quality since they have the greatest impact on the receiving waters. Phosphorus entering the lake is a concern because it is the primary nutrient for plant growth and algal blooms. Phosphorus can be added to the lake by runoff from agricultural fields, livestock areas, and lakeshore lawn fertilizer and from improperly operating septic systems, groundwater, atmosphere, detergents, and internal phosphorus loading.

Total suspended solids entering the lake is often a significant factor affecting a lake's transparency as well as its fisheries. Total volatile solids is determined as part of the TSS. Total volatile solids is that portion of the overall suspended solids that is organic matter, primarily algae, plants, plankton, etc. Table 7 summarizes the 2000-2001 water quality in many of the flowages to and from Lake Francis. The complete data may be found in the Appendices.

Table 7 Mean Water Quality at Flow Stations 1999-2001

Parameter	LFI (inlet)	LFO (outlet)
TP (ug/l)	128	316
OP (ug/l)	66	51
TSS (mg/l)	5	180
TVS (mg/l)	3	150
NO_2+NO_3 (mg/l)	0.86	0.33
Ammonia (mg/l)	0.23	0.77
TKN (mg/l)	1.34	6.16
TN (mg/l)		

IN-LAKE WATER QUALITY

In-Lake water quality parameters are summarized in the following section. Complete data may be found in the Appendices.

Dissolved Oxygen and Temperature

Dissolved oxygen and temperature were measured at one station. The lake is polymictic (frequently mixing) and dissolved oxygen concentrations were rarely depressed or depleted, with a thermocline in place, during late summer and late winter.

The minimum amount of dissolved oxygen in water required to maintain a warm water fishery is generally accepted to be between 4 and 5 mg/l (EPA. 1986). Dissolved oxygen concentrations near or below these limits tend to restrict fish and zooplankton habitat and may lead to the elimination of one species, only to be replaced by a species more tolerant of low oxygen.

Water in dimictic lakes circulates twice a year (spring and fall) and becomes stratified in the summer (cold water on the bottom) and inversely stratified in the winter (colder water on top). Because Lake Francis is so shallow, only two meters, the lake tends to be polymictic except under ice cover. During 2000, dissolved oxygen concentrations were normally well above 4mg/l, but were periodically measured in the range of 0 to 2mg/l between mid July to mid September and again from mid December to mid February for and estimated 90 days.

The thermocline is defined as the region in the water column where the temperature changes at the rate of 1^{o} C per meter of depth. Above the thermocline water is warmer, less dense and less able to hold dissolved oxygen. Below the thermocline water is colder, more dense and can hold dissolved oxygen longer. Periods of anoxia (without oxygen) during the winter are common and normal in ice and snow-covered shallow lakes when photosynthesis is reduced and oxygen, used by metabolic processes for decay and respiration, increases.

Oxygen Depletion Rates

Oxygen depletion rates were calculated for the whole lake using a 90-day period between June 12 - September 10, 2000. The result indicated an oxygen deficit of 3.3 metric tons or 37kg/day (Appendix).

Water Transparency

The measurement of how deeply light penetrates into a lake is most easily done by using a Secchi disc. A Secchi disc gives a simple index of water transparency, or clarity. It is also a measure of algal biomass as well as an indication of the trophic state of the lake. A reduction in water transparency is usually the result of turbidity composed of phytoplankton, organic matter, and suspended sediments.

The 2000 mean summer water transparency in Lake Francis averaged 1.5 meters (4.6 feet). During 1997 the Secchi depth was 0.3 meters (0.9 ft. to 1 ft). Turbidity from sediment and algae are the reason for the reduced water transparency in Lake Francis. Summer Secchi disc average in the region is 1.5 - 3.2 meters (MDNR 1990).

Chlorophyll-*a*

Chlorophyll-*a* is a photosynthetic component found in algae and aquatic vascular plants. It is also an indication of algal biomass. Mean 2000 summer chlorophyll-*a* concentrations in Lake Francis were found to be 219 ug/l, which is somewhat less than the 256 to 342 ug/l range measured in 1997. The majority of the chlorophyll-a in Lake Francis is apparently due to algae since there were very few aquatic vascular plants found during the surveys.

Phosphorus

Phosphorus is a major nutrient involved in eutrophication and is generally associated with the growth of aquatic vascular plants, algal blooms, and a reduction in water transparency. A lack of dissolved oxygen in the lake's hypolimnion along the substrate interface can result in the release of sediment-bound phosphorus. Elevated TP concentrations resulting from anoxia commonly occurs in early spring before ice-out and in late summer. Common sources of phosphorus include dissolved and sediment attached phosphorus in runoff from agricultural fields, livestock areas, urban areas and lakeshore lawn fertilizer, detergents; organic matter (e.g. leaves and grass clippings); airborne deposition, failing septic systems, and etc. TP and OP, a component of TP and the form readily available for use as a nutrient, are two of the most important water quality indicators.

The 2000 mean summer surface water TP concentrations in Lake Francis was 456 ug/l. During the 1997 sampling, the comparative TP concentration was from 273 to 325 ug/l (Table 8). Summer average TP for lakes in the North Central Hardwood Region range from 23 - 50 ug/l (Wilson 1991).

Nitrogen

Nitrogen is a major nutrient in an aquatic environment. Several forms of nitrogen are important indicators in determining a lake's state of eutrophication. TKN, NH_3-N, and NO_2+NO_3-N, and total nitrogen (TN) are all indicators of an aquatic system's well being.

NH_3-N is a product of biological degradation of nitrogenous organic material and is the form of nitrogen most readily usable as a nutrient. It is toxic in various degrees to aquatic life and can contribute to the depletion of oxygen as a result of nitrification. During 2000, surface NH_3-N concentrations in Lake Francis averaged 40 ug/l.

NO_3-N is another form of nitrogen readily usable as a nutrient. This type of nitrogen was analyzed as NO_2+NO_3-N, NO_2 usually being only a small fraction. Mean 2000 surface NO_2+NO_3-nitrogen concentration was approximately 50 ug/l.

TKN, a measure of organic nitrogen, in the surface water of Lake Francis averaged 3,910 ug/l. NH_3-N is a component of TKN.

Table 8 **Lake Francis Surface Water Quality Summary**

Parameter	2000 Summer Mean	1999-2001 Study Range	Ecoregion* Summer Typical Range
Secchi (meter)	1.4	0.2-2.4	1.5-3.2
Chlorophyll-a (ug/l)	219	78-313	5-21
Total Phosphorus (ug/l)	456	88-703	22-50
Ortho-phosphorus (ug/l)	118	5-314	-
Total Suspended Solids	84	26-110	1-3
Total Volatile Solids (mg/l)	60	16-77	-
Nitrate+Nitrate-N (mg/l)	0.05	0.05	<0.01
Ammonia-N (mg/l)	0.05	0.02-0.08	-
Total Kjeldahl Nitrogen (mg/l)	3.91	2.82-4.57	0.8-1.2
Total Nitrogen (mg/l)	3.96	2.87-4.62	-
Conductivity (umhos/cm)	189	173-300	300-400
Alkalinity (mg/l)	82	82-110	140-195
pH	9.3	8.8-9.4	8.6-8.8
TP:OP Ratio	3.9	-	-
TN:TP Ratio	8.7	-	26-37

Source: *Heiskary and Wilson (1989)

Nitrogen-Phosphorus Ratio

TN, which is equivalent to TKN + NO_2+NO_3-N, can be compared to TP to give an estimate of which major nutrient (N or P) is the growth limiting nutrient in an aquatic system. TN to TP ratios (TN:TP) of less than 10 generally indicate nitrogen is the growth limiting nutrient while a ratio of greater than 12 is suggestive of a phosphorus limited system. Lake Francis is borderline nitrogen limited as Table 8 demonstrates. For comparison, the TN:TP range for the North Central Hardwood Forest ecoregion is 26:1 - 37:1.

Suspended Solids

TSS in surface water is a significant factor affecting the transparency of the water body as well as its fishery. TVS is determined as part of the TSS. TVS is the portion of the overall suspended solids which is made up of organic matter, primarily algae, plants, plankton, etc. The mean 1999-2001 TSS concentration in Lake Francis surface waters was 84 mg/l (Table 8). The TSS concentrations were approximately 71 percent organic (TVS). Average TSS concentrations in the North Central Hardwood Forests is 2 - 6 mg/l (Wilson and Schupp 1991).

Trophic State Index

The Minnesota Pollution Control Agency has determined regions within the state where water quality may be expected to be similar from one lake to another due to various influences. The project area is within a region known as the North Central Hardwood Forest (NCHF) (MPCA, 1985). Modeling by researchers (Carlson, 1977) has resulted in the development of a trophic state indexe (TSI) based on three parameters. These parameters include; water transparency, TP and chlorophyll-a. TSI range 0-100 units corresponds oligotrophic waters at the low end (without nutrient) and hypereutrophic waters at the upper end (with excessive nutrient).

Lake Francis is well within the hypereutrophic range (71 - 100 units) with a overall TSI of 82 units. An increase or decrease in the TSI between the two sampling years does not necessarily represent a trend Table 9.

Table 9 Trophic State Index*

Parameter	2000
Secchi TSI	72
Phosphorus TSI	90
Chlorophylll-a TSI	82
Mean TSI	82

* Growing season (between May-Septembe)r

Hydrologic Budget

The unit of measurement for the hydrologic budget was cubic hectometers per year (hm^3/yr). Components of the budget include inflow, outflow, precipitation, and evaporation. Precipitation during the water year October 1999 through September 2000 was 0.48 meters (18.72in) below the 30-year average of 0.72 meters, but during the second water year October 2000 through September 2001 precipitation was higher than the 30-year average at 0.96 meters (28.6 inches). The average precipitation of the two water years was equal to the 30-year average and was used in hydrologic budget calculations. Precipitation measurements were obtained from climatology observers located throughout the project watershed. Evaporation from the lake surfaces, estimated at 0.97 meters or 38 inches, was determined from the Minnesota Hydrology Guide (1975).

Local runoff from the Lake Francis watershed was calculated to be 0.31 m/yr and 0.79 m/yr at the lake outlet. Total inflow was calculated to be 1.14 hm^3/yr. Water left the lake outlet at a rate of 1.22 hm^3/yr. Evaporation was approximately 1.83 hm^3/yr. A flow of 0.3 hm^3/yr was assigned to facilitate the movement of groundwater and septic leachate loading. The hydrologic balance or difference between what came into the lake (precipitation, groundwater and inflow) minus what went out of the lake (evaporation and outflow), over the monitoring is indicated on Table 10. Mean water residence time (tw) for Lake Francis, the time it takes to replace all the water in the lake, was 1.07 years (Table 11).

Table 10 Gross Water Balance

Location	Drainage Area (km^2)	Mean Flow (hm^3/yr)	Runoff (m/yr)
Local Runoff	0.320	0.100	0.313
Groundwater	-	0.300	-
Precipitation	1.220	0..878	0.720
Tributary Inflow	14.000	1.150	0.080-
Total Inflow	15.540	2.328	0.150
LFO (CD-10 outflow)	15.540	1.220	0.790
Total Outflow	15.540	1.145	0.740
Evaporation	-	1.183	-

Source: BATHTUB modeling - Appendices

Table 11 Hydrologic Parameters

Net Inflow (hm^3/yr)	Residence Time (yrs)	Overflow Rate (m/yr)	Mean Velocity (km/yr)
1.14	1.066	0.94	1.0

Phosphorus Budget

There are no point sources, tributaries or major storm drains other than CD-10 entering Lake Francis. The small farms on the northeast and southwest sides of the lake do not influence the lake (DeMuth, 2002). The inlet ditch contributes 186 kg/yr (5.6 percent) of the TP. Septic leachate was included in the groundwater and modeled at 85.7 kg/yr (2.6 percent). Atmospheric loading (precipitation) was calculated as 54.7 kg/yr (1.6 percent). Local runoff was modeled from storm runoff to contribute 28.6 kg/yr (0.9 percent). Internal loading, the difference in in-lake TP concentrations during 2000 was calculated to be 2,994.5 kg/yr. or 89.4 percent. TP income, including atmospheric, was calculated to be 3,349.8 kg/yr. (Table 12).

The modeled 2000 phosphorus budget, using second-order, available phosphorus (phosphorus which is used by plants and algae. When they die they release the phosphorus for reuse) indicated that the lake had a net phosphorus retention of 3,060.5 kg and a phosphorus retention coefficient of 0.91.

Table 12 TP Budget Based on Estimated Concentrations

Location	Load (kg/yr)	Load (%)	Concen-tration (ug/l)
Local Runoff	28.6	0.9	286
CD-10 (LFI)	186.3	5.6	177
Precipitation	54.7	0.9	62
Groundwater/Septic Leachate	85.7	2.6	286
Internal Load	2.994.5	89.4	-
Total Inflow	3,349.8	100.0	1,439
Gauged Outflow	427.8	12.8	351
Advective Outflow	-26.3	-0.8	351
Total Outflow	401.5	12.0	351
Retention	2,948.3	88.0	-

Note: Using 2nd order, available phosphorus modeling as determined by BATHTUB version 5.4

Sediment Phosphorus Release

The change in phosphorus mass in Lake Francis, 738 kg, was calculated from the change in volume weighted phosphorus concentrations and lake-volume over the monitoring period. There were, however, approximately two to four months when dissolved oxygen intermittently and spatially depleted at the sediment-water interface. Anoxia at the sediment-water interface is a condition that results in sediment phosphorus release, so it is not inconceivable that there may have been a greater release of phosphorus. Because the lake is strongly polymictic and shallow the re-suspended phosphorus is likely continually mixed throughout the water column where it is available for use by algae and vegetation.

Dissolved oxygen profiles indicate the lack of anoxic conditions conducive to resuspension of phosphorus. Whole lake phosphorus loading was calculated to be 6.72 $mg/m^2/day$ from 122 hectares. Calculations for internal phosphorus loading may be found in the Appendix.

Phytoplankton

The algal (phytoplankton) composition of Lake Francis was characterized by two samples, one in late May and one in Late August. The May sampling was equally dominated by *Stephanodiscus astraea, Scenedesmus quadricauda* and *Microcystis aeruginosa* at 19.4, 18.4, and 17.5 percent, respectively. *Microcystis aeruginosa* was the dominant (76.9 percent) phytoplankton in the August sample.

Phytoplankton density ranged from 1,968 organisms per milliliter in May to 6,918 organisms per milliliter in August. These densities coincided with total bio-volumes of 6.2 and 5.3 million cubic micrometers per milliliter. Phytoplankton diversity index was 3.51 in May and 1.27 in August (Table 13).

The phytoplankton composition of Lake Francis consisted of 20 species. This number included 7 genera of Chlorophyta (green algae), 6 genera of Chrysophyta (yellow-green, brown and Diatoms), 3 genera of Cyanophyta (blue-green algae) and 1 Euglenopyta (Euglenoids).

Zooplankton

The zooplankton composition of Lake Francis, during 2000, consisted of 5 genera of Cladocera, 5 genera of Copepoda and 4 genera of Rotifera. Cladocera were dominant in abundance (density) during both sampling periods. Total density for Lake Francis zooplankters was 457 organisms per liter (#/l) and 131 #/l from the May and August samples, respectively. Table 14 portrays the zooplankton community of Lake Francis.

Table 13 Phytoplankton Summary

	May 21, 2000				August 30, 2000			
Species	**Density**	**%**	**Biovolume**	**%**	**Density**	**%**	**Biovolume**	**%**
Stephanodiscus astraea	382	19.4	3688416	59.3	67	1.0	534947	10.1
Scenedesmus quadricauda	363	18.4	92044	1.5	665	9.6	129712	2.4
Microcystis aeruginosa	344	17.5	343983	5.5	5322	76.9	3405782	64.1
Aphanizomenon flos-aquae	134	6.8	88289	1.4	-	-	-	-
Fragilaria crotonensis	96	4.9	1605254	25.8	-	-	-	-
Ankistrodesmus falcatus	96	4.9	2867	0.0	-	-	-	-
Oocystis pusilla	76	3.9	16511	0.3	-	-	-	-
Scenedesmus abundans	76	3.9	15288	0.2	133	1.9	19956	0.4
Asterionella formosa	76	3.9	50451	0.8	-	-	-	-
Melosira ambigua	57	2.9	124940	2.0	532	7.7	1159722	21.8
Tetraedron regulare	57	2.9	6593	0.1	-	-	-	-
Anabaena flos-aquae	57	2.9	74530	1.2	-	-	-	-
Trachelomonas volvocina	38	1.9	72045	1.2	-	-	-	-
Pediastrum boryanum	38	1.9	11466	0.2	67	1.0	26608	0.5
Selenastrum minutum	19	1.0	382	0.0	-	-	-	-
Staurastrum gracile	19	1.0	10319	0.2	-	-	-	-
Cymbella muelleri	19	1.0	7644	0.1	-	-	-	-
Melosira varians	19	1.0	12422	0.2	-	-	-	-
Chlamydomonas sp.	-	-	-	-	67	1.0	21619	0.4
Scenedesmus acuminatus	-	-	-	-	67	1.0	15965	0.3
			May		**August**			
Total Density (#/ml)			1968		6918			
Total Biovolume (cu.uM/ml)			6223444		5314310			
Trophic State Index			63		62			
Diversity Index			3.51		1.27			

Table 14 Zooplankton Summary

	May 21, 2000		August 28, 2000	
	Density #/L	**Standard Error**	**Density #/L**	**Standard Error**
Cladocera				
Daphnia pulex *	19	4.7	2	0.7
Daphnia galeata mendotae *	58	8.1	27	2.3
Daphnia rosea *	310	18.7	89	4.1
Ceriodaphnia lacustris	1	1.1	1	0.5
Bosmina longirostris	25	5.3	0	
Chydorus sphaericus	2	1.6	0	0.2
Leptodora kindti *	0		0	0.2
Total Cladocerans	415	21.7	120	4.8
Copepoda				
Diaptomus siciloides	15	4.1	1	0.4
Small diaptomid copepodites	12	3.7	0	0.2
Diaptomus leptopus *			0	0.2
Larger diaptomid (copepodites only)	2	1.6	0	0.2
Cyclops bicuspidatus thomasi	2	1.6	1	0.4
Cyclops vernalis	1	1.1	0	
Mesocyclops edax	3	2	2	0.6
Cyclopoid copepodites	0		0	0.2
Copepod nauplii			0	0.2
Total Copepods	36	6.4	5	0.9
Rotifera				
Asplanchna herrickli	6	2.5	0	
Keratella cochlearis	0		1	0.5
Kellicottia longispina	0		1	0.3
Polyarthra vulgaris	0		3	0.8
Total Rotifers	6	2.5	5	1
Miscellaneous Zooplankton				
Chaoborus larvae *	0		1	0.3
Total Density	457.1	22.7	130.5	5
Density of Edible Zooplankton (*)	387.1	20.9	119.8	4.7
Edible Zooplankton (%)	85.8		95.5	
Total Sample Biovolume (in ml)	7		1.5	
Total Sample Dry Weight (in mg)	40.6		0.1	
Biovolume Density (ml/L)	0.123		0.035	
Dry Weight Density (mg/L)	0.716		0.002	
Mean Daphnid Length	0.9		0.93	
Length S.D.	0.24		0.29	

Aquatic Vascular Vegetation

The aquatic plants in Lake Francis were sampled on May 21, 2000 and again on August 30, 2000. Sampling eleven transects between 100 and 200 feet in length perpendicular to the shoreline during each of the two sample dates yielded only traces of coontail (*Ceratophyllum demersum*) and bushy pondweed (*Najas flexilis*). Scattered along the shoreline were monospecific stands of *cattail* (*Typha sp*.), yellow water lily (*Nuphar sp.*), water lily (*Nymphaea sp.*) and bulrush (*Scirpus sp*.). One would expect the entire lake area to be vegetated given that almost the entire lake area is littoral (less than 3 meters or 15 feet deep). The absence of vegetation is due to the poor water clarity from turbulence and foraging by roughfish.

Lake Eutrophication Computer Modeling

Data from both lakes was subjected to computer analysis using the computer model BATHTUB (5.1). The model employs a number of empirical eutrophication models to the lake simultaneously and compares observed variables to predicted values based on a constructed data set and model coefficients. Coefficients were adjusted to approximate the observed values for use in a predictive mode. Table 15 compares observed and estimated diagnostic variables of the Lake.

Table 15 Water Quality Modeling
Observed and Estimated Diagnostic Variables

Variable	Observed	Estimated
Total P (ug/l)	394	351
Total N (ug/l)	3,960	3,960
Chlorophyll-a (ug/l)	196	235
Secchi (meters)	0.15	0.14
Organic N (ug/l)	3,870	5,050
TP-Ortho P (ug/l)	298	410
Freq. (Chl-*a*>10) %	100.00	100.00
Freq. (Chl-*a*>20)%	99.96	99.97
Freq. (Chl-*a*>30) %	99.67	99.76
Freq. (Chl-*a*>40)%	98.79	99.07
Freq. (Chl-*a*>50) %	97.08	97.69
Freq. (Chl-*a*>60)%	94.51	95.55
TSI - Phosphorus	90.33	88.65
TSI - Chlorophyll-*a*	82.38	82.99
TSI - Secchi	87.34	88.07

Mean observed and estimated variables represent a comparison of observed data (annual) to the BATHTUB model based on a constructed data set.

Water Quality Predictive Modeling

The computer model BATHTUB was used in a predictive mode by substitution of phosphorus concentrations to estimate predicted mean summer water quality values under different flow conditions. Much of the Lake Francis watershed is wetland and most is very permeable. Since there is always outflow at the lake outlet, it is likely that groundwater discharge is continuous in all but the driest of years and as seen during the October 1999 through September 2000 water year.

Precipitation during 1999-2001 was at approximately the 30-year mean. The first water year was approximately half the 30-year mean and the second water year was approximately twice the 30-year mean.

Predictive modeling was done by maintaining the mean flow and altering the concentration of inflow phosphorus load by 50 percent and internal phosphorus load by 90 percent.

A no-action management alternative was used as a comparison to remedial management alternatives. While "no-action" alternatives are not considered viable options, they do offer a means of comparing remedial management alternatives as a worst case scenario.

Water quality sampling suggests the lake has little in the way of external nutrient inputs and even fewer alternatives to further reduce the advancement of eutrophication. For the most part, the lakeshore residents are in control of the future of Lake Francis. Agricultural land use is declining and agricultural runoff is minimal. Local runoff containing yard debris, ashes, lawn fertilizer, pesticides, herbicides, and recreational use can heavily degrade water quality, but also appear to be minimal. Septic system failure is unknown, but given the age and lot sizes they may be a significant factor. Clearly, internal loading is the overwhelming problem. Lakeshore residents need to realize the limitations that must be placed on lake use and the on-going cost involved and effort needed to maintain the lake quality. Currently, the lake's average summer Trophic State Index places it in about the 0^{th} percentile range when compared to other lakes in the region, or almost all of the lakes in the Central Hardwood Forest Ecoregion have better water quality.

Because the percent of external phosphorus inputs to Lake Francis are minor in comparison to the internal loading, improvement of water quality by reducing the phosphorus load, through either reduction in flows or concentrations is difficult. Since external loading accounts for less about 10 percent of the total phosphorus load. Predictive modeling suggests that even a 75 percent reduction in phosphorus concentration of the external inputs would make no change in the current water quality. The largest source of phosphorus is internal loading (89%). Internal phosphorus loading could be reduced and is considered a cost effective alternative for this lake (Table 16).

Table 16 Summary of Predicted* Water Quality

	Management Alternatives	Mean Predicted Water Quality TP (ug/l)	Chl-*a* (ug/l)	Secchi (m)
1.	No Action	394	196	.15
2.	Reduce Internal P by 90%	105	33	.38
3.	Reduce Internal P by 90% + Reduce LFI P by 50%	97	31	.39

* Predicted by BATHTUB 2nd order, available phosphorus modeling;
NOTE: Reduce P 50% means reduce P concentration in LFO outfall by 50%; Internal loading rates by 90 %; Atmospheric and groundwater loading rates remained constant

It is recommended that a short-term goal for Lake Francis should be 100ug/l phosphorus. The short-term goal should be met in two to three years. A reduction to at least 60ug/l phosphorus is recommended as a long-term goal (Table 17).

Table 17 Long and Short Term Water Quality Goals*

	TP** (ug/l)	Chl-*a* (ug/l)	Secchi (m)
1999-2002	394	196	.15
Short Term 2003 - 2005	100	33	.4
Long Term 2005 - 2008	60	10	1

* Based on average hydrologic year
** Values +/- 5 percent

Short-term goals are achievable by reducing the internal phosphorus load by 90 percent. Long-term goals may be achieved by reducing all phosphorus loading by 90 percent. Lake Francis is and will continue to function as a wetland, storing nutrient in its sediment for use by vegetation and algae. If the sediment is consolidated periodically (perhaps every five years), vegetation is allowed to grow, and the bottom sediments are disturbed less frequently, water clarity will improve dramatically. This of course will result in a dense submerged vegetation crop that will need to be managed.

Internal phosphorus loading accounts for about 89 percent and can and must be reduced. Reducing phosphorus and sediment loads from CD-10, local runoff and phosphorus loads from septic systems, all of which account for about 9 percent of the phosphorus load, will not make any noticeable change in the lake's condition or trophic state.

Clean up of the lake should not be limited to the agricultural community alone. The lakeshore residents must be mindful of their responsibility to lake stewardship. Septic systems, yard debris, ashes, lawn fertilizer, pesticides, herbicides, and some recreational activities can heavily influence the rate of eutrophication and water quality degradation. Only with the concerted effort of the lakeshore residents, agricultural interests, and recreational visitors will further eutrophication of Lake Francis be abated.

FEASIBILITY OF RESTORATION ALTERNATIVES FOR LAKE FRANCIS

Upon consideration of the diagnostic report and predictive lake water quality, many alternatives were considered as possible options to attain reduced nutrient and sediment loading which would protect and enhance Lake Francis's water quality. Considered alternatives were judged by the following criteria: the alternative must produce a measurable pollutant load reduction; the alternative must be environmentally sound; the alternative should have a positive impact, e.g., improved aesthetics, improved water quality, improved fish and wildlife habitat, or improved economic value; and the alternative must be cost effective. All criteria are judgement calls, whether or not an alternative is feasible or cost effective is dependent on the viewpoint of the reviewer. The following restoration alternatives were considered and are marked either yes or no for recommendation.

Education

Educating the lakeshore homeowner, recreationalist, and lake user is a key component in improving lake and water quality. As sources of nutrients, groundwater, atmospheric deposition, and waterfowl are not usually controllable. The public's impact on the lake is controllable through education to curtail non-point source pollution. Educating the public in better management practices (BMPs) takes time and should be an ongoing effort. The MDNR Divisions of Fish and Wildlife and Waters and Isanti County SWCD have technical as well as local expertise. Education and programs for the public and lake stewards should include:

- Proper care of lawns and gardens
- Preventing soil erosion
- Proper use of fertilizers and pesticides
- Yard waste disposal
- Minimizing runoff from shoreland
- Preventing introduction of exotic species
- Limiting the impact of recreation
- Storm drain stenciling
- Use and abuse of septic systems
- Lakehore landscaping
- Benefits of aquatic vegetation
- Lake monitoring methods
- Lake processes
- Agricultural BMPs
- Watershed protection
- Environmental school program

The LFIA should start a lake steward program to disseminate this information. Federal, state, and local agencies, universities, and extension agencies have produced considerable literature. Literature could be made available to all residents, seminars on the various topics could be held, and new residents to the community and especially the lakeshore could be brought on board through an old fashioned "Welcome Wagon." Businesses and the city could become involve by encouraging use of lake friendly products and practices through contests, raffles, special sales, recognition and support during "Lake Days" projects. This alternative is highly recommended. Cost is estimated at $2,000 for supplies, copying, mileage, and other.

Feasibility Summary

Yes	No	
X		1. Produce a measurable pollutant load reduction
X		2. Environmentally Sound
		3. Has a positive impact and result in:
X		a. Improved water quality
X		b. Improved aesthetics
X		c. Improved fish and wildlife habitat
X		d. Improved economic value
X		4. Cost effective

Recommended?

✓ **YES**

Lake Drawdown

It is feasible to retard phosphorus re-suspension and initially strip the water column of most dissolved phosphorus by exposing lake bottom sediments to the atmosphere and thereby accelerating sedimentation. Lake drawdown is usually done over winter by draining the lake to some selected elevation and allowing the bottom sediments to consolidate or compact. Where base flow conditions exist, the flow is diverted or prevented from entering the lake basin. After suitable exposure, freezing and settling of the loose particulate on the lake bottom, the lake is allowed to refill and in some cases sediment removed. The primary reason for exposure to the atmosphere and freezing is the consolidation of bottom sediments so that when the lake refills re-suspension of phosphorus-laden bottom sediments and organic matter are not re-suspended in the water column for use by algae. The drawdown will also eliminate the majority, if not all, the current fish population. Lake Francis's internal phosphorus re-suspension is the lake's primary problem. Phosphorus re-suspension accounts for approximately 89 percent of its phosphorus load.

By drawing down the lake's water level by about 2 ½ to 3 feet approximately 200 acres of the lake's bottom would be exposed and the remainder would likely freeze. Because most of the lake bottom is devoid of vegetation, which normally helps to reduce re-suspended sediment, a full year of drawdown (and possibly two years) would be needed to allow vegetation to reestablish itself. The drawdown, along with re-vegetation and elimination of the roughfish (winterkill) could eliminate as much as 80 percent of the available phosphorus during the first couple of years. Subsequent periodic over-winter drawdowns may be needed because of the lake's shallowness and the occasional backing up of the Rum River bringing in roughfish.

The drawdown would need to be facilitated by excavating a channel through the berm near the lake's dam. Drawdown using only the dam is not possible due to the dam height. Further, the point at which CD-10 is diverted from its channel into the lake would be closed forcing the flow into its original channel and by pass the lake. The result would be the reduction, possibly elimination, of most baseflow and spring runoff. Concurrently with the drawdown, some minimal dredging along the lakeshore to facilitate boat movement could be undertaken. The minor sediment removal in some areas would help reduce re-suspension from boat propellers.

Cost for the drawdown is minimal and is estimated at $1.67 per kg of phosphorus ($5,000) to eliminate approximately 2,400 kg of phosphorus. The project would require an engineering review by the MDNR and channel excavation for both the outlet and upstream ditch diversion. Cost for sediment removal along the shoreline would be incurred by the landowner under MDNR permit.

Feasibility Summary

Yes	No	
X		1. Produce a measurable pollutant load reduction
X		2. Environmentally Sound
		3. Has a positive impact and result in:
X		a. Improved water quality
X		b. Improved aesthetics
X		c. Improved fish and wildlife habitat
X		d. Improved economic value
X		4. Cost effective

Recommended?

✓ **YES**

Water Craft Limitations

Disturbance of lake bottom sediments from power boats, personal water craft, waves and bottom-feeding fish result in the resuspension of sediment, organic material nutrient and pollutants back into the water column. This resuspension or internal loading is currently the primary problem in Lake Francis. Wind and wave action and roughfish are probably the largest contributors to the problem, but because the lake is so shallow, less than three feet deep, all boating contributes to the problem. Lake drawdown resulting in bottom sediment consolidation, elimination of roughfish and re-establishment of submerged vegetation will eliminate most of the resuspension. Nothing can be done about wind action, but the bottoms of most boat hulls, almost all gasoline and electric boat motors and all personal watercraft (jet skis) also disturb the sediment and something can be done to reduce the problem.

Limiting boating to "No Wake" will reduce wave action and reduce the damage turbulence does to the lake bottom. Further reducing the resuspension can be accomplished by limiting boat motors to electric only or some small horsepower gasoline motors, i.e., 10 hp. Restricting motors to electric also has the benefit of eliminating further water quality contamination by hydrocarbons. Water-skiing and jet skis should not be allowed on Lake Francis. Larger boats, i.e., pontoons and larger motors could remain if the "No Wake" rule was invoked. Currently, the lake is not heavily used by recreationalist. If the lake becomes a periodic fish-rearing pond, the establishment of viable fishery and improved water transparency will result in increased lake visitations. The improved water clarity and quality from the compaction of bottom sediments and reestablishment of bottom vegetation will not last long if there is no ordinance in place to help reduce the impact of the increased lake visitations. There is no estimate of the amount of resuspension of nutrient and pollutants caused by boats, but “No Wake” will help control the problem.

Feasibility Summary

Yes	No	
X		1. Produce a measurable pollutant load reduction
X		2. Environmentally Sound
		3. Has a positive impact and result in:
X		a. Improved water quality
X		b. Improved aesthetics
X		c. Improved fish and wildlife habitat
X		d. Improved economic value
X		4. Cost effective

Recommended?

✓ **YES**

Spent Lime or Alum Application for the Inactivation of Phosphorus

It has been found feasible to retard phosphorus resuspension and initially strip the water column of dissolved phosphorus with spent lime/alum treatments (Schuler, 1992). Alum (aluminum hydroxide), as a component of spent lime and by-product of water softening and conditioning at water utilities, has been successfully used to reduce phosphorus concentrations even under anaerobic (reducing) conditions. Spent lime can be applied to the lake bottom to provide sufficient adsorption sites for dissolved phosphorus and additionally provide a benthic seal to eliminate re-suspension of sediment bound phosphorus. Aluminum has been found to be toxic to a variety of aquatic species if pH is to low (acidic).

Alum (aluminum sulfate) can also be added to the lake in either granular or liquid form. It does not have calcium as a buffering agent. Care must be taken to prevent the aluminum component from becoming toxic. Toxicity occurs when the pH drops below 5.5 or 50 micrograms of Al per liter (Kennedy and Cooke, 1982).

The addition of spent lime to Lake Francis could work, but is not an option for at least two reasons: one, the cost is approximately $40,000 per treatment and, two, the lake is already very shallow. Adding material to the shallow lake only worsens the situation and any positive impact on the phosphorus level would be erased with each disturbance of the bottom sediments. Failure of phosphorus inactivation occurs from insufficient application dosage, polymixes, and insufficient nutrient diversion. This alternative is not recommended at this time.

Feasibility Summary

Yes	No	
X		1. Produce a measurable pollutant load reduction
	X	2. Environmentally Sound
		3. Has a positive impact and result in:
	X	a. Improved water quality
	X	b. Improved aesthetics
	X	c. Improved fish and wildlife habitat
	X	d. Improved economic value
	X	4. Cost effective

Recommended?

✓ **NO**

Repair and Upgrade of Non-Complying Individual Septic Systems

Lakeshore residents are the first to notice a reduction in water quality whether from reduced aesthetic, recreational or property value and therefore are caretakers of the lake. Each has the responsibility of maintaining proper care of their septic system to prevent nutrient loading to the lake. Generally, the estimate of houses contributing septic leachate to the lake is quite small (about 10 to 15 percent), which would mean about 10 homes around the lake may need some upgrade or replacement. The estimate of substandard septic systems may be as high as 70 percent or 50 homes (MDNR 1994). Cost for an in-ground septic system run about $2,500 each. Cost for a mound system is about double ($5,000). Bringing some of these septic systems up to compliance may not include total replacement of the system, rather slight upgrades or less expensive “tune-ups.”

Nutrient loading from septic leachate usually represents about 5 to 15 percent of the total nutrient budget for a lake. It is likely to be a higher percentage in Lake Francis due to the small lots and age of the systems and because there are so few sources of phosphorus input to the lake. While phosphorus-loading rates, from septic leachate, are generally average one kilogram per capita per year, the rate can be highly variable. Loading is dependent on system usage, volume, soil types, percent break through into groundwater, groundwater gradient, and etc. Phosphorus loading from septic systems to the lakes was over estimated to total about 50 kg/yr, which might be closer to 50 percent of the homes. Cost for septic improvements to essentially eliminate septic leachate contamination may be as high as $50,000. The initial cost would be about $1,000 per kilogram of phosphorus. If this is extended over 10 years and a reduction of 500 kg (50kg/yr for 10yrs) is realized, the cost would be around $50 per kilogram. This alternative is highly recommended.

Feasibility Summary

Yes	No	
X		1. Produce a measurable pollutant load reduction
X		2. Environmentally Sound
		3. Has a positive impact and result in:
X		a. Improved water quality
X		b. Improved aesthetics
X		c. Improved fish and wildlife habitat
X		d. Improved economic value
X		4. Cost effective

Recommended?

✓ **YES**

Aeration for the Prevention of Winterkill

A aeration is available to help control winterkill, reduce odors, and internal phosphorus resuspension of phosphorus during times of anoxia. Surface diffusion or surface aspirating systems add oxygen to the water column through mixing. They are mainly used to increase metabolic rates of decomposition and maintain adequate dissolved oxygen concentrations for fish during winter and summer periods, when oxygen deficit rates increase and oxygen saturation rates are likely to be low, reduce algae through turbulence and increase oxygen for metabolic decay process.

Many types of aeration are expensive, all have ongoing maintenance and power costs and all can have operational problems. Aeration could be employed during the winter to reduce the frequency of winterkill on an as-needed basis and will help reduce odors associated with anoxia. Aeration will not prevent all winterkill nor by itself bring about a change in the present type fishery. Only the surface diffusion/aspiration system would be cost effective. Depending on the type of aeration unit, extent of area and frequency used. Cost for three to six no-maintenance 2-horsepower units would be in the range of $14,000-$28,000. Electrical costs to operate three to six units (depending on cost per kilowatt-hour) would be approximately $225-$450 per month. Three-phase power would reduce the costs (Aeromix 2002). This alternative is recommended only in conjunction with both efforts to reduce in-lake phosphorus loading and use by the MDNR as a fishery rearing area.

Feasibility Summary

Yes	No	
X		1. Produce a measurable pollutant load reduction
X		2. Environmentally Sound
		3. Has a positive impact and result in:
X		a. Improved water quality
X		b. Improved aesthetics
X		c. Improved fish and wildlife habitat
X		d. Improved economic value
X		4. Cost effective

Recommended?

✓ **YES**

Removal of Rough Fish to Reduce Phosphorus Resuspension

Large populations of rough fish, such as carp and bullheads, are associated with hypereutrophic lakes and lakes which experience winterkill. Roughfish are able to tolerate lower dissolved oxygen concentrations than game fish. They are also very efficient tactile bottom feeders, which enable them to do well in waters, which have decreased water transparency. Most game fish are predators and require better water clarity to find their prey. The feeding habits of rough fish cause the destruction of sediment-filtering aquatic vegetation and re-suspension of bottom sediments, thereby reducing water transparency and releasing pollutants back into the water column during excretion of nutrient-rich benthic material.

Removing fish studies (Lamarra, 1975; National Biocentrics, 1979) indicate that rough fish act as phosphorus pumps by excreting phosphorus at the rate 0.024 lb. P/day/1,000 lb. of bullheads (the rate of phosphorus excretion are temperature dependent). The removal of rough fish should improve the water clarity, reduce the resuspension of phosphorus, and allow for the reestablishment of aquatic vegetation used by game and forage fish. With the removal of rough fish, it is envisioned that game fish populations could eventually increase. Theoretically, a reduction of 10,000 kg of rough fish annually could reduce potential internal phosphorus recycling by approximately 100 kg annually. However, internal loading rates can be highly variable and this approach may just increase rough fish productivity in the void created by harvesting. Harvesting is cost effective, since commercial fisherman pay to harvest the fish, but the outcome on internal loading and change in fishery is unknown. This alternative is not recommended at this time.

Feasibility Summary

Yes	No	
	X	1. Produce a measurable pollutant load reduction
X		2. Environmentally Sound
		3. Has a positive impact and result in:
X		a. Improved water quality
	X	b. Improved aesthetics
		c. Improved fish and wildlife habitat
	X	d. Improved economic value
X		4. Cost effective

Recommended?

✓ **NO**

Biomanipulation of Algae by the Addition of Zooplankton

Fish, zooplankton, and algae are all part of the natural food web, or chain, in the aquatic environment. An over or under abundance of any one of the components in the web can result in cyclic population explosions and reductions. Algae are primary producers and are normally grazed upon by herbivorous zooplankton. Planktivorous (plankton eating) fish graze upon zooplankton, in turn, and these fish are, in turn, preyed upon by piscivorus fish (fish eating). The addition of *Daphnia*, a genus of zooplankton, and the primary zooplankton in the diet of many fish, e.g. bluegill and crappie, has been used in the past to control algal populations.

The introduction of *Daphnia* as a form of biomanipulation would probably meet with limited, if any, success mainly because the addition would be redundant. *Daphnia* is already the dominant zooplankter in the lake. The use of biomanipulation as an alternative to control algal populations is not recommended.

Feasibility Summary

Yes	No	
	X	1. Produce a measurable pollutant load reduction
X		2. Environmentally Sound
		3. Has a positive impact and result in:
X		a. Improved water quality
X		b. Improved aesthetics
	X	c. Improved fish and wildlife habitat
	X	d. Improved economic value
	X	4. Cost effective

Recommended?

✓ **NO**

County Ditch 10 Erosion Control

Erosion and contribution from agricultural runoff appears minimal along County Ditch 10 and its feeders. While no intensive inspection of the system has been undertaken, Isanti County Soil and Water Conservation District indicates little in the way of runoff and erosion impact in the watershed (SWCD 2002). The reduction of acreage being cultivated and the lack of livestock having access to the ditch system combined with the sale and subdividing of former crop land appears to have reduced runoff to the ditch system. As a result, flow has probably also diminished as evidenced by stagnation in much of the ditch system. In an effort to further reduce potential sediment and nutrient loading the U.S. Dept of Agriculture, through the Natural Resources Conservation Service, offers 10-year paid cropland set-asides for buffer strips along the ditch system.

The Isanti SWCD is contacting each property owner along the ditch system to offer this program. Both the cost $160 per acre for seeding 100-foot wide buffer strips along the ditch and manpower is furnished by the SWCD at no cost to the property owner. In addition the property owner is paid $45 per acre annually for the 10-year period. Approximately 35 acres could be placed into the program at no cost to the project or landowners. It is estimated that this could potentially reduce the sediment and phosphorus loading to about half of the current loading rates. Currently, approximately 3,837 kg of TSS, of which 2,338 kg is organic material (TVS) and 93 kg of TP, which is attached to sediment and organic material is carried by the ditch. This alternative is highly recommended.

Feasibility Summary

Yes	No	
X		1. Produce a measurable pollutant load reduction
X		2. Environmentally Sound
		3. Has a positive impact and result in:
X		a. Improved water quality
X		b. Improved aesthetics
X		c. Improved fish and wildlife habitat
X		d. Improved economic value
X		4. Cost effective

Recommended?

✓ **YES**

Removal of In-Lake Sediment

Removal of sediment in shallow areas along the lakeshore where boat traffic continually displaces bottom sediment could be done under individual MDNR and U.S. Army Corps of Engineers permits. This would be done in conjunction with the lake drawdown for the purpose of reducing re-suspended sediments thereby allowing vegetation to establish and improve water quality and clarity. Cost for the sediment removal would be by lakeshore property owner and could be done during drawdown.

Feasibility Summary

Yes	No	
X		1. Produce a measurable pollutant load reduction
X		2. Environmentally Sound
		3. Has a positive impact and result in:
X		a. Improved water quality
X		b. Improved aesthetics
X		c. Improved fish and wildlife habitat
X		d. Improved economic value
X		4. Cost effective

Recommended?

✓ **YES**

No Action

No action was considered as an alternative for Lake Francis. Water quality and lake values will be better some years and worse other years based on watershed activities and seasonal and annual averages. However, improvements in recreation and aesthetic values, water quality, fishery and wildlife habitat or increased property values should not be expected.

Feasibility Summary

Yes	No	
	X	1. Produce a measurable pollutant load reduction
	X	2. Environmentally Sound
		3. Has a positive impact and result in:
	X	a. Improved water quality
	X	b. Improved aesthetics
	X	c. Improved fish and wildlife habitat
	X	d. Improved economic value
	X	4. Cost effective

Recommended?

✓ **NO**

Table 18. Summary of Recommended Restoration Alternatives for Lake Francis

Restoration Technique	Objective	Approach	Anticipated Results	Potential Undesirable Effects	Estimated Costs (including in-kind)
Education	Promote better management practices to reduce nutrient loading and soil erosion.	Implement a community wide education program using existing educational materials.	Reduced nutrient and sediment load to Lake Francis.	None	$2,000 for materials.
Individual Septic System Repairs and Upgrades	Reduce nutrient loading.	Repair or upgrade non-complying septic systems.	Decrease the phosphorus concentration in Lake Francis.	None	$25,000-$50,00 depending on repairs or upgrades to mound systems.
Lake Drawdown	Compact lake bottom sediments to reduce internal resuspension of nutrient and sediments. Elimination of the roughfish population.	Drain approximately 66% of the lake for up to 2 years to compact sediments and establish vegetative growth on the lake bottom.	Up to a 90 percent reduction in internal phosphorus loading, dramatic improvement in water clarity.	Increase in submerged aquatic vegetation.	$5,000 for MDNR planning, excavation through berm for outlet and reconnection of CD10 diversion around lake.
Aeration	Reduce winterkill of fishery during some winters.	Purchase and install up to 6 2-hp submerged diffuser aerators to maintain adequate DO levels for the fishery in a portion of the lake.	Reduction or elimination of winterkill.	None	$14,000-$28,000 for aeration system plus approximately 275-$450 per month for electric power as needed (less for 3-phase).
Removal of Lake Sediment	Reduce turbidity and nutrient resuspension.	Allow minor sediment removal, by individual MDNR permit, along some very shallow lakeshore.	Reduction in bottom sediment resuspension by boat motors to improve water clarity.	None	Costs to be determined for individual shoreline property and paid for by lakeshore property owner.
Water Craft Limitations	Reduce turbidity and nutrient resuspension.	Adopt an ordinance to provide for “No Wake” on Lake Francis and possibly limitation on horsepower of boat motors.	Reduction in bottom sediment resuspension by boat motors to improve water clarity.	None	None
CD-10 Erosion Control	Reduce turbidity and sediment and nutrient deposition.	Stabilize bank erosion and reduce sediment and nutrient loading with 100-foot buffer strips along the CD10 corridor.	Improve water clarity and prevent sedimentation in spawning beds.	Potential increase in aquatic vegetation.	$5,600 for SWCD materials and labor to plant approximately 35 acres in buffer strips along the CD10 corridor.

Project Funding
Estimated total project cost is $133,000 over a three-year period (Table 19). Up to fifty percent ($66,500) could be eligible for matching funds by the state and federal agencies including, the Isanti County SWCD/NRCS, MPCA and MDNR. The remaining fifty-percent would need to be funded through cash and in-kind efforts of LFIA, Isanti County local conservation and service organizations and individual lakeshore owners.

Table 19 Estimated Phase II Budget

Administration	$ 5,000
Public Meetings and Education	$ 2,000
Monitoring	
Phase II Plans and Meetings	$ 4,000
Field Work	$ 6,000
Laboratory Analysis	$ 5,000
Implementation of Alternatives	$ 88,000
Data Analysis and Assessment	$ 5,000
Annual Reports	$ 3,000
Final Report	$ 5,000
Contingencies	$ 10,000
Total	$133,000

Particular Benefits
It is anticipated that the implementation of this project will result in a reduction in nutrients followed by a reduction in algal blooms and increase in submerged aquatic vegetation, a dramatic increase in water clarity and warm water fishery. This improvement in water quality should result in increased recreational opportunities and increased aesthetic value.

Phase II Monitoring
Once Phase II begins, this project will largely become a MDNR Fishery project. However, limited monitoring of both flows and in-lake water quality will be continued under an approved monitoring plan as was used during Phase I. In-lake will be limited primarily to oxygen concentrations, temperature and trophic state monitoring (TP, Chl-a, Secchi). Flow monitoring will be limited to flow and suspended solids and phosphorus concentrations. All monitoring will be done in conjunction with the MDNR.

Relationship with Other Programs
The objective of this study was to determine baseline hydrologic, water quality, and ecological information to make necessary remedial and management decisions. It is anticipated that Isanti County and local (proposed) water plans, the MDNR fisheries program and Isanti County Soil and Water Conservation District plan and programs will guide and implement the majority of the restoration alternatives.

Proposed Milestone Work Schedule
A rough estimate of the proposed work schedule can be found in Table 20

Table 20 Proposed Work Schedule

2002	Steering committee meeting Public informational meeting Phase II application
2003	MDNR Engineering review and planning Issue project informational pamphlet Begin educational alternative Begin individual septic system alternative Begin lake drawdown alternative Begin CD-10 erosion control alternative Petition County for 'No Wake' alternative
2004	Public informational meeting Lakeshore owners obtain MDNR permits for sediment removal along lakeshore and implement alternative Continue drawdown Annual project report
2005	Public informational meeting Completion of alternatives Begin trophic state and DO monitoring MDNR to stock lake with gamefish Annual project report
2006	Public informational meeting Submit final report On-going educational alternative On-going limited monitoring

Public Participation, Information, and Education
The Lake Francis Improvement Association steering committee, composed of representatives from Isanti County Soil and Water Conservation District, Minnesota Department of Natural Resources Division of Fisheries, Minnesota Pollution Control Agency, lakeshore and farm community residents are the mainframe of this process. For the proposed project to be a success, the community needs to understand and take part in the recommended optional remedial alternatives. A project pamphlet, informational meetings, and quarterly newsletter are planned.

Project Maintenance
Funding for maintenance activities will be the responsibility of Isanti County SWCD, MDNR

and LFIA. It is anticipated that costs for maintenance will be low and are primarily related to electric power for aeration.

Required Permits for Implementation
Required permits for implementation of alternatives will be obtained form the Minnesota Department of Natural Resources, U.S. Army Corps or Engineers and Isanti County.

CONCLUSION

The purpose of this study was to (1) review available lake and water quality data, (2) determine and assess base-line water quality and streamflow data, (3) determine remedial alternatives to reduce point and non-point pollution. Concerns about the degraded condition of Lake Francis are shared by both lake property owners, recreationalist and regulatory agencies. Cultural eutrophication has had a great impact on the lake and will continue if no action is taken. Symptoms of eutrophication are the major concern in Lake Francis. These concerns are poor water transparency, frequent algal blooms, reduced sport fishing, and frequent winterkill.

A review of available information indicates frequent algal blooms, poor water transparency due to algal and suspended solids turbidity, high total phosphorus concentrations, periods of reduced dissolved oxygen concentrations resulting in winterkill, and a fishery dominated by roughfish.

A review of data shows that the lake is polymictic, very shallow and nitrogen is the growth-limiting nutrient. The primary source of phosphorus (89%) is internal loading from resuspended sediments. This resuspension occurs naturally during wind and wave action and anoxic conditions and mechanically by boat turbulence and bottom feeding fish. Modeling indicates that with the eventual reduction of internal phosphorus, CD-10, atmospheric deposition and groundwater (septic systems) will be the primary sources, but reduction phosphorus from these sources will do little to improve the water quality. It is not realistic to suggest that in-lake phosphorus concentrations will be lower until internal phosphorus is substantially reduced.

Planning should reflect a realistic goal for in-lake phosphorus concentrations. Planning efforts should focus on reducing the turbidity and elevated phosphorus concentrations through the compaction of lake-bottom sediments, reestablishment of bottom vegetation, adoption of a ‘No Wake’ ordinance to reduce mechanical resuspension, elimination of bottom feeding fish and aeration. Additional efforts to reduce all other phosphorus sources, by upgrading non-compliant septic systems, education of the lakeshore homeowner, recreationalist, general public, and municipality in best management practices to reduce and prevent point and non-point source pollution. These efforts along with addition of buffer strips along CD-10 to prevent erosion and runoff will help chip away at the problem.

In summary, only a drastic reduction in internal phosphorus loading will improve Lake Francis’s problem. The implementation of restoration alternatives and lake management by the MDNR are key to the lake’s future.

Author

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