IPS ENVIRONMENTAL AND ANALYTICAL SERVICES
Appleton, Wisconsin

PHASE III
ENGLISH LAKE MANAGEMENT PLAN
MANITOWOC COUNTY, WISCONSIN

LPL-341

REPORT TO:
ENGLISH LAKE MANAGEMENT DISTRICT

April, 1997

ACKNOWLEDGMENTS

Thanks are extended to the English Lake Management District, Tim Rasman (Wisconsin Department of Natural Resources) and Tom Ward (Manitowoc County Soil and Water Conservation Department) for assistance with development of this management plan.

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SUMMARY

The Phase III Lake Planning Grant for English Lake was intended to bridge the gap between Phase I and Phase II baseline studies and future implementation phases. Phase III activities included final baseline water quality monitoring, definition of existing drain tile locations, an analysis of alternative control measures that could apply to English Lake, continuation of the public involvement /education elements of the project, and coordination with the WDNR and other agencies to prepare an application for funding to implement control measures. Below is a brief summary of the results of the water quality monitoring, drain tile assessment, and alternative control measures analysis, and a list of the suggested management recommendations.

Water Quality Monitoring

Water sampling conducted during Phase III studies indicated similar water quality conditions at the routine and event sites as was discovered during Phase I and II studies. As in Phases I and II, English Lake was shown to be phosphorus limited, and, as a result, sensitive to increased phosphorus inputs.

An analysis of the cumulative data from Phases I through III (1991 to 1997) indicated that total phosphorus concentrations in English Lake peaked in the winter, declined in spring, and then stabilized in summer and fall. This trend is believed to be closely related to changes in biologic activity and limnologic turnover. Total nitrogen showed a similar but less defined trend during this time period. Seasonal decreases in total nitrogen where less drastic, thus supporting the conclusion that English Lake is phosphorus limited.

A cumulative analysis of event monitoring data over the 1991 to 1997 study period indicated that sites 16E3 and 16E8 (both located east of the lake on agricultural property) had drastically higher mean total phosphorus concentrations than the other event sites. Sites 16E2 and 16E3 had the highest mean total nitrogen concentrations over the duration of the study period. Given the phosphorus limited status of English Lake, controlling the phosphorus inputs at sites 16E3 and 16E8 is likely the highest priority action for remediating English Lake water quality.

Drain Tile Assessment

The "historic" English Lake watershed covered approximately 93 acres, and the total annual phosphorus load from the "historic" watershed is 473 pounds. The drain tile networks identified in Phase III were estimated to increase the English Lake watershed by approximately 78 acres. The tiled areas add approximately 34.8 pounds of phosphorus to the lake annually. Of the total annual phosphorus load to English Lake, 77 percent is from barnyard/feedlot runoff, 17 percent is from agricultural crop land, and 7 percent is a result of loading from Tiles A and B.

Alternatives to Maintain and Enhance the Lake

Analyses conducted using WLMS showed agricultural activities to contribute the majority of the total phosphorus to the lake, and event monitoring identified specific sites where nutrient concentrations were high. Given these facts, a variety of alternative concepts that may be applicable to remediating English Lake water quality were reviewed. The potential methods identified for maintaining and enhancing the lake included plugging or breaking drain tiles, use of sedimentation basins and treatment systems, installation of buffer strips, barnyard and feedlot management, and aluminum sulfate treatment. Most of the management strategies listed above could be directly applicable to English Lake; however, most also require landowner participation and/or land purchase. The applicability of these concepts to specific locales in the English Lake watershed should be analyzed in detail in subsequent studies.

Management Recommendations

1. Specific management strategies should be defined to reduce the elevated nutrient concentrations recorded at event sites 16E2, 16E3, and 16E8, and, thereby, reduce the nutrient load to English Lake. Of these three sites, priority should be given to 16E3 and 16E8 due to the high total phosphorus concentrations recorded at these sites. Management options for the barnyard/feedlot located near sites 16E3 and 16E8 should be explored. The feasibility of a sedimentation basin/wetland treatment system should also be studied.

2. The potential for removal of the direct drainage to English Lake from Tiles A and B should be explored, and the feasibility of a wetland restoration project on the lands drained by Tiles A and B should be studied. An examination of the availability of the tiled property for purchase and remediation will need to be conducted. If the land is able to be purchased or landowner cooperation is obtained, detailed management strategies should be developed.

3. Management strategies for English Lake that incorporate plugging, breaking or diverting drain tiles; use of sedimentation basins and/or treatment systems; installation of buffer strips; or aluminum sulfate treatment should be analyzed as they pertain to specific locales surrounding English Lake.

INTRODUCTION

The English Lake Management District (ELMD), which serves as the main steward for the resource, was formed in 1982 and currently has approximately 60 voting members. The ELMD was concerned with lake eutrophication and recreational use issues, and applied for and received its first Wisconsin Department of Natural Resources (WDNR) Lake Management Planning Grant in April, 1991. IPS Environmental & Analytical Services (IPS) of Appleton, Wisconsin was selected as their consultant to begin management planning efforts.

Phase I efforts included baseline assessment activities (for water quality and aquatic plants) and a public involvement program. Specific physical properties of the English Lake resource, preliminary methods, and other introductory and technical information were presented in the Phase I report which was completed in 1992.

A Phase II grant was received in September, 1992. The Phase II study included more intensive assessment of areas of concern in the watershed, continuation of the water quality monitoring and public involvement programs, and an assessment of recreational use and a review of sanitary systems for homes bordering the lake. The Phase II report was completed in February, 1995.

A Phase III grant was received in January, 1996. The Phase III efforts are the subject of this report. Phase III was intended to bridge the gap between the study phases of this project and the future implementation phases wherein measures could be employed to remediate problems identified through the Phase I and II studies. Phase III included the final baseline water quality monitoring effort, an investigation to define the extent and location of drain tiles discharging into the lake, a literature review of alternative control measures, continuation of the public involvement/education elements of the project and coordination with the WDNR and other agencies to prepare an application for funding to implement control measures.

The remainder of this report contains a description of the methods employed in the study, a discussion of the results, baseline conclusions and management recommendations. Refer to the Phase I and II reports for a description of the study area.

The Phase III efforts were initiated by IPS. Resource Management Group, Inc. (RMG) was contracted by IPS in November of 1996 to conduct the remaining analyses required to complete the work elements outlined in the Lake Planning Grant and prepare the report.

METHODS

Public Involvement Program

The main purpose of the public involvement program was to keep interested parties aware of the progress of the planning effort and solicit comments and suggestions. As stated in the Phase III Lake Planning Grant application, the ELMD had the main responsibility for this effort. Public involvement activities conducted by IPS were coordinated to inform and educate the ELMD about lake management in general and specifics regarding the English Lake resource. IPS activities included development and distribution of a brochure explaining pertinent lake and shoreline regulations, meeting attendance, and updates on the lake planning process.

Water Quality Monitoring

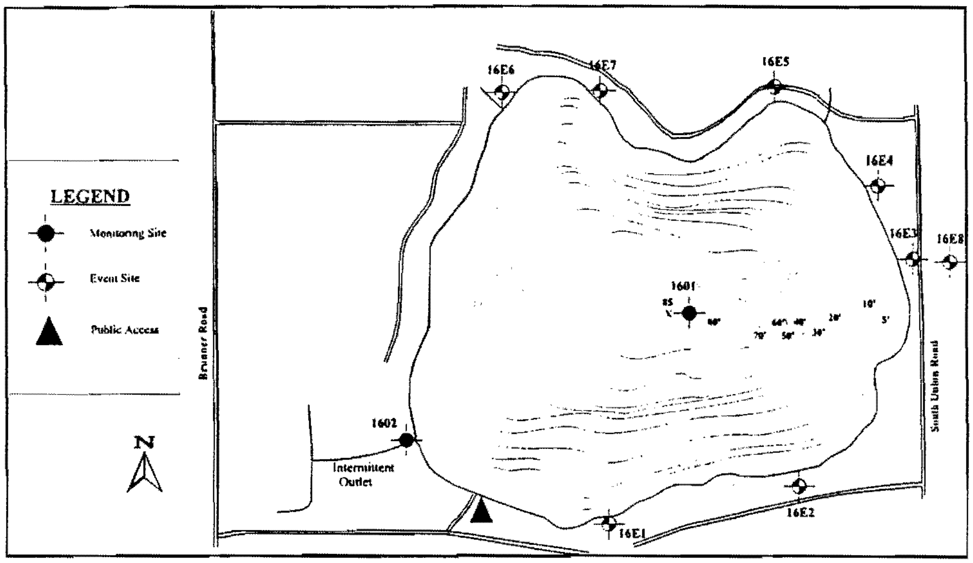
English Lake water samples were collected by IPS on June 13, July 31, August 14, and September 23, 1996. An additional sample was collected by RMG on February 3, 1997. Samples were collected three feet below the surface and three feet above bottom for Station 1601 (deepest point) and at mid-depth for Station 1602 (outlet) when flow was present (June 13, 1996) (Figure 1 and Table 1). Parameters measured in the field were Secchi depth, water temperature, pH, dissolved oxygen (DO), and conductivity (see the Phase I document for specific equipment and methods information).

Table 1. Sampling Station Locations, English Lake

REGULAR MONITORING	
Site	Depth
1601	85.0 feet
1602	1.0 feet
EVENT MONITORING	
Site	Description
16E1	Overland flow on property at 9304 S. Lake Drive
16E2	Drain tile outfall (multiple tiles) between 9112 and 9122 S. Lake Drive
16E3	Drain tile outfall between 4350 and 4402 S. Union Road
16E4	Overland flow between English Lake and parking lot at 4420 S. Union Road
16E5	Drain tile outfall between 9031 and 9109 N. Lake Drive
16E6	Overland flow between Westland and Rexrode residences
16E7	Overland runoff near 9221 North Lake Drive (on north side of road) - goes into tile and enters lake subsurface
16E8	Overland flow about 150 feet upstream from Site 16E3

Surface runoff event samples were collected by IPS on June 17, 1996 at locations around the perimeter of the lake to further evaluate nutrient inflows from the watershed. Eight event sample sites were located at

Figure 1. Location of Sample Sites, English Lake



drain tile outfalls and areas of significant runoff contribution to the lake (Figure 1).

RMG compiled water quality monitoring data from Phases I, II, and III and performed basic statistical analyses to evaluate historic trends in English Lake. The data covered portions of the time period from 1991 to 1997.

Drain Tile Assessment

The Manitowoc County Soil & Water Conservation Department and Madson Tiling & Excavating were contacted in an attempt to attain drain tile maps; however, neither of these sources had any drain tile information. Landowners were also contacted and asked to identify the location of tiles on their property through use of aerial photographs of the site. The landowners visited (Eugene Schwantz and Ken Luebke) were able to locate the tiles present on their property.

The drain tile locations were mapped and used, along with the United States Geologic Survey (USGS, 1978) topographic map of the site, to determine the "historic" and current English Lake watershed boundary. The "historic" watershed boundary was determined by an examination of topographic relief. The current English Lake watershed boundary was determined as the "historic" boundary plus additional drainage area resulting from installation of agricultural drain tiles which discharge to the lake.

The USGS topographic map and 1995 aerial photography were used to define land uses in the watershed. Land use data was entered by RMG into the phosphorus loading module of Version 2.00 of the Wisconsin Lake Model Spreadsheet (WLMS) to estimate phosphorus loads to English Lake and partition the loads into the various landuse categories. WLMS was also used to compare phosphorus loads to English Lake before and after installation of agricultural drain tiles. Output from WLMS can be found in Appendix I.

Alternatives to Maintain and Enhance the Lake

A literature review was conducted to analyze and identify feasible and applicable nutrient control measures for remediation of English Lake water quality. It is intended that the compiled background data be used for development of future conceptual remediation designs for English Lake.

Public Education and Monitoring of Exotic Species

English Lake was observed throughout the study period for occurrences of nuisance exotic species such as Eurasian water milfoil (*Myriophyllum spicatum*) or purple loosestrife (*Lythrum salicaria*). To educate the public, brochures regarding exotic species and their associated dangers were provided to the ELMD for circulation.

DISCUSSION

Water Quality Monitoring

Table 2 presents the results of the routine water quality monitoring. In-lake surface total phosphorus levels during the Phase III study period averaged 0.053 mg/l. Surface total nitrogen was only measured for one sample (June 13, 1996), with a value of 1.180 (mg/l). For the one data point, the nitrogen to phosphorus ratio was 26.8. This value indicates, as did data in Phases I and II, that English Lake is phosphorus limited. Flow at the lake outlet (Site 1602) was sufficient for sampling on only one sample date (June 13, 1996).

From 1991 to 1997, the average in-lake surface total phosphorus value was .071 mg/l, and the average total nitrogen value was 1.36 mg/l. The average total phosphorus and total nitrogen values were similar to those reported for lakes in the Southeast Region of Wisconsin (.079 mg/l and 1.43 mg/l respectively; Lillie and Mason, 1983).

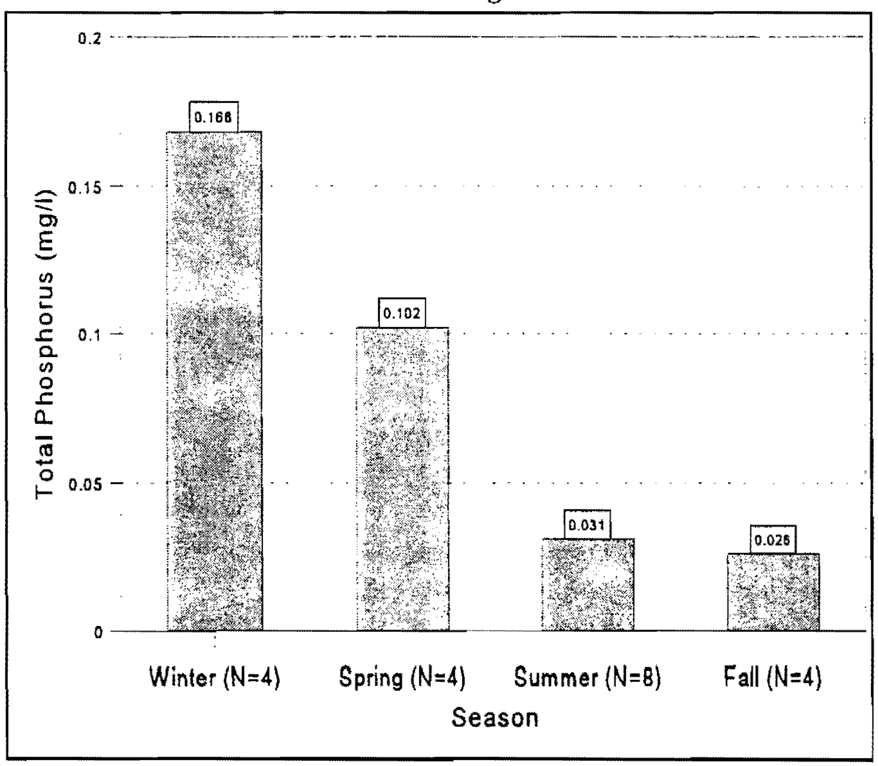
Table 2. Water Quality Parameters, Stations 1601 and 1602, English Lake, June 13, 1996 - February, 1997.

STATION		1601	1601	1601	1601	1601	1602
PARAMETER	SAMPLE[1]				DATE		
		06/13/96	07/31/96	08/14/96	09/23/96	02/03/97	06/13/96
Secchi (feet)		10.8	6.7	10.1	8.1	NR	NR
Cloud Cover		0	100	10	100	100	NR
Temperature (degrees Celsius)	S	20.94	22.32	24.9	17.79	3.30	NR
	B	4.48	5.19	4.32	4.33	1.67	—
pH (surface units)	S	7.72	8.83	8.54	8.21	6.90	NR
	B	5.27	6.41	7.05	6.87	6.90	—
D.O. (mg/l)	S	9.82	10.81	8.68	8.49	12.50	NR
	B	3.94	5.43	0.14	0.31	NR	—
Conductivity (umhos/cm)	S	423	394	415	418	NR	415
	B	477	460	520	547	NR	—
Laboratory pH (surface units)	S	8.78	NR[2]	NR	NR	NR	8.84
	B	NR	NR	NR	NR	NR	—
Total Alkalinity (mg/l)	S	173	NR	NR	NR	NR	169
	B	NR	NR	NR	NR	NR	—
Tot. Kjeld. Nitrogen (mg/l)	S	1.1	NR	NR	NR	NR	1.2
	B	NR	NR	NR	NR	NR	—
Ammonia Nitrogen (mg/l)	S	0.041	NR	NR	NR	NR	0.032
	B	NR	NR	NR	NR	NR	—
$NO_2 + NO_3$ Nit. (mg/l)	S	0.080	NR	NR	NR	NR	0.013
	B	NR	NR	NR	NR	NR	—
Total Nitrogen (mg/l)	S	1.180	NR	NR	NR	NR	1.213
	B	NR	NR	NR	NR	NR	—
Total Phosphorus (mg/l)	S	0.044	0.033	0.017	0.018	0.154	0.051
	B	0.438[3]	0.652[3]	0.672[3]	0.753[3]	0.227	—
Dissolved Phos. (mg/l)	S	0.005[3]	ND[4]	0.002	ND	0.147	0.003[3]
	B	0.375[3]	0.590	0.650	0.143	0..149	—
Nit./Phos Ratio	S	26.8	—	—	—	—	23.8
	B	—	—	—	—	—	—
Chlorophyll a (ug/l)	S	5.09	24.2	3.12	4.49	NR	10.7
Total Solids (mg/l)	S	268	NR	NR	NR	NR	268

[1] S = surface, B = bottom; [2] NR = no reading; [3] holding time exceeded by SLOH; [4] ND = not detectable;

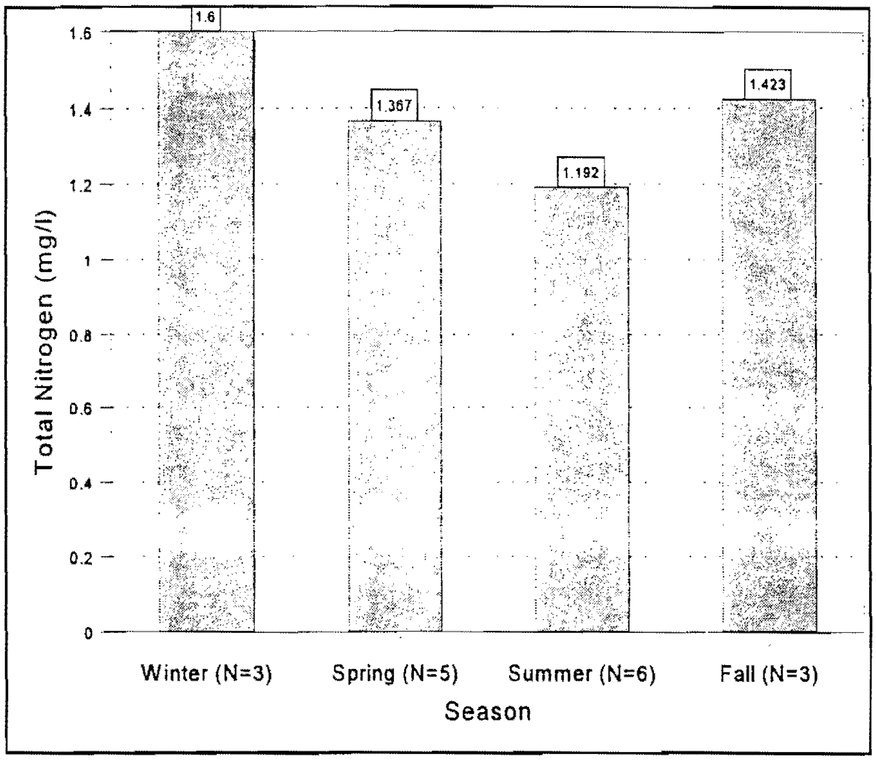
Cumulative data from all of the English Lake planning grant studies was used to determine the distribution of total phosphorus by season for 1991 through 1997 (Figure 2). Total phosphorus concentrations in English Lake are highest in the winter and continue to decrease through the summer and fall seasons. The probable reason for this trend relates to nutrient dynamics in eutrophic waterbodies. Lake sediments contain much higher concentrations of phosphorus than does lake water (Wetzel, 1983). Under anaerobic conditions, like those present at the sediment interface in English Lake (Table 2), sediments release phosphorus to the overlying water. In winter, phosphorus uptake by algae and aquatic vegetation is minimal, and phosphorus concentrations in the lake remain elevated as a result. In spring, phosphorus loading from runoff increases, but is offset by an increase in biological uptake of phosphorus. Summer conditions are dominated by rapid algal and vegetative utilization of available phosphorus, resulting in depressed epilimnetic phosphorus levels. This condition persists through fall until biological activity decreases and fall turnover releases hypolimnetic nutrients, thereby increasing epilimnetic phosphorus levels during winter months.

Figure 2. Total Phosphorus Seasonal Averages from 1991 to 1997 Based on Planning Grant Studies.



Seasonal trends in total nitrogen over the English Lake study period from 1991 to 1997 showed a similar trend, but with less drastic reductions during the growing season (Figure 3). As mentioned earlier, English Lake is phosphorus limited, and, therefore, it is likely that a greater percentage of available phosphorus than available nitrogen is utilized for biological activity. The reason for the fall increase in total nitrogen is unclear, but it may be an anomalous result due to the small data set available.

Figure 3. Total Nitrogen Seasonal Averages from 1991 to 1997 Based on Planning Grant Studies.



Over the study period from 1991 to 1997, the Carlson Trophic State Index (TSI) indicated primarily eutrophic conditions (Figure 4). Carlson (1974) suggests that priority be given to the chlorophyll *a* TSI values in summer months, and to the phosphorus TSI values in spring, fall, and winter when algae production may be limited by factors other than phosphorus, such as light and temperature. An examination of the data with the above recommended emphasis clearly indicates that eutrophic conditions predominate in English Lake.

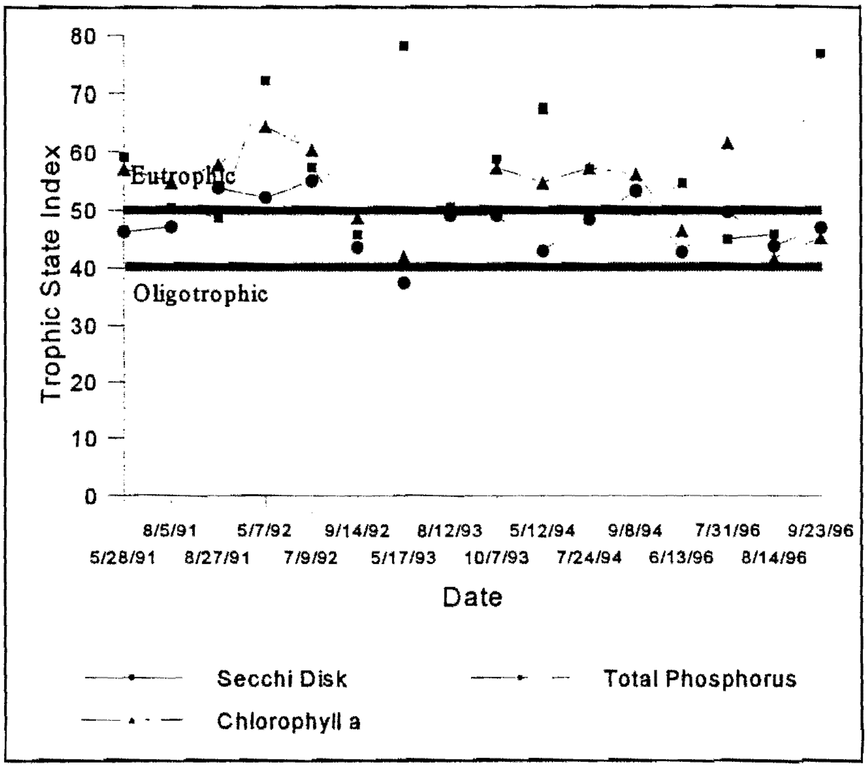
Event monitoring was conducted during one rain event, and indicated that the highest total nitrogen and total phosphorus values were recorded at sites 16E6 and 16E8 (Table 3).

Table 3. Event Phosphorus and Nitrogen Parameters, English Lake, June 17, 1996

DATE PARAMETER	EVENT[1]	16E1	16E2	16E3	16E4	16E5	16E6	16E7	16E8
		SAMPLE SITE							
06-17-96									
Diss. P	0/3.50[1]	NS[2]	0.011	0.008	NS	NS	0.093	NS	1.95
Tot. P		NS	0.077	0.067	NS	NS	0.498	NS	3.33
TKN		NS	1.5	1.2	NS	NS	1.9	NS	7.6
NH_4-N		NS	0.046	0.031	NS	NS	0.050	NS	0.730
NO_2+NO_3-N		NS	0.941	0.037	NS	NS	2.9	NS	0.964
Tot. N		NS	2.44	1.24	NS	NS	4.80	NS	8.56

[1] rainfall (in.): day prior/day of (10); [2] NS = no sample collected;

Figure 4. Trophic State Index Values During the Planning Grant Study Period



Event sites 16E3 and 16E8 produced the highest mean total phosphorus concentrations over the period from 1991 to 1997 (Figure 5). The mean total phosphorus concentrations at these sites was approximately 400% higher than the concentration at the next highest event site (16E1). Site 16E3 is associated with a drain tile outfall located east of English Lake, and site 16E8 is associated with overland flow entering a grassed waterway approximately 150 feet upstream of site 16E3. The drain tile outfalls at sites 16E2 and 16E3 produced the highest mean total nitrogen concentrations over the duration of the study period (Figure 6). Site 16E2 is an outfall from a tile network that drains agricultural land located on the southeast corner of English Lake

Figure 5. Mean Total Phosphorus by Event Site from 1991 to 1997 Based on Planning Grant Studies.

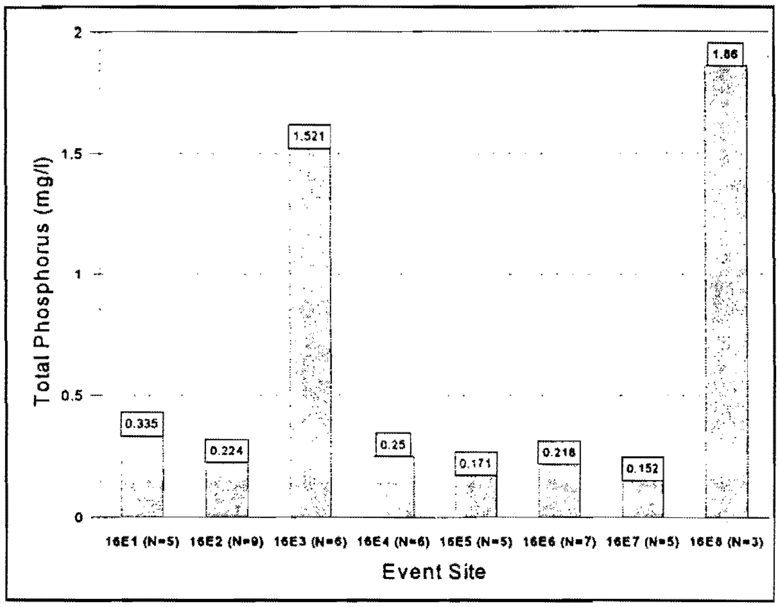
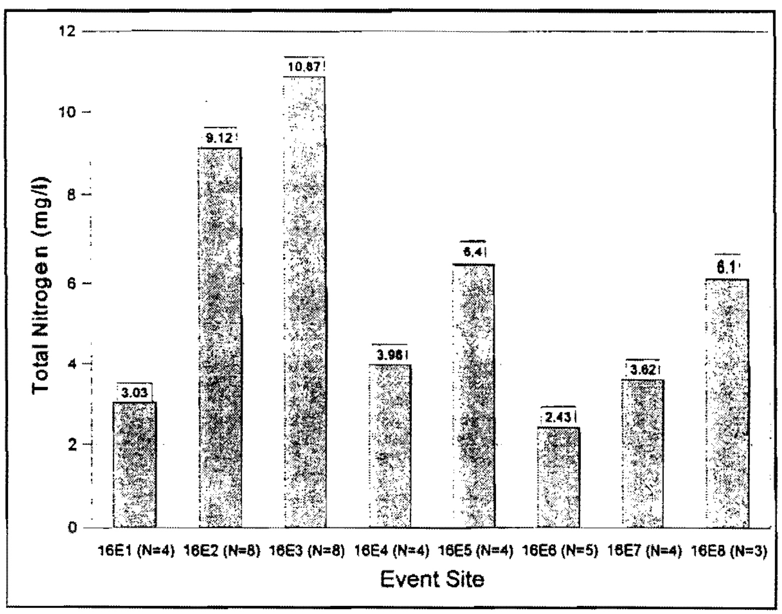


Figure 6. Mean Total Nitrogen by Event Site from 1991 to 1997 Based on Planning Grant Studies.



Drain Tile Assessment

A number of drain tile outfalls discharging to the lake were identified in the Phase I and Phase II studies. However, the location and extent of the drain tile networks was not known. These tiles were identified as a significant source of nutrients and sediment to the lake and further study was recommended in Phase II. The purpose of this assessment is to define the drain tile networks, assess their affect on English Lake and determine if there is a need for the implementation of control measures.

As described previously, various agency and landowner contacts were made to obtain information regarding the location of the drain tile networks. The majority of these tiles were installed greater than ten years ago. The known drain tiles that discharge to the lake are shown in Figure 7. Each of the drain tile networks have been identified by letter. As can be seen in Figure 7, the tile networks to the south have expanded the watershed tributary to the lake considerably. The "historic" English Lake watershed is approximately 93 acres. The drain tile networks add approximately 78 additional acres of land area to the English Lake watershed. Of the drain tiles identified, Tiles A and B are the only tiles that add substantial land area to the watershed. The remaining tiles exist primarily within the "historic" lake watershed.

WLMS was used to estimate the phosphorus loads from both the "historic" watershed and the additional watershed areas associated with the drain tiles. WLMS does not provide a phosphorus loading coefficient for barnyard/feedlot land use. Two acres of this land use, however, does exist within the English Lake watershed. To incorporate this land use into the phosphorus loading module of WLMS, a phosphorus loading coefficient for barnyards/feedlots developed by Reckhow et al. (1980) was used. Total annual phosphorus loads are summarized in Table 4.

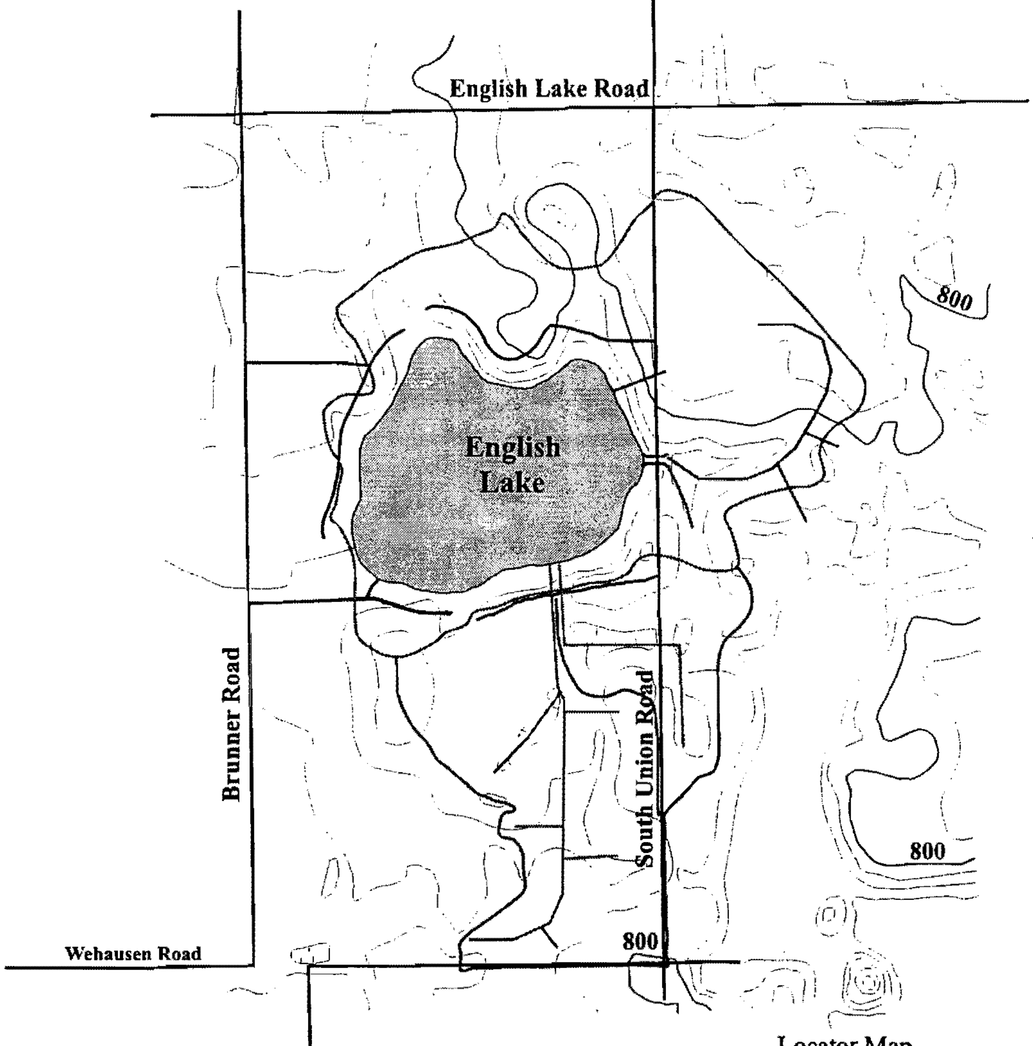
Table 4. English Lake Total Annual Phosphorus Loads

Watershed	Total Phosphorus Load (pounds per year)
Historic	473
Tile A	24.1
Tile B	10.7

Phosphorus loads are calculated in WLMS by multiplying the acreage in each land use category (e.g., mixed agriculture, medium density residential, forest, etc.) by a loading coefficient for that land use category. A range of three coefficients (low, most likely and high) are presented to allow the model user to select the value that best fits the site conditions. A high coefficient would be selected where the lands in a given category are in poor condition resulting in greater than average runoff and erosion or, for example, if it is known that high levels of fertilizer are used on a given field. Conversely, the low coefficient would be selected when circumstances indicate that the loading may be less than normal for a given land use category.

The most likely coefficients were used for the analysis of the "historic" watershed. The total annual phosphorus load from the "historic" watershed is 473 pounds. To be conservative, the low coefficients were used for the analysis of the additional watershed areas associated with the drain tiles. The low coefficients were selected to account for possible phosphorus reductions associated with infiltration through the soil column prior to entering the tile system. The watersheds for tile A and tile B total 54

Figure 7. Location of Drain Tiles and Watershed Boundary



Locator Map

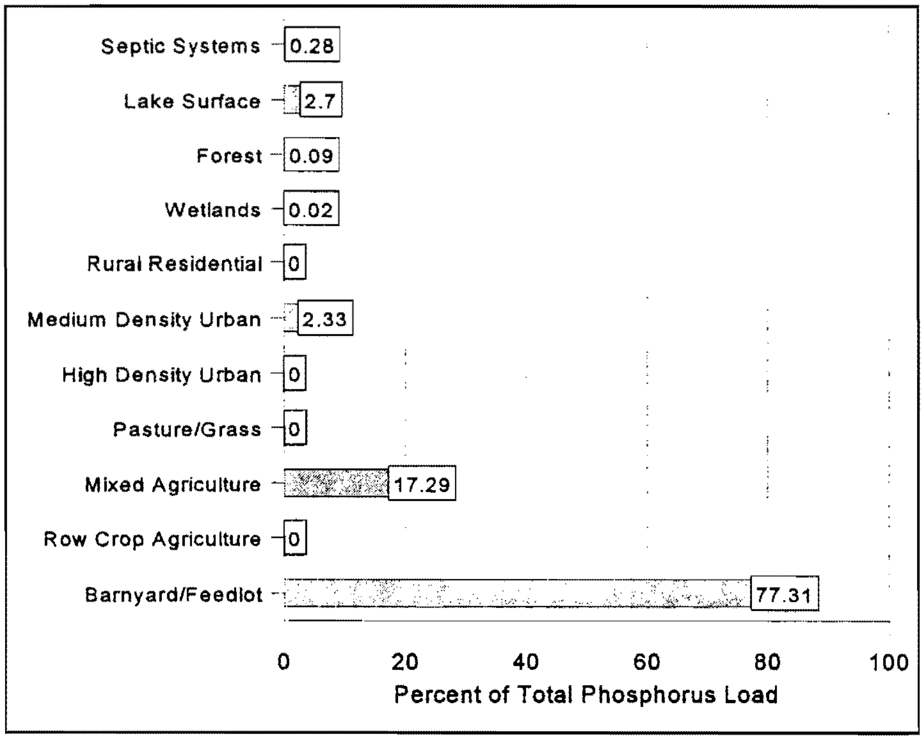
Legend

- Tile A
- Tile B
- Tile C
- Tile D
- Tile E
- Historic Watershed Boundary
- Increase In Watershed Due To Tile Networks

English Lake **E/2 of Section 7, T18N, R23E, Town of Newton, Manitowoc County, WI**	**By: SLR**	**Date: 3/14/97**
	Scale: 1" = 1000'	**Sheet: 1 of 1**

and 24 acres, respectively. The total annual phosphorus loads (low values) are 24.1 pounds for Watershed A and 10.7 pounds for Watershed B. As a result, the current total annual phosphorus load to English Lake is 507.8 pounds. Of the total load, 77 percent is from barnyard/feedlot runoff, 17 percent is from agricultural crop land (Figure 8), and 7 percent is a result of loading from the two tiled watersheds outside of the lake's "historic" drainage area.

Figure 8. Percent of Phosphorus Load by Land Use for the Existing English Lake Watershed



Alternatives to Maintain and Enhance the Lake

A number of alternative measures to improve water quality and manage the lake were proposed in the Phase I and Phase II study reports. Based on the studies conducted in Phase III, agricultural activities have been shown to contribute the majority of the total phosphorus to the lake. The watershed surrounding English Lake is primarily agricultural and the effective watershed tributary to the lake has been considerably enlarged as a result of agricultural drainage activities. As a result, the focus of the alternative concepts presented herein is on the control of agricultural runoff, and other measures that may be applicable once these sources have been controlled.

Enlarging the watershed area of English Lake through agricultural drainage activities has resulted in increased hydrologic loading and increased nutrient and sediment loading. The majority of the tiled areas artificially draining to the lake are in agricultural use. Although no historic water quality data exists, this factor has most likely had a significant water quality impact on the lake. The most drastic, yet most effective means of reducing the nutrient and sediment loads from the tiled areas is to plug or break the tiles before they reach the lake. Unfortunately, this would likely result in flooding areas that were purposely drained such that they would be unavailable for agricultural use. This alternative is only viable if the owners of the drained lands are willing to convert portions of their property into wetlands or wildlife lands. These land use conversions do not necessarily result in reduced land values. In fact, payments may be available to landowners who willingly enroll in programs, such as the Conservation Reserve Program (CRP), that promote the conversion of agricultural lands to wetlands. Also, the Wisconsin Department of Transportation and other agencies/organizations are often interested in purchasing lands that can successfully be converted to wetlands. Further funding may also be available through a WDNR Lake Protection Grant. The net affect to lake water quality if these tiled areas are separated from the lake, is 100% removal of the tile nutrient and sediment loads.

A less drastic means of controlling inputs to the lake from the drain tiles is to route the drain tile outlet through a treatment system prior to discharging to the lake. A number of measures could be applicable, including grassed channels, sedimentation basins, constructed wetlands, etc. Higgens, et al. (1993) presents a case study of a constructed wetland system used to treat agricultural runoff prior to discharge to a lake in northern Maine. The site conditions described in this case study are very similar to the portion of the English Lake watershed in the vicinity of monitoring station 16E8.

Agricultural runoff was found to be the largest source of phosphorus and sediment to Long Lake in the St. John Valley of northern Maine. In a fashion similar to the Priority Watershed Program work done on the Eugene Schwantz property by the Soil Conservation Service, St. John Valley Soil and Water Conservation District (SWCD), and the Maine Department of Environmental Protection developed a watershed management plan that targeted agricultural sources of phosphorus. It was estimated that standard conservation practices (e.g., contour row cropping, conservation tillage, buffer strips, grassed waterways, etc.) reduced phosphorus loads to the lake by 10% and sediment loads by 25% to 30%.

In this case, however, the Soil Conservation Service also designed and constructed four "nutrient/sediment control systems" to further reduce the nutrient and sediment loads to the lake. The constructed nutrient/sediment control system includes, in series, a sedimentation basin, grass filter strip, constructed wetland, and detention pond which discharges to a final vegetated polishing filter. Runoff collected and diverted from cropland first enters the sedimentation basin where the water is slowed and detained to allow larger particles to settle and to reduce the hydraulic impact on downstream components. Once the basin fills, the overflow is directed through the grass filter strip where the runoff is further slowed and some suspended solids and attached nutrients are removed. Water next enters a shallow wetland, where plant uptake and biological activities further remove nutrients, and finally a detention pond which provides the retention time necessary to settle out the smaller particles.

The effectiveness of this system was monitored for two years. Total annual phosphorous removals ranged from 82 to 91 percent. Total annual suspended solids removals ranged from 96 to 97 percent. The sediment basin component alone, accounted for about half of the total removal.

The above described system was built in 1988 to treat an approximate 17 acre watershed. The system itself occupies approximately 1.5 acres. Excluding land surveying, engineering and land acquisition costs, the system was constructed for approximately $14,000.

In addition to eliminating inputs to English Lake via drain tiles, a variety of potentially applicable best management practices (BMPs) to treat nonpoint source pollution resulting from agricultural practices exist. A buffer or filter strip is an example of a BMP that could be used in the English Lake watershed. A buffer strip is an area of vegetation that is used to filter sediment, organic matter, and other pollutants from surface runoff. The buffer strip may consist of natural, undeveloped land, or it may be an area that has been planted with vegetation. Buffer strips 100 to 125 feet wide have been shown to filter approximately 75% of the sediment load from normal field runoff on moderate slopes. As buffer strip width increases beyond 125 feet, there is a decline in the rate of increase of removal ability (Karr and Scholsser, 1981). The effectiveness of buffer strips in removing phosphorus and nitrogen from surface runoff has been found to be variable, with reported ranges of 6% to 80% and 4% to 90% respectively (Karr and Schlosser, 1977).

Buffer strips could provide the greatest potential benefit adjacent to steep slopes on the periphery of English Lake by acting as a receiving area for runoff, and reducing nutrient and sediment loads contained in surface runoff. Buffer strips would be especially effective on the border of agricultural lands. Funding may be available through programs such as CRP for design and implementation of buffer strips on agricultural lands surrounding English Lake.

The barnyard/feedlot located east of English Lake is the largest source of phosphorus for the lake (Figure 8). Barnyards and feedlots can be substantial contributors of nutrient laden runoff. A single dairy cow produces approximately 186 grams of nitrogen and 33 grams of phosphorus per day (Hammer, 1993). Efforts should be made, when possible, to reduce the proximity of barnyards and feedlots to waterbodies, and also to treat surface runoff resulting from these areas. Additional BMPs such as conservation tillage, crop rotation, and manure management can also be effective in reducing nonpoint source pollution.

Even if influent phosphorus sources to a lake are controlled, eutrophication and algal blooms can continue for a period. The addition of chemicals has been used for controlling eutrophication in phosphorus limited lakes and is most effective as one of the final management measures after the sources of influent phosphorus have been controlled to the maximum extent possible. Aluminum sulfate is one of the most commonly used chemicals for lake phosphorus treatment. Aluminum sulfate is acidic in an aqueous solution and tends to bind with phosphorous, forming a floc which ultimately settles to the bottom and forms a protective cover that may reduce nutrient releases from the benthos (Krenkel and Novotny, 1980).

In 1988, the Bullhead Lake Advancement Association successfully treated their lake with aluminum sulfate to trap phosphorus that would normally be available for algae production (Rasman, 1988). Bullhead lake is a 67 acre lake located in west central Manitowoc County, Wisconsin with a maximum depth of 40 feet. In response to increased algal blooms, 9600 gallons of 17% aluminum sulfate (i.e., nine tons dry weight of aluminum) was applied at a depth of four to six feet below the water surface. Water quality monitoring data collected four days after the treatment indicated that total phosphorous levels were reduced. Visibility was also increased after the treatment.

The total cost to treat 713 acre-feet at Bullhead Lake in 1988 was less than $11,000. The volume of English Lake is approximately 2.5 times greater than that of Bullhead Lake. As a result, one would expect that the costs for chemical treatment of English Lake using similar methods would be approximately $27,500, plus any costs as a result of inflation since 1988.

BASELINE CONCLUSIONS

The Phase III Lake Planning Grant was intended to bridge the gap between the study phases of this project and the future implementation phases wherein measures could be employed to remediate problems identified through the Phase I and II studies. Phase III included the final baseline water quality monitoring, definition of existing drain tile locations, an analysis of alternative control measures that could apply to English Lake, continuation of the public involvement/education elements of the project, and coordination with the WDNR and other agencies to prepare an application for funding to implement control measures.

Water Quality Monitoring

Water sampling conducted during Phase III studies indicated similar water quality conditions at the routine and event sites as was discovered during Phase I and II studies. As in Phases I and II, English Lake was shown to be phosphorus limited, and, as a result, sensitive to increased phosphorus inputs.

An analysis of the cumulative data from Phases I through III (1991 to 1997) indicated that total phosphorus concentrations in English Lake peaked in the winter, declined in spring, and then stabilized in summer and fall (Figure 2). This trend is believed to be closely related to changes in biologic activity and limnologic turnover. Total nitrogen showed a similar but less defined trend during this time period (Figure 3). Seasonal decreases in total nitrogen where less drastic, thus supporting the conclusion that English Lake is phosphorus limited.

A cumulative analysis of event monitoring data over the 1991 to 1997 study period indicated that sites 16E3 and 16E8 (both located east of the lake on agricultural property) had drastically higher mean total phosphorus concentrations than the other event sites (Figure 5). Sites 16E2 and 16E3 had the highest mean total nitrogen concentrations over the duration of the study period (Figure 6). Given the phosphorus limited status of English Lake, controlling the phosphorus inputs at sites 16E3 and 16E8 is likely the highest priority action for remediating English Lake water quality.

Drain Tile Assessment

The "historic" English Lake watershed covered approximately 93 acres, and the total annual phosphorus load from the "historic" watershed is 473 pounds. The drain tile networks identified in Phase III (Figure 7) were estimated to increase the English Lake watershed by approximately 78 acres. The tiled areas add approximately 34.8 pounds of phosphorus to the lake annually. Of the total annual phosphorus load to English Lake, 77 percent is from barnyard/feedlot runoff, 17 percent is from agricultural crop land, and 7 percent is a result of loading from Tiles A and B.

Alternatives to Maintain and Enhance the Lake

Analyses conducted using WLMS showed agricultural activities to contribute the majority of the total phosphorus to the lake, and event monitoring identified specific sites where nutrient concentrations were high. Given these facts, a variety of alternative concepts that may be applicable to remediating English Lake water quality were reviewed. The potential methods identified for maintaining and enhancing the lake included plugging or breaking drain tiles, use of sedimentation basins and treatment systems, installation of buffer strips, barnyard and feedlot management, and aluminum sulfate treatment. Most of the management strategies listed above could be directly applicable to English Lake; however, most also require landowner participation and/or land purchase. The applicability of these concepts to specific locales in the English Lake watershed should be analyzed in detail in subsequent studies.

MANAGEMENT RECOMMENDATIONS

1. Specific management strategies should be defined to reduce the elevated nutrient concentrations recorded at event sites 16E2, 16E3, and 16E8, and, thereby, reduce the nutrient load to English Lake. Of these three sites, priority should be given to 16E3 and 16E8 due to the high total phosphorus concentrations recorded at these sites. Management options for the barnyard/feedlot located near sites 16E3 and 16E8 should be explored. The feasibility of a sedimentation basin/wetland treatment system should also be studied.

2. The potential for removal of the direct drainage to English Lake from Tiles A and B should be explored, and the feasibility of a wetland restoration project on the lands drained by Tiles A and B should be studied. An examination of the availability of the tiled property for purchase and remediation will need to be conducted. If the land is able to be purchased or landowner cooperation is obtained, detailed management strategies should be developed.

3. Management strategies for English Lake that incorporate plugging, breaking, or diverting of drain tiles; use of sedimentation basins and/or treatment systems; installation of buffer strips; or aluminum sulfate treatment should be defined as they pertain to specific locales surrounding English Lake.

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