IPS ENVIRONMENTAL AND ANALYTICAL SERVICES
Appleton, Wisconsin

LAKE MANAGEMENT PLAN
WEYAUWEGA LAKE
WAUPACA COUNTY, WISCONSIN

REPORT TO:
WEYAUWEGA LAKE CONSERVATION CLUB

October, 1992

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GLOSSARY OF TERMS (1, 2, 3)

Best Management Practices (BMP's) — Land use practices to control the interactive processes of erosion, runoff and nutrient or pesticide inflows.

Chlorophyll a — Green pigment present in all green plant life and needed in photosynthesis. The amount present in lake water is related to the amount of algae and is therefore used as an indicator of water quality.

Drainage Lake — Generally referred to as those natural lakes having inflowing and outflowing streams.

Edge — A biologically diverse area located at the interface of differing habitat types.

Eutrophic — From Greek for "well nourished", describes a lake of high photosynthetic activity and low transparency.

Eutrophication — The process of lake aging or enrichment with nutrients, generally with associated increases in algae or weeds. The extent to which this process has progressed is described by trophic status terms, e.g., oligotrophic, mesotrophic, or eutrophic.

Fetch — The longest distance over which the wind can sweep unobstructed.

Littoral — The shallow area of a lake from the shore to the depth where light no longer penetrates to the bottom.

Macrophyte — Commonly referred to as lake "weeds", actually aquatic vascular plants that grow either floating, emergent or submergent in a body of water.

Mesotrophic — A lake of intermediate photosynthetic activity and transparency.

N/P Ratio — Total nitrogen divided by the total phosphorus found in a water sample. A value greater than 15 indicates that phosphorus is limiting for primary production.

GLOSSARY OF TERMS
(Continued)

Physicochemical	Pertaining to physical and/or chemical characteristics.
Residence Time	Commonly called the hydraulic residence time. The amount of time required to completely replace the lake's current volume of water with an equal volume of "new" water.
Secchi Depth	A measure of optical water clarity as determined by lowering a weighted Secchi disk (20 cm in diameter) into the water body to a point where it is no longer visible.

SUMMARY

Weyauwega Lake, an impoundment of the Waupaca River, is located in the City of Weyauwega, Waupaca County, Wisconsin. It drains an extensive (250 sq mi) primarily open/agricultural watershed through several inlets, as well as paved/residential areas through stormwater discharge pipes.

Water quality, according to the Trophic State Index, indicated a **mesotrophic** to **eutrophic** status (with lower than expected levels of total phosphorus); total phosphorus was very high in rain event inflows. Light penetration was such that the entire lake bottom received sunlight for plant production most of the time.

Aquatic plants were widespread and very abundant; coontail and common waterweed, both potentially nuisance species, were most abundant. Nuisance aquatic plant growth makes much of the lake impassible during open water months.

Sedimentation in Weyauwega Lake was estimated to be relatively high (like in many impoundments) and contributes to reduced impoundment capacity and increased plant growth. Upstream areas of dense emergent and submergent vegetation help to filter sediment during periods of relatively lower flow.

Management recommendations target reduction of nutrient and sediment inflows, improved recreational and aesthetic values, and improvement of wildlife and fishery habitat:

- Water quality monitoring should be continued on a similar schedule to track trends; event and Self-Help monitoring should be continued to further assess stormwater inputs.
- Riparian land use practices, including fertilizer, sediment and runoff management, should be encouraged.
- Effective localized macrophyte harvest should be implemented to improve access and maximize **edge**.
- Use zones (upstream vs. downstream) should be considered.
- The feasibility of stormwater discharge reduction or redirection should be assessed.
- Efforts to establish the Waupaca River Watershed as a priority watershed should continue to facilitate implementation of **Best Management Practices** (BMP's) throughout the watershed.
- Dredging options may be addressed, but only after a watershed-wide erosion control plan is designed.

[1] Text terms in bold print defined in glossary (pp. vi-vii)

INTRODUCTION

Weyauwega Lake is located in the Town and City of Weyauwega in south-central Waupaca County, Wisconsin. Weyauwega Lake is actually a 251 acre impoundment of the Waupaca River created in 1940 by the construction of a hydroelectric dam which currently remains in operation.

The Weyauwega Lake Conservation Club (WLCC) was formed in 1978 to provide leadership and coordination of lake preservation and educational activities pertinent to the Weyauwega Lake resource. Overall, the major concerns in development of a lake management plan included extensive nuisance weed growth, siltation, and non-point source nutrient input. Currently, the WLCC has 5 elected officers and about 42 members.

The WLCC, in September 1990, decided to pursue the development of a long range management plan under the Wisconsin Department of Natural Resources (WDNR) Lake Management Planning Grant Program. The WLCC officers selected IPS Environmental & Analytical Services (IPS) of Appleton, Wisconsin as its consultant to assist in development the plan. A grant application, incorporating required or recommended program components and the following objectives, was prepared, submitted, and approved in March, 1991:

- quantification of nutrient and sediment problems,
- identification of sources of nutrients and sediment,
- development of nutrient and sediment control measures,
- increase public awareness, knowledge and participation in lake management efforts management efforts,
- document the multi-use potential of the lake.

A Planning Advisory Committee, comprised of representatives from WLCC and IPS met initially in March, 1991 to provide program guidance and direction.

DESCRIPTION OF AREA

Weyauwega Lake (T21N R13E S4, 5) is a **drainage lake** (possessing a permanent inlet and outlet) located partially in the City of Weyauwega, in Waupaca County, Wisconsin (Figure 1). The lake is actually an impoundment of the Waupaca River created by a dam for generation of hydroelectricity.

The general topography of Waupaca County is related to glacial activity. The watershed is about 250 sq. miles; the more immediate Weyauwega Lake subwatershed (i.e., 26 sq. miles and comprised of lands draining downstream from the confluence of the Waupaca and Crystal Rivers) was analyzed by 40 acre parcels and comprised of open/agricultural areas (80%), marsh/wetland areas (11%) and forested areas (9%) (Figure 2). Land slopes in the subwatershed were nearly level (76%), gently sloping (6%) and sloping (19%). Soils textures were silt (81%), sand (18%) with small areas of clay.

Topography adjacent to the lake is nearly level to gently sloping. The major soil types adjacent to Weyauwega Lake are moderately well drained Borth silty clay loams on 1-4 percent slopes (mostly to the North), excessively drained Plainfield loamy sands on 0 to 6 percent slopes (to the South and East) and somewhat poorly drained Symco loams on 0 to 3 percent slopes (to

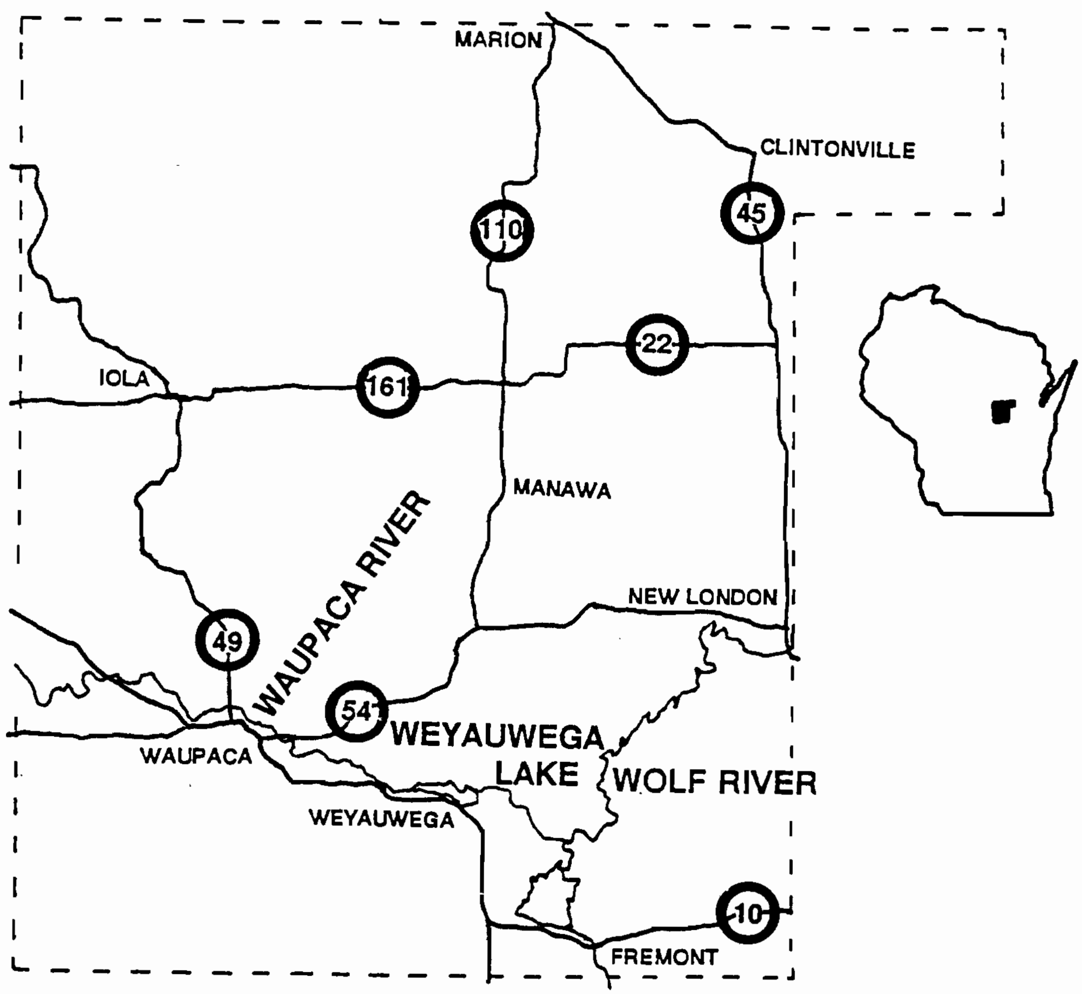
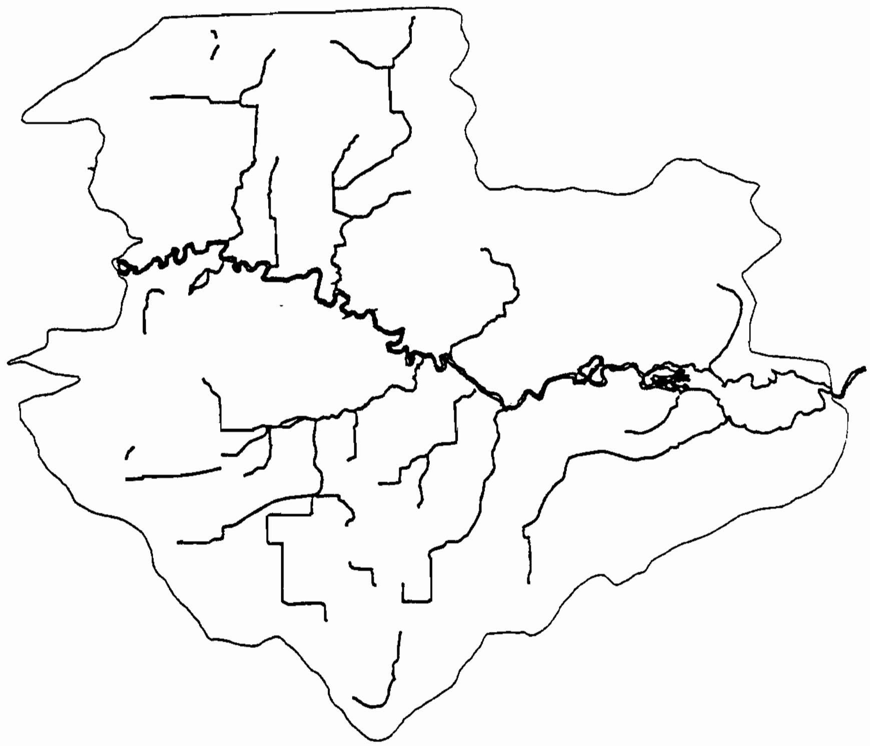


Figure 1. Location Map, Weyauwega Lake, Waupaca County, WI.



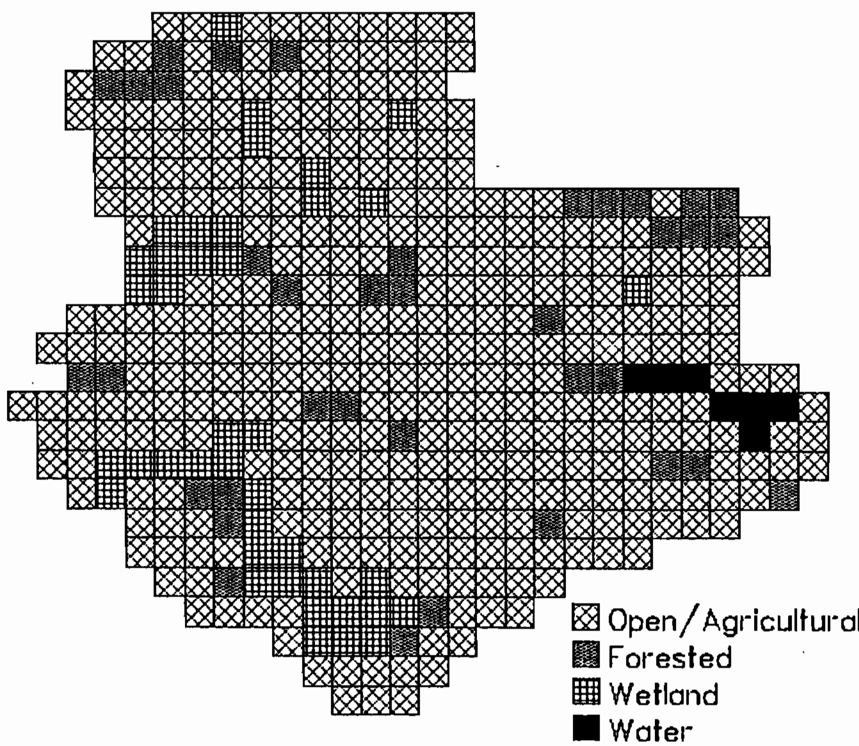
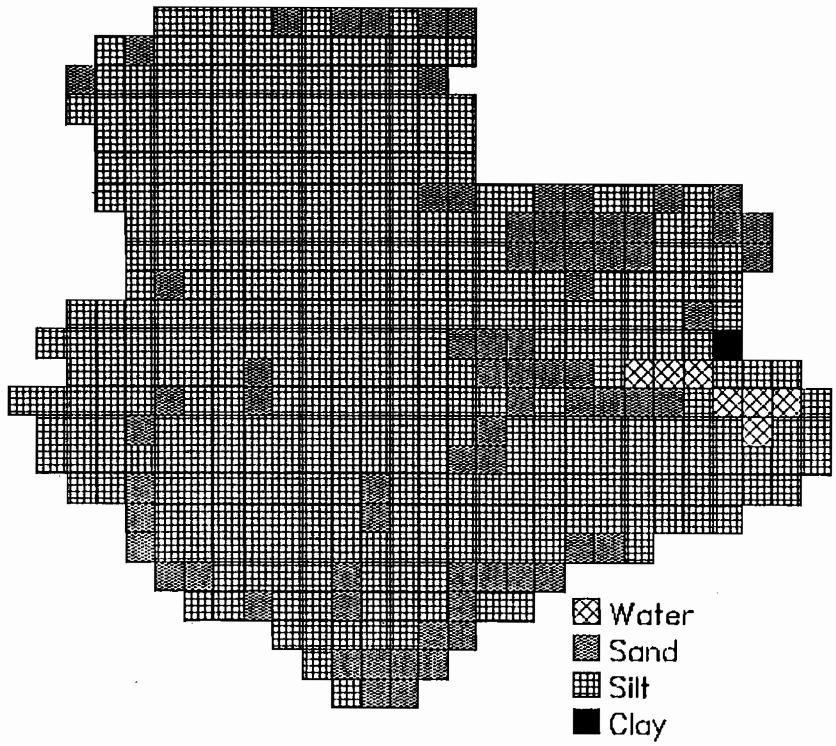


Figure 2. Some Physical Characteristics of the Weyauwega Lake Subwatershed.



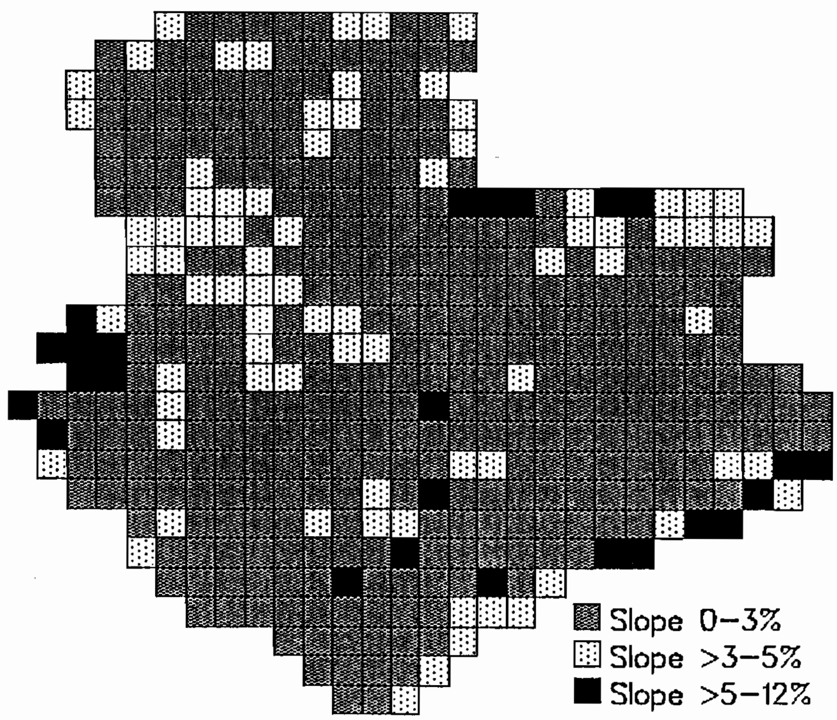


Figure 2 (continued). Some Physical Characteristics of the Weyauwega Lake Subwatershed.

the South and West). Soil permeability is rapid in Plainfield soils and moderately slow in Borth and Symco soils. Soils are poorly suited for septic systems since there is potential of septic runoff or infiltration to groundwater or surface waters because of wetness (Symco, Borth) or high permeability (Plainfield, 4).

Weyauwega Lake has a surface area of 251 acres, an average depth of about 5 feet, and a maximum depth of 10 feet (5). The **fetch** is 1.56 miles and lies in a west-east orientation and the width is 0.6 miles in a north-south orientation. The Weyauwega Lake watershed to lake ratio is about 445 to 1 which means that 445 times more land than lake surface area drains to the lake. Lake volume is approximately 755 acre feet with a **residence time** of 2.65 days (6). Predominant **littoral** substrates include sand (70%), muck (15%), rubble (8%), gravel (5%) and clay (2%) (Pers. comm. WDNR).

Four storm sewers are located along the southeast shore and drain to Weyauwega Lake. Storm sewer discharge is untreated runoff from lawns, streets, parking lots and other paved areas and is a potential source of salts, sand, nutrients, pesticides, vegetative debris, oil, grease and potentially toxic pollutants.

Weyauwega Lake was the downstream terminus of an extensive rough fish control project in 1971. The project encompassed 42 miles of the Tomorrow-Waupaca River and tributaries, 8 miles of the Crystal River and tributaries, several lakes and numerous (37) private ponds (Table 1). Weyauwega Lake was drawn down to the original stream channel for antimycin treatment; over 85,000 pounds of fish including carp (52.9%) and mixed suckers and redhorse (40.6%) were removed. Subsequent reintroduction of forage organisms and sport fish stocking began in November, 1971 and continued in 1972 (Table 2, Pers. comm. WDNR).

Recent fish surveys show that Weyauwega Lake supports fish species including: largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieui*), rock bass (*Ambloplites rupestris*), yellow perch (*Perca flavescens*), black crappie (*Pomoxis nigromaculatus*), common sunfish (*Lepomis* spp.), northern pike (*Esox lucius*), black bullhead (*Ictalurus melas*), brown bullhead (*Ictalurus nebulosus*), yellow bullhead (*Ictalurus natalis*), madtoms (*Noturus* sp.), carp (*Cyprinus carpio*), white sucker (*Catostomus commersoni*), hog sucker (*Hypentelium nigricans*), and dogfish (*Amia calva*) (Pers. comm. WDNR).

Public access (paved ramp with parking) is available near the dam just east of Highway 110 and at a less improved public landing (with parking) on Lake Street.

Table 1. Tomorrow - Waupaca River Lakes or Ponds Treated With Antimycin, 1971.

Lake or pond	County	Acreage
Nelsonville Pond	Portage	31.8
Meyer's Lake	Portage	26.7
Amherst Pond	Portage	47.9
Makuski Lake	Portage	9.0
Eberts Lake	Portage	12.1
Shadow Lake	Waupaca	42.5
Mirror Lake	Waupaca	12.6
Big Birchyard Pond	Waupaca	5.1
Little Birchyard Pond	Waupaca	4.3
Cary Pond	Waupaca	26.4
Weyauwega Lake	Waupaca	250.6
	TOTAL	469.0

Table 2. Restocking Effort After Antimycin Treatment, 1971 - 1972, Weyauwega Lake, Waupaca County, WI.

Year	Organism	Amount
1971	*Daphnia* spp.	5 quarts
1971	Largemouth Bass fingerlings	8,420
1971	Walleye fingerlings	1,000
1972	*Daphnia* spp.	17 quarts
1972	Bluegill adults	25,000
1972	Yellow Perch adults	100
1972	Largemouth Bass fry	77,000
1972	Largemouth Bass fingerlings	18,140
1972	Walleye fry	3,000,000
1972	Walleye fingerlings	6,000
1972	Walleye yearlings	3,098
1972	Northern Pike fry	3,614,000

METHODS

FIELD PROGRAM

Water sampling was conducted in Winter (March 7), late-Spring (May 28), Summer (August 1) and late-Summer (September 10), 1991, and Spring (April 27) and Summer (July 1), 1992, at Stations 0301, the deepest point, and 0302, the Waupaca River inlet (Table 2, Figure 2). Station 0301 was sampled near surface (designated "S") and near bottom (designated "B"); Station 0302 was sampled mid-depth (designated "M").

Physicochemical parameters measured in the field were **Secchi depth**, water temperature, pH, dissolved oxygen (DO), and conductivity. Field measurements were taken using a standard Secchi disk and either a Hydrolab Surveyor II or 4041 multiparameter meter; Hydrolab units were calibrated prior to and subsequent to daily use.

Samples were taken for laboratory analyses with a Kemmerer water bottle. Samples were labelled, preserved if necessary, and packed on ice in the field; samples were delivered by overnight carrier to the laboratory. All laboratory analyses were conducted at the State Laboratory of Hygiene (Madison, WI) using WDNR or APHA (7) methods. Winter water quality parameters

Table 3. Sampling Station Locations, Weyauwega Lake, 1991 - 1992.

WATER QUALITY

Site	Latitude/Longitude		Depth
0301	44° 19' 30"	88° 56' 05"	10.0 ft.
0302	44° 19' 40"	88° 57' 55"	2.0 ft.

MACROPHYTE TRANSECTS

Transect	Latitude/Longitude Origin	End	Transect Length(m)	Bearing (Degrees)	Depth Range[1]
A	44° 19' 44" 88° 57' 43"	44° 19' 34" 88° 57' 40"	18	144	1/2
B	44° 19' 34" 88° 57' 11"	44° 19' 28" 88° 57' 04"	18	268	1/2
C	44° 19' 32" 88° 56' 49"	44° 19' 16" 88° 56' 56"	155	195	1/2/3
D	44° 19' 39" 88° 56' 36"	44° 19' 19" 88° 56' 26"	180	167	1/2/3
E	44° 19' 30" 88° 56' 11"	44° 19' 28" 88° 56' 20"	120	238	1/2/3

[1] 1 = 0.0 - 0.5m (0.0 - 1.7ft)
2 = 0.5 - 1.5m (1.7 - 5.0ft)
3 = 1.5 - 3.0m (5.0 - 10.0ft)

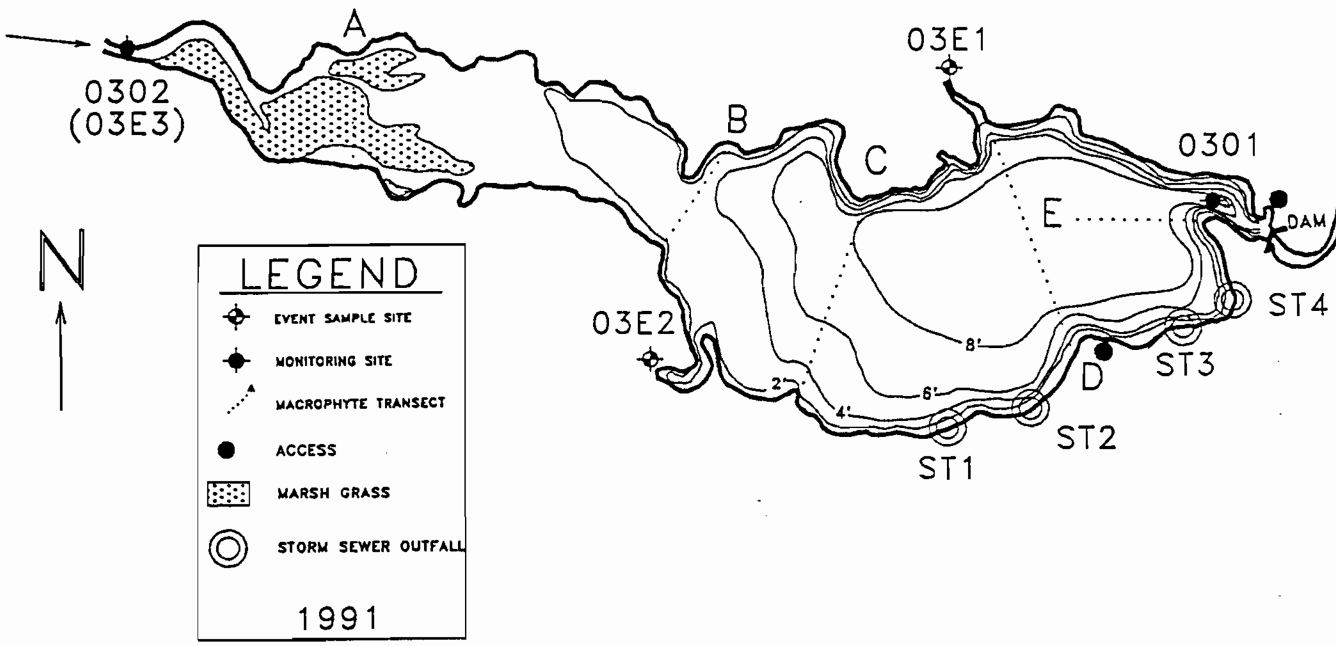


Figure 3. Sampling Sites, Weyauwega Lake, Waupaca County, WI, 1991 - 1992.

included laboratory pH, total alkalinity, total Kjeldahl nitrogen, ammonia nitrogen, nitrate/nitrite nitrogen, total phosphorus and dissolved phosphorus. Spring parameters determined by the laboratory included laboratory pH, total alkalinity, total solids, total Kjeldahl nitrogen, ammonia nitrogen, nitrate/nitrite nitrogen, total phosphorus, dissolved phosphorus, **chlorophyll a**. Summer and late Summer laboratory analyses included total Kjeldahl nitrogen, ammonia nitrogen, nitrate/nitrite nitrogen, total phosphorus, dissolved phosphorus, and chlorophyll a.

Event sampling sites were located at two major inlets to the impoundment (Sites 03E1 and 03E2) and at each of the four storm sewers (ST1, ST2, ST3 and ST4) to assess the quality of overland runoff inflows. Event samples were collected from the major inlets after a major storm event (1" precipitation in a 24 hour period) on August 9, 1991. Storm sewer event samples were also collected after a major storm event on August 26, 1992 at each of the four storm sewer outfalls. Event sample laboratory analyses included total Kjeldahl nitrogen, ammonia nitrogen, nitrate/nitrite nitrogen, total phosphorus and dissolved phosphorus.

Macrophyte surveys were conducted in early Summer (June 25) and again later in the season (September 10) using a method developed by Sorge et al and modified by the WDNR-Lake Michigan District (WDNR-LMD) for use in the Long Term Trend Lake Monitoring Program (8). Transect endpoints were established on and off shore for use as reference from one sampling period to the next. These points were determined using a Loran Voyager Sportnav latitude/longitude locator and recorded with bearing and distance of the transect (line of collection) for future surveys. Five transects sampled in 1991 were chosen to provide information from various habitats and areas of interest.

Data were recorded from three depth ranges, i.e., 0 to 0.5 meters (1.7 feet), 0.5 to 1.5 meters (5.0 feet), and 1.5 to 3.0 meters (10.0 feet), as appropriate along each transect. Plants were identified (collected for verification as appropriate), density ratings assigned (see below), and substrate type recorded along a six foot wide path on the transect using a garden rake, snorkel gear or SCUBA where necessary. Macrophyte density ratings, assigned by species, were: 1 = Rare, 2 = Occasional, 3 = Common, 4 = Very Common, and 5 = Abundant. These ratings were treated as numeric data points for the purpose of simple descriptive statistics in the Field Data Discussion section of this report.

Sediment dating was performed on one of three sediment samples taken July 1, 1992 from a depositional area in the upstream reach of the impoundment. Samples were collected by pushing an 8 foot

(1.5" diameter) core liner into the substrate as far as possible (about 7 - 7.5 feet). The top of the core was capped, the core removed, and the bottom capped upon removal from the sediment.

Cores were frozen overnight, removed from the liner and cut every 1 cm for the first 5 cm and every 2 cm thereafter. The samples were then dried and sent to the University of Wisconsin-Milwaukee, Center for Great Lakes Studies for Lead-210 analyses to determine time of deposition (in years before present).

OTHER

Water Quality Information

Additional lake information was retrieved from the WDNR Surface Water Inventory (6), WLCC water quality data, Wisconsin Self Help Monitoring Program (9), the WDNR Wisconsin Lakes publication (5) and the WDNR WI LAKES Bulletin Board System.

Land Use Information

Details of zoning and specific land uses were obtained from the UW-Extension, Waupaca County zoning maps, United States Soil Conservation Service soil maps (4), aerial photographs, and United States Geological Survey quadrangle maps. This information, when considered questionable or out-dated, was confirmed by field reconnaissance.

Ordinance information was taken from Waupaca County Zoning Ordinance, Waupaca County Floodplain Zoning Ordinance, and Waupaca County Erosion Control and Animal Waste Management Plans which were acquired from the Waupaca County Land Conservation Department.

Public Involvement Program

A summary of public involvement activities coordinated with the lake management planning process is outlined in Appendix I.

FIELD DATA DISCUSSION

Impoundments differ from natural lakes in that they characteristically have much larger watersheds, exhibit periodic flushing, and "fill-in" with deposition of the river's sediment load. While natural lakes tend toward a state of dynamic equilibrium, the physical, chemical and biological characteristics of impoundments can vary substantially over time as they are continuously affected by flow conditions of the parent river. Physicochemical parameters and biological communities in reservoirs are longitudinally and transectionally related to basin morphometry, are temporally affected by flow conditions (in the upstream reach) and water mass retention time (in the lower reach), which may be influenced substantially by flow release operations at the dam.

Weyauwega Lake is particularly prone to nutrient and sediment inputs because the impoundment drains a predominantly open/agricultural watershed (80%) with few wetland and forested areas. The impoundment also has the potential to receive substantial input from four city storm sewers. If nutrient and sediment inputs from the watershed can be minimized, periodic flushing during high flow periods can rapidly improve conditions in an impoundment.

Phosphorus is often the limiting major nutrient to algal and plant production in lakes. Surface total phosphorus during 1991-1992 monitoring ranged from 0.025 to 0.033 mg/l (parts per million, average = 0.028, median = 0.028, standard deviation (σ) = 0.003 mg/l) at Station 0301 (Table 4). Total phosphorus at Station 0302 (Waupaca River inflow) ranged from 0.025 to 0.053 mg/l (average = 0.034, median = 0.033, σ = 0.010 mg/l) over the same period (Table 5). Nitrogen to phosphorus ratios (**N/P ratio**) generally greater than 15 (for regular monitoring) indicated Weyauwega Lake to be phosphorus limited. Monitoring of feeder creeks and storm sewers (Table 6) during rain events showed significant inflow of nutrients from the watershed and from storm sewers.

Summer surface phosphorus levels in 1991-1992 (0.025, 0.026, 0.030 mg/l; average = 0.027, median = 0.026, (σ) = 0.002 mg/l) at Site 0301 were, according to a recent compilation of summer total phosphorus levels in upper midwestern lakes (10), slightly lower than typical (.030 to .050 mg/l) for lakes in the transitional region in which Weyauwega Lake is located. The average summer surface total phosphorus value for Weyauwega Lake was also somewhat lower than that found in a summary of 100 Wisconsin impoundments (ave. = 0.064, median = 0.035, σ = 0.100 mg/l) and well below that for impoundments with 0-14 day residence times (ave. = 0.094, median = 0.075, σ = 0.079) (11).

Table 4. Water Quality Parameters, Station 0301, Weyauwega Lake, 1991 - 1992.

PARAMETER	SAMPLE[1]	03/07/91	05/28/91	08/01/91	09/10/91	04/27/92	07/01/92
Secchi (feet)		NR[2]	8.0	>10.0	>10.0	5.5	>10.0
Cloud Cover (%)		NR	100	0	NR	0	90
Temperature (°C)	S	--	22.9	21.99	21.40	8.5	20.19
	B	0.25	21.1	20.58	21.32	7.93	19.29
pH (S.U.)	S	--	8.11	8.45	8.08	8.31	7.71
	B	7.15	7.71	7.66	8.02	8.27	7.66
D.O. (mg/l)	S	--	9.85	8.74	8.12	12.13	6.87
	B	8.35	5.09	6.70	7.58	NR	6.59
Conductivity (µmhos/cm)	S	--	338	366	366	321	372
	B	352	361	384	367	322	373
Laboratory pH (S.U.)	S	--	8.4	NR	NR	8.40	NR
	B	8.1	8.0	NR	NR	8.30	NR
Total Alkalinity (mg/l)	S	--	170	NR	NR	166	NR
	B	186	173	NR	NR	165	NR
Total Solids (mg/l)	S	--	2.	NR	NR	230	NR
	B	NR	2.	NR	NR	236	NR
Total Kjeldahl N (mg/l)	S	--	0.6	0.3	0.3	0.8	0.5
	B	0.6	0.6	0.4	0.4	0.7	0.4
Ammonia Nitrogen (mg/l)	S	--	0.035	0.026	0.019	0.028	0.108
	B	0.182	0.061	0.041	0.022	0.013	0.102
NO_2 + NO_3 Nitrogen(mg/l)	S	--	1.00	1.15	1.16	1.87	1.05
	B	2.25	1.04	1.07	1.0	1.84	1.61
Total Nitrogen (mg/l)	S	--	1.6	1.45	1.46	2.67	1.55
	B	2.85	1.64	1.47	1.4	2.54	2.01
Total Phosphorus (mg/l)	S	--	0.033	0.025	0.026	0.028	0.030
	B	0.037	0.043	0.038	0.029	0.029	0.031
Diss. Phosphorus (mg/l)	S	--	0.012	0.016	0.010	0.002	0.012
	B	0.025	0.025	0.029	0.012	0.002	0.012
N/P Ratio	S	--	48.5	58.0	56.2	95.4	51.7
	B	77.0	38.1	38.7	48.3	87.6	64.8
Chlorophyll *a* (µg/l)	S	--	4	NR	3	11	2

[1] S = Near Surface; B = Near Bottom
[2] NR = No Reading

Table 5. Water Quality Parameters, Station 0302, Weyauwega Lake, 1991 - 1992.

PARAMETER	SAMPLE[1]	05/28/91	08/01/91	09/10/91	04/27/92	07/01/92
Secchi (feet)		>5.0	>2.0	>3.0	>2.0	>2.0
Cloud Cover (%)		80	0	10	0	90
Temperature (°C)	M	21.13	24.18	19.60	8.73	20.69
pH (S.U.)	M	7.77	8.57	7.99	8.24	8.35
D.O. (mg/l)	M	6.22	10.74	7.44	12.02	11.11
Conductivity (µmhos/cm)	M	357	374	399	326	365
Laboratory pH (S.U.)	M	7.8	NR[2]	NR	8.30	NR
Total Alkalinity (mg/l)	M	178	NR	NR	169	NR
Total Solids (mg/l)	M	6.	NR	NR	244	NR
Total Kjeldahl N (mg/l)	M	0.6	0.4	0.3	0.5	0.3
Ammonia Nitrogen (mg/l)	M	0.044	0.026	0.048	0.028	0.048
NO_2 + NO_3 Nitrogen(mg/l)	M	1.28	1.24	1.82	1.87	1.56
Total Nitrogen (mg/l)	M	1.88	1.64	2.12	2.37	1.86
Total Phosphorus (mg/l)	M	0.053	0.033	0.027	0.033	0.025
Diss. Phosphorus (mg/l)	M	0.028	0.014	0.014	0.002	0.008
N/P Ratio	M	35.5	49.7	78.5	71.8	74.4
Chlorophyll a (µg/l)	M	4	3	3	13	3

[1] M = Mid-depth
[2] NR = No Reading

Table 6. Event Water Quality Parameters, Weyauwega Lake, August 9, 1991 (Sites 03E1, 03E2) and August 26, 1992 (Sites ST1 - ST4).

PARAMETER	03E1	SITE 03E2	ST1	ST2	ST3	ST4
Total Kjeldahl N (mg/l)	3.3	1.6	3.4	6.5	5.2	NR
Ammonia Nitrogen (mg/l)	0.033	0.085	0.427	0.281	0.261	NR
NO_2 + NO_3 Nitrogen (mg/l)	0.010	1.48	0.584	0.219	0.307	NR
Total Nitrogen (mg/l)	3.310	3.08	3.984	6.719	5.507	NR
Total Phosphorus (mg/l)	0.56	0.45	0.59	3.04	2.05	NR
Diss. Phosphorus (mg/l)	NR	NR	0.112	0.011	0.70	0.102
N/P Ratio	5.9	6.8	6.8	2.2	2.7	NR

Total nitrogen is highly variable among lakes and should only be related on a relative scale within the same lake. Total surface nitrogen for the 1991-1992 monitoring dates ranged from 2.67 mg/l to 1.45 mg/l. Event sample results, particularly for storm sewers 2 and 3, were much higher for total nitrogen. High nitrogen values may indicate fertilizer and/or animal waste input to the system.

Other indicators of lake **eutrophication** status include light penetration and algal production. Numerous summarative indices have been developed, based on a combination of these and other parameters, to assess or monitor lake eutrophication or aging. The Trophic State Index (TSI) developed by Carlson (12) utilizes Secchi transparency, chlorophyll a, and total phosphorus. As with most indices, application is generally most appropriate on a relative and trend monitoring basis. This particular index does not account for natural, regional variability in total phosphorus levels nor in Secchi transparency reduction unrelated to algal growth (e.g. that associated with color).

TSI numbers for Weyauwega Lake with respect to in-lake surface total phosphorus (first five readings, Figure 5) indicate a eutrophic classification; application of TSI's to event sample results (last five readings Figure 5) would indicate a highly eutrophic situation. TSI numbers varied between mesotrophic and

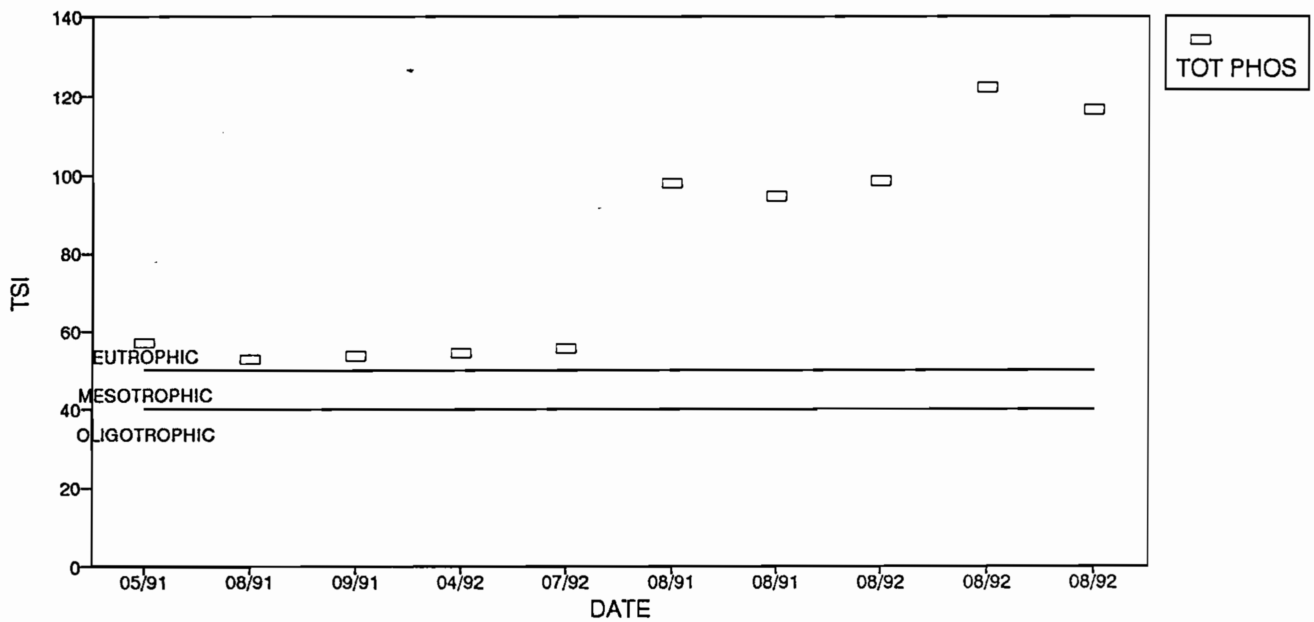


Figure 4. Trophic State Index for Total Phosphorus, Weyauwega Lake.

slightly eutrophic for Secchi depth (Figure 6) and chlorophyll a readings (Figure 7). Secchi depth TSI trends were biased high by readings "to bottom" on most sample dates. A statistical summary of 100 Wisconsin impoundments indicated an average chlorophyll a reading of 22.3 μg/l (median = 11.0 μg/l, standard deviation = 27.2 μg/l), compared to the 1991-1992 in-lake average of 5.0 μg/l (median = 3.5, σ = 3.5 mg/l) for Weyauwega Lake.

During recent macrophyte surveys (Appendix III), macrophytes (Table 7) were found at 25 of 26 sample sites (sample sites =

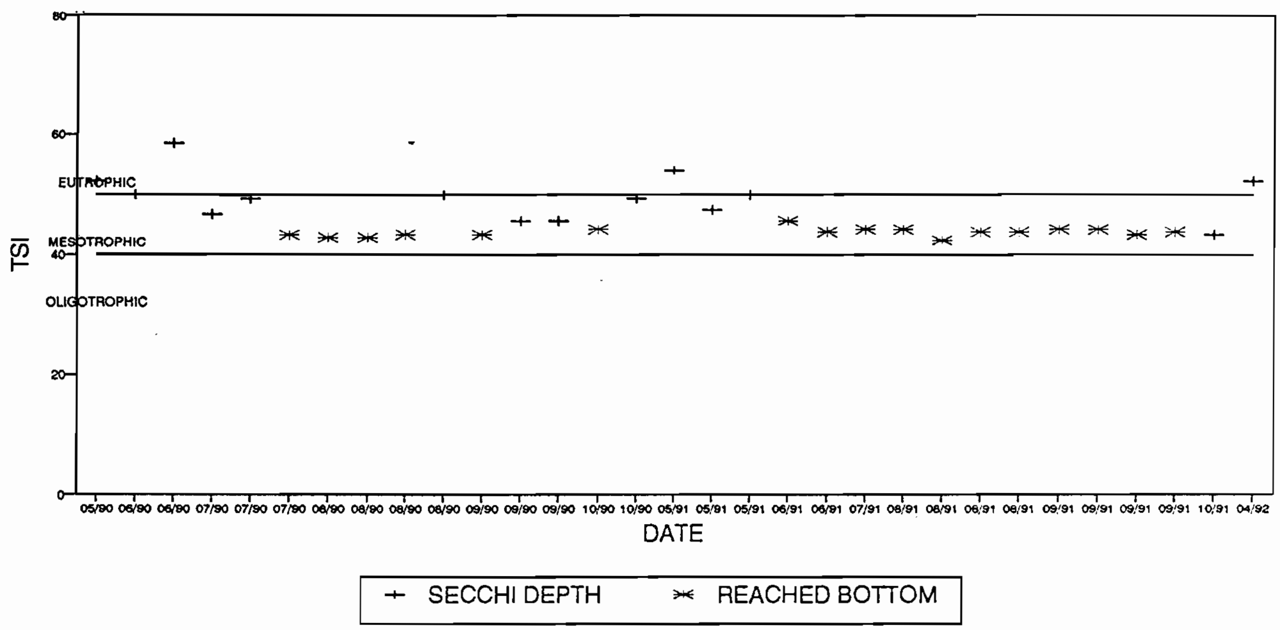


Figure 5. Trophic State Index for Secchi Depth, Weyauwega Lake.

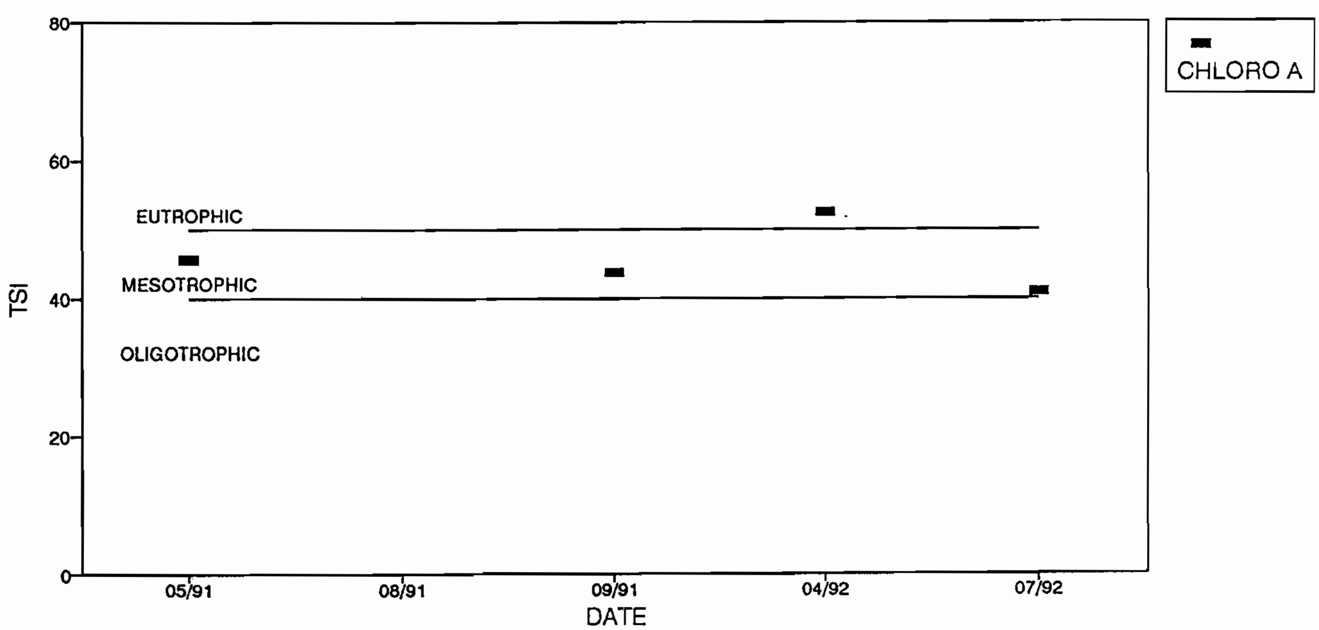


Figure 6. Trophic State Index for Chlorophyll a, Weyauwega Lake.

Table 7. Macrophyte Species Observed, Weyauwega Lake, 1991 (13).

Taxa	Code
Watershield (Brasenia scherberi)	BRASC
Coontail (Ceratophyllum demersum)	CERDE
Muskgrass (Chara sp.)	CHASP
Common waterweed (Elodea canadensis)	ELOCA
Filamentous algae	FILAL
Duckweed (Lemna minor)	LEMMI
No plants found	NOPLT
White pond lily (Nymphaea sp.)	NYMSP
Large-leaf pondweed (Potamogeton amplifolious)	POTAM
Curly-leaf pondweed (Potamogeton crispus)	POTCR
Leafy pondweed (Potamogeton foliosus)	POTFO
Sago pondweed (Potamogeton pectinatus)	POTPE
Clasping-leaf pondweed (Potamogeton richardsonii)	POTRI
Flat-stem pondweed (Potamogeton zosteriformis)	POTZO
Rush (Scirpus sp.)	SCISP
Cattail (Typha latifolia)	TYPLA
Eel grass (water celery) (Vallisneria americana)	VALAM
Watermeal (Wolffia columbiana)	WOLCO

number of depth ranges sampled on both dates). Coontail (Ceratophyllum demersum) was widely distributed (at 21 of 26 sites), and the most abundant macrophyte overall (Tables 8-11). Coontail has worldwide range, is a submergent plant typically

Table 8. Occurrence and Abundance of Macrophytes by Depth, Weyauwega Lake, June, 1991.

CODE	Depth Ranges: 1 (N=5) % of Sites	1 (N=5) Σ Abundance (range)	2 (N=5) % of Sites	2 (N=5) Σ Abundance (range)	3 (N=3) % of Sites	3 (N=3) Σ Abundance (range)
BRASC	0	0	20	1(1)	0	0
CERDE	60	10(3-4)	80	12(1-4)	100	10(3-4)
CHASP	0	0	20	3(3)	0	0
ELOCA	0	0	80	12(1-4)	100	9(3)
FILAL	0	0	60	4(1-2)	67	5(2-3)
LEMMI	60	14(4-5)	80	11(1-4)	0	0
NOPLT	20	0	--	-	--	-
NYMSP	0	0	20	2(2)	0	0
POTAM	0	0	20	1(1)	33	1(1)
POTCR	0	0	80	9(2-3)	100	10(3-4)
POTFO	0	0	60	9(2-4)	0	0
POTPE	20	1(1)	20	1(1)	0	0
POTRI	0	0	20	1(1)	0	0
POTZO	0	0	0	0	0	0
SCISP	80	14(3-4)	40	2(1)	0	0
TYPLA	0	0	20	2(2)	0	0
VALAM	0	0	0	0	0	0
WOLCO	20	5(5)	40	7(3-4)	0	0

found on soft substrates, and often does well in turbid water where many plants do not. It is rated as a fair waterfowl food and provides fish with both forage and spawning habitat (13). The plant develops roots but does not need them as it can often be found free-floating. Coontail has been known to reach nuisance levels and does so in part because the plant can grow to over six feet long with numerous branches (14). Thorny seeds are produced underwater during the growing season but coontail

Table 9. Occurrence and Abundance of Macrophytes by Depth, Weyauwega Lake, September, 1991.

	Depth Ranges					
CODE	1 (N=5)		2 (N=5)		3 (N=3)	
	% of Sites	Σ Abundance (range)	% of Sites	Σ Abundance (range)	% of Sites	Σ Abundance (range)
BRASC	0	0	0	0	0	0
CERDE	80	7(1-3)	100	13(2-3)	67	7(3-4)
CHASP	0	0	0	0	0	0
ELOCA	40	2(1)	60	7(1-3)	100	10(3-4)
FILAL	0	0	60	3(1)	67	5(2-3)
LEMMI	80	8(1-4)	80	7(1-4)	0	0
NOPLT	-	-	-	-	-	-
NYMSP	20	1(1)	0	0	0	0
POTAM	0	0	0	0	0	0
POTCR	40	2(1)	80	7(1-2)	67	8(4)
POTFO	20	1(1)	60	6(2)	0	0
POTPE	0	0	0	0	0	0
POTRI	0	0	0	0	0	0
POTZO	0	0	60	5(1-2)	0	0
SCISP	60	6(1-3)	60	4(1-2)	0	0
TYPLA	40	3(1-2)	20	2(2)	0	0
VALAM	0	0	20	3(3)	0	0
WOLCO	40	8(4)	60	7(1-4)	0	0

Table 10. Comparison of Occurrence as Percent of Total Abundance for Selected Macrophytes by Depth, Weyauwega Lake, 1991.

Species Code	Depth Range					
	1		2		3	
	JUNE	SEP	JUNE	SEP	JUNE	SEP
CERDE	23	18	16	20	29	23
ELOCA	0	5	16	11	26	33
LEMMI	32	21	14	11	0	0
POTCR	0	5	12	11	29	27
WOLCO	11	21	9	11	0	0
SCISP	32	16	3	6	0	0

Table 11. Abundance Distribution and Substrate Relations for Selected Macrophytes, Weyauwega Lake, 1991.

Transect	Substrate	Species Code																			
		CERDE		ELOCA		LEMMI		POTCR		WOLCO		SCISP		FILAL		POTFO		TYPLA		POTZO	
		I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S
A1	MUCK/ROCK	3	1	0	1	5	1	0	0	0	0	4	3	0	0	0	1	0	0	0	0
A2	MUCK	1	2	1	0	2	0	2	0	0	0	0	1	0	1	4	2	0	2	0	0
B1	MUCK/SAND	0	3	0	0	0	1	0	0	0	0	4	1	0	0	0	0	0	0	0	0
B2	SAND/MUCK	0	3	0	1	1	1	0	1	0	0	1	1	1	1	0	2	2	0	0	2
C1	GRAVEL/ROCK	3	2	0	0	4	4	0	0	0	4	3	2	0	0	0	0	0	2	0	0
C2	MUCK	4	2	4	0	4	4	2	2	3	4	0	2	0	0	3	2	0	0	0	2
C3	MUCK	3	4	3	4	0	0	4	0	0	0	0	0	2	3	0	0	0	0	0	0
D1	MUCK	4	0	0	0	5	2	0	1	5	4	3	0	0	0	0	0	0	1	0	0
D2	MUCK	4	3	4	3	4	1	3	2	4	1	1	0	2	0	2	0	0	0	0	0
D3	MUCK	3	3	3	3	0	0	3	4	0	0	0	0	0	2	0	0	0	0	0	0
E1	ROCK/MUCK	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
E2	MUCK	3	3	3	3	0	1	2	2	0	2	0	0	1	1	0	0	0	0	0	1
E3	MUCK	4	0	3	3	0	0	3	4	0	0	0	0	3	0	0	0	0	0	0	0

reproduces primarily by the formation of winter buds which fall to the bottom and form new plants in the Spring (14).

Common waterweed (Elodea canadensis) was the second most abundant macrophyte (at 15 of 26 sites) and is also a common nuisance plant in Wisconsin (13). Common waterweed also favors soft substrates and grows completely submerged (rooted or free-floating) and often in thick beds. It is also a perennial and the plant can often survive under ice cover and thus get a earlier start than other plants in the Spring. Reproduction is almost entirely by plant fragmentation and the plant foliage provides fair waterfowl food (14).

Two generally accepted methods to estimate sedimentation utilize Lead-210 or Cesium-137 isotopes (1). Lead-210 dating of a sediment core taken off of the main channel in the upstream reach of the impoundment was inconclusive, due primarily to equipment malfunction, and the results, which indicated little current sedimentation, are very suspect. Mathematical formulas for estimating sedimentation suggested significant sedimentation taking place in Weyauwega Lake. One formula (probably the most accurate of the three to be discussed) is based on inflowing and in-lake average annual total phosphorus levels and indicated a sedimentation rate (unitless number) of 29.5 (Table 12). Another estimate of sedimentation rate (FR) was derived using the square root of the flushing rate (which equals the inverse of the retention time). This estimate for Weyauwega Lake is probably low because retention time, based on lake volume, has not recently been determined, e.g., after further filling in of the basin. The FR estimate indicated Weyauwega Lake to have a

Table 12. Sedimentation Rates for Wisconsin Impoundments, Natural Lakes and Weyauwega Lake as Determined by Three Estimates.[1]

Sedimentation Rate Based on:	Impoundments	Natural Lakes	Weyauwega Lake
Phosphorus	-	-	29.5
FR	5.8	1.1	11.7
10/mean depth (m)	5.4	2.4	6.6

[1] Adapted from "Limnological Characteristics of Wisconsin Lakes" (11)

sedimentation rate over 2 times that expected in impoundments (Table 12). The third estimate equates sedimentation rate with 10 divided by the lake's mean depth (in meters). This estimate may also be in error since the average depth may have changed since last determined. This estimate also shows Weyauwega Lake to have a higher sedimentation rate than expected for impoundments. If data for the last two estimates were modified to account for filling in, the estimates would increase because flushing rate would be higher (decreased less lake volume) and the mean depth would be lower; it may then be assumed that the FR and mean depth rates probably underestimated sedimentation.

Lakes are estimated to fill in from 0.10 to 0.50 inches per year (1). Using this estimate, combined with the sedimentation factors in Table 12, sedimentation for impoundments would typically range from 0.2 inches to 2.6 inches per year; Weyauwega Lake sedimentation would be estimated between 0.3 and 5.3 inches per year (11).

BASELINE CONCLUSIONS

- Weyauwega Lake water quality, despite heavy nutrient inflow from the watershed and storm sewers is fair to good. The in-lake nutrient readings overall, were less than expected for natural lakes in the region and less than the average for impoundments. This, coupled with comparatively low chlorophyll a and good transparency, suggested that the nutrients are probably being bound in sediments or utilized by the extensive macrophyte assemblages.
- Macrophyte growth is widespread, very abundant and dominated by a few species. Adequate water clarity and nutrients and predominantly soft, shallow shelf areas make conditions in Weyauwega Lake (like many other impoundments) conducive to nuisance aquatic plant growth. The most abundant species were coontail and common waterweed; both have the potential to grow in nuisance proportions. Recreational use of the resource is restricted by dense macrophytic growth throughout much of the open-water season.
- Weyauwega Lake sedimentation was estimated by Lead-210 dating as low but results are considered inconclusive and suspect. Mathematical formulas estimated sedimentation to be significant and possibly severe in

upstream reaches of the impoundment. Physical characteristics of the impoundment, particularly as they relate to a large, predominantly agricultural watershed and storm sewer inflows contribute significantly to sedimentation of Weyauwega Lake.

MANAGEMENT ALTERNATIVES DISCUSSION

WATER QUALITY AND SEDIMENTATION

Weyauwega Lake is an impoundment with basin characteristics prone to sedimentation, non-point source runoff effects and extensive macrophytic growth. Event samples collected by WLCC indicated high nutrient inputs (from feeder creeks and particularly from storm sewers 2 and 3); regular in-lake monitoring indicated nutrient levels lower than those typical of other impoundments and even natural lakes in the region. Sedimentation is probably significant and may be severe, especially in the upstream reaches of the impoundment. Macrophyte growth is dominated by few species at nuisance levels. Recreational use of the impoundment is severely impaired throughout open-water periods as most of the lake is impassible shortly after ice-out.

Before drastic management measures are taken to reclaim or "rejuvenate" the resource, steps must be taken to reduce sediment and nutrient inputs to the extent possible and/or practical. Efforts should be made to identify runoff or erosion prone areas and control nutrient and sediment inflows on a watershed-wide basis. Major emphasis should be given to installation of devices to reduce nutrient and sediment inputs to the drainage basin (i.e., animal waste containment facilities, barnyard runoff control devices and fencing around waterways). Designation of the Waupaca River Watershed as a priority watershed should be strongly encouraged to facilitate acquisition of cost-share funding. The feasibility of redirecting city storm sewers should also be assessed.

While inflows from the upstream watershed are probably of primary importance, riparian land use practices can, cumulatively, have a significant influence on water quality and land owner diligence should be strongly emphasized and encouraged. Common sense approaches are relatively easy and can be very effective in minimizing inputs.

Yard practices can minimize both nutrient and sediment inputs. Lawn fertilizers should be used sparingly, if at all. If used, the land owner should use phosphate-free fertilizers and apply small amounts more often instead of large amounts at one or two times. Composting lawn clippings and leaves away from the lake can reduce nutrient inputs to the lake. If leaves are burned, it should be done in an area where the ash cannot wash directly into the lake (15), or indirectly to the lake via roadside ditches.

Creation of a buffer strip with diverse plants at least 20 feet wide immediately adjacent to the lake can control wave erosion, trap soil eroded from the land above, increase infiltration (to filter nutrients and soil particles), and shade areas of the lake to reduce macrophyte growth (especially on south shores) and provide fish cover. Placement of a low berm in this area can enhance effectiveness of the buffer strip by further retarding runoff during rainfalls. A buffer zone protects lake water quality, creates habitat for wildlife, and provides privacy (15).

There are a number of informational sources for land owners with questions regarding land management practices. Some sources are outlined in Appendix V.

MACROPHYTES

Management of macrophyte populations should be a major objective for Weyauwega Lake. While macrophytic growth can positively affect the resource through forage fish and wildlife production/protection, shoreline stabilization and nutrient uptake, populations in Weyauwega Lake are present at nuisance levels. Nuisance levels of macrophytes can cause organic sediment build-up, preclude development of desirable diverse plant populations, reduce aesthetics, reduce DO (potential fishkills), impair recreational use and contribute to the development of stunted panfish populations. A macrophyte management plan should be carefully thought out by prioritizing differing use areas in the lake. Numerous methods of macrophyte control and management are available ranging from radical habitat alteration to more subtle habitat manipulation and are discussed below relative to Weyauwega Lake applicability.

Dredging is a drastic and costly form of habitat alteration. Before any dredge plan is developed or implemented on Weyauwega Lake, steps must be taken to ensure dredging results will be most cost-effective (i.e., last as long as possible). Only when erosion and nutrient control measures are implemented (to the extent practical) on a watershed-wide basis, should a dredging plan be considered feasible. A dredge plan should involve as little sediment removal as possible (be cost effective) to create access and edge (removal to a depth at which macrophyte growth would be retarded due to reduced sunlight). A basic plan for Weyauwega Lake might involve dredging a relatively smaller area in the upstream reach (wildlife/fish production/protection zone) as a catchment basin for future sedimentation (extend the longevity between dredges) and a larger area in the lower reaches adjacent to deepest areas for increased access (most cost effective area) and edge. Emphasis should also be given to the potential for redistribution of existing unconsolidated sediment beds in the feasibility/design stage.

Chemical treatment for macrophyte control has been shown to eradicate some undesirable species and leave others intact. The

WDNR strongly discourages the use of chemicals because of nutrient release, oxygen depletion, sediment accumulation, bioaccumulation and other unknown environmental hazards including invasion potential from nuisance exotics. Chemical effects are nondiscriminate and may harm desireable or beneficial plant populations; chemical treatment should not be considered for Weyauwega Lake at this time.

Aquatic plant screens have been shown to reduce plant densities in other lakes and may be applicable in near-shore areas here. A fiberglass screen or plastic sheet is placed and anchored on the sediment to prevent plants from growing. This may also make some sediment nutrients unavailable for algal growth. Screens should be removed each fall and cleaned in order to last a number of years. Screens are generally used in small areas of concern, i.e., around beaches, landings or piers.

A newer technique of rototilling sediments to destroy plant roots appears to be effective in controlling plant growth for a relatively longer period than harvesting. The process is about the same cost per hour as a contracted macrophyte harvester (16). A potential problem is disturbance of the sediments and resuspension of nutrients or toxics.

Installation of floating platforms (black plastic attached to wooden frames) just after ice-out can shade the sediments, restrict plant growth and help to open corridors for swimming or boat navigation. Shading is usually required for three weeks to two months to impact nuisance plant growth (17). A drawback is that the area cannot be used while the platform is in place.

Remaining control methods consist, in one form or another, of macrophyte harvest. It is a commonly used technique which can be applied on a widespread or localized basis. Its efficiency, based on method of cut/harvest, can vary substantially with depth.

Several conditions should be considered with respect to macrophyte harvest. Macrophyte growth on Weyauwega Lake is dense and widespread; even intense harvest efforts will probably not manage all areas of concern in the impoundment. Milfoils, coontail and common waterweed all spread easily by fragmentation; strong consideration should be given to the potential of these species to become even more dominant by becoming better established where competing macrophytes have been removed.

Macrophyte harvesting is typically conducted with a mechanical harvester which cuts the vegetation and removes (harvests) it onto a platform for out-lake disposal. Given the precautions regarding potential nuisance species dispersal and the ability of some plants to survive and spread when detached from the substrate, harvest practices may even enhance the nuisance macrophyte problem through seed dispersal, fragmentation or incomplete removal. Indiscriminate power boat usage, through formation of "prop cut" floating weed masses, may also contribute to this problem.

Selective SCUBA assisted harvest has been shown to selectively manage macrophytes. It can be used in deeper areas and to target only desired species (e.g., Eurasian milfoil) or nuisance growth areas. This method is labor intensive, but has proved to effectively reduce nuisance plant levels for up to two years (16). With the large area of potential macrophyte management in Weyauwega Lake, SCUBA assisted harvest probably is not a viable option for widespread application.

Raking weeds (using an ordinary garden rake) in the frontage area can be a very effective localized plant control method when done on a regular basis. Such concentration on the problem shallow water areas would reduce efforts expended on other control methods.

MANAGEMENT RECOMMENDATIONS

Management objectives for Weyauwega Lake must address the lake/subwatershed and the extended watershed areas. Lake/subwatershed management should involve near term implementation and longer term feasibility assessment to address nutrient, sediment and macrophyte problems. Near term measures should include:

- emphasis of riparian land use management (buffer stripping, fertilizer management, septic upkeep),
- implementation of effective localized macrophyte management to create edge and recreational access,
- definition of use zones (e.g., upstream reach for wildlife, downstream reach for recreation).

Longer term measures should include:

- assessment of the feasibility of reducing storm sewer impacts on the lake,
- assessment of the feasibility and subsequent development/implementation of larger scale macrophyte management and/or dredging programs.

The success and longevity of these subwatershed measures will depend upon attainment of objectives for the extended watershed. Extended watershed measures should include:

- identification of erosion prone areas or nutrient inflows in the primarily agricultural watershed,

- implementation of BMP's (Appendix VI) in areas of concern (i.e., adjacent to channels, erodible lands, etc.),
- pursue designation of the Waupaca River Watershed as a priority watershed to obtain cost-share funding to implement long term conservation practices.

IMPLEMENTATION

The success of any lake management plan relates directly to the ability of the association/district to obtain funds and regulatory approval necessary to implement the plan. The WLCC is a voluntary association that does not have a lake district's specific legal or financial powers (to adopt ordinances or levy taxes or special assessments) to meet plan objectives.

The Weyauwega Lake watershed is located within the political jurisdictions of the Town of Weyauwega, County of Waupaca and the State of Wisconsin. These units have the power to regulate land uses and land use practices. Waupaca County ordinances and plans possibly pertinent to the Weyauwega Lake plan are summarized in Appendix VII.

Potential sources of funding are listed in Appendix VIII.

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IPS ENVIRONMENTAL AND ANALYTICAL SERVICES
Appleton, Wisconsin

PHASE II
WEYAUWEGA LAKE
WAUPACA COUNTY, WISCONSIN

REPORT TO:
WEYAUWEGA LAKE CONSERVATION CLUB

November, 1996

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SUMMARY

Weyauwega Lake, Waupaca County, Wisconsin is characterized by good water quality, prolific aquatic plant growth and ongoing sedimentation. An initial resource assessment was made in 1992 (Phase I Weyauwega Lake Management Plan); this document supplements the 1992 report and outlines further efforts toward development of a comprehensive lake management plan.

The Weyauwega Lake watershed, primarily agricultural but with significant forested and wetland areas, is a subwatershed of the Tomorrow/Waupaca River basin which has been granted Priority Watershed Project Status. Variable, but generally low groundwater nitrate levels were observed in the Weyauwega subwatershed during the appraisal phase of the Priority Watershed Project. Overland flow nutrient and sediment inputs were estimated to be lower than expected, but field estimates for nutrients were substantially higher.

Weyauwega Lake nutrient levels are lower than expected for natural lakes in the region and lower than average in comparison to most impoundments; event inflows, however, were considerably higher. Water clarity is such that much of the lake bottom receives sunlight during the growing season. Overall, water quality parameters indicated a mesotrophic to early eutrophic status.

A comparison of aquatic plant control methods for Weyauwega Lake indicated mechanical harvest to be cost-efficient for widespread application and SCUBA cutting to be the most effective control for localized areas.

Recommendations applicable to the Weyauwega Lake resource emphasize continued focus and expanded involvement (designated Weyauwega Conservation Club individuals or committees) in watershed-wide surface water and groundwater quality issues, improved recreational access (through aquatic plant control), use management, and exotic species control. These recommendations, which include trend monitoring for water quality, are designed to identify potential problem areas or conflicts before they become widespread or severe.

- Areas of concern should be assessed for nutrient and sediment contributions to surface and groundwaters. Designation of the basin as a priority watershed has greatly facilitated this area-wide assessment.

- Water quality monitoring should be continued to track trends and develop an accurate nutrient budget for the impoundment; event monitoring should be continued to further assess stormwater inputs and feeder creeks.

- While in-lake plant growth provides benefits such as shoreline stabilization, nutrient uptake and fish food and habitat production, populations consist of nuisance levels of few species. Mechanical harvesting should be inititiated (contracted) to improve recreational use of the impoundment,

reduce organic sediment build-up, help prevent stunted panfish growth, improve aesthetics and enhance development of desireable diverse plant populations.

- Measures to prevent or reduce the potential for invasion of Eurasian milfoil and purple loosestrife (exotic species) should be identified and implemented. Signs should be posted to educate landowners and lake users about these resource dangers.

- Land purchase or park development should be considered to increase recreational opportunities for Weyauwega Lake.

- A fishery survey should be completed in the next five years to determine the status of fish populations.

INTRODUCTION

This report presents Phase II management planning efforts for Lake Management Plan, Weyauwega Lake, Waupaca County, Wisconsin. Specific physical properties of the resource, preliminary methods, and other introductory and technical information were presented in the Phase I report (printed in 1992).

Weyauwega Lake is an impoundment in the Village of Weyauwega, with good recreational use potential, prolific aquatic plant growth, ongoing sedimentation and significant wildlife use. Historic management activities have generally targeted control of aquatic plants.

The Weyauwega Lake Conservation Club (WLCC) was formed in 1978 and serves as the main steward for the resource. The WLCC, received its first Wisconsin Department of Natural Resources (WDNR) Lake Management Planning Grant in March, 1991 and selected IPS Environmental & Analytical Services (IPS) of Appleton, Wisconsin as its consultant to begin management planning efforts. Phase I efforts included assessment activities (for water quality and aquatic plants) and a public involvement program. The Phase II grant was received in October, 1993; Phase II efforts included continuation of the water quality monitoring and public involvement programs, more intensive review of areas of concern in the watershed, in-lake sediment sampling and development of a sediment removal feasibility study, and a feasibility study to reduce adverse impacts of storm sewer discharges.

DESCRIPTION OF AREA

Weyauwega Lake is an impoundment of the Waupaca River located partially in the City of Weyauwega, in Waupaca County, Wisconsin (Figure 1).

The general topography of Waupaca County is related to glacial activity. The watershed is about 250 sq. miles; the more immediate Weyauwega Lake subwatershed (i.e., 26 sq. miles and comprised of lands draining downstream from the confluence of the Waupaca and Crystal Rivers) was analyzed by 40 acre parcels and comprised of open/agricultural areas (80%), marsh/wetland areas (11%) and forested areas (9%). Land slopes in the subwatershed were nearly level (76%), gently sloping (6%) and sloping (19%). Soils textures were silt (81%), sand (18%) with small areas of clay.

Topography adjacent to the lake is nearly level to gently sloping. The major soil types adjacent to Weyauwega Lake are moderately well drained Borth silty clay loams on 1-4 percent slopes (mostly to the North), excessively drained Plainfield loamy sands on 0 to 6 percent slopes (to the South and East) and somewhat poorly drained Symco loams on 0 to 3 percent slopes (to the South and West). Soil permeability is rapid in Plainfield soils and moderately slow in Borth and Symco soils. Soils are poorly suited for septic systems since there is potential of septic runoff or infiltration to groundwater or surface waters because of wetness (Symco, Borth) or high permeability (Plainfield, 1).

Weyauwega Lake has a surface area of 251 acres, an average depth of about 5 feet, and a maximum depth of 10 feet (2). The fetch is 1.56 miles and lies in a west-east orientation and the width is 0.6 miles in a north-south orientation. The Weyauwega Lake watershed to lake ratio is about 445 to 1 which means that 445 times more land than lake surface area drains to the lake. Lake volume is approximately 755 acre feet with a residence time of 2.65 days (3). Predominant littoral substrates include sand (70%), muck (15%), rubble (8%), gravel (5%) and clay (2%) (Pers. comm. WDNR).

Four storm sewers are located along the southeast shore and drain to Weyauwega Lake. Storm sewer discharge is untreated runoff from lawns, streets, parking lots and other paved areas and is a potential source of salts, sand, nutrients, pesticides, vegetative debris, oil, grease and potentially toxic pollutants.

Weyauwega Lake was the downstream terminus of an extensive rough fish control project in 1971. The project encompassed 42 miles of the Tomorrow-Waupaca River and tributaries, 8 miles of the

Crystal River and tributaries, several lakes and numerous (37) private ponds. Weyauwega Lake was drawn down to the original stream channel for antimycin treatment; over 85,000 pounds of fish including carp (52.9%) and mixed suckers and redhorse (40.6%) were removed. Subsequent reintroduction of forage organisms and sport fish stocking began in November, 1971 and continued in 1972 (Pers. comm. WDNR).

Public access (paved ramp with parking) is available near the dam just east of Highway 110 and at an improved public landing (with parking) on Lake Street.

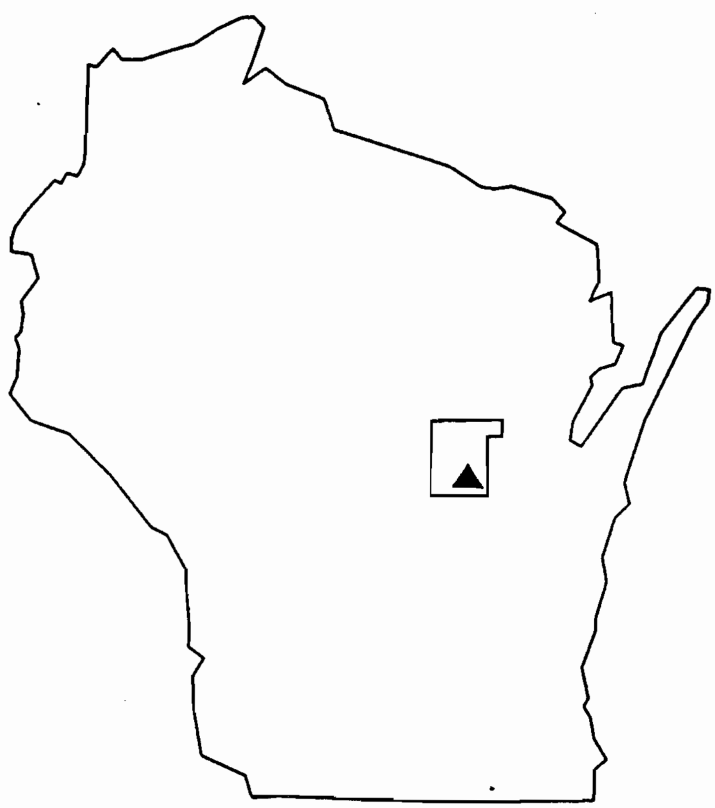

Figure 1. Location Map, Weyauwega Lake, Waupaca County, WI.

METHODS

Watershed Characteristics

Most watershed information was obtained during the appraisal process of the Tomorrow/Waupaca River Priority Watershed (TWRPW) Project. The appraisal began February, 1994 and was approved/completed in October, 1995. Pertinent information from the appraisal as it relates to Weyauwega Lake is included in the Field Data Discussion section of this report.

Water Quality Monitoring

Weyauwega Lake water samples were taken in January, June, July, and September, 1994 and February, May, July, August and September, 1995. Samples were collected, mid-depth in the water column at Station 0301 (deepest point) and Station 0302 (inlet - Waupaca River) (Table 1, Figure 2). Parameters measured in the field were Secchi depth, water temperature, pH, dissolved oxygen (DO), and conductivity (see Phase I document for equipment and methods).

In addition to regular monitoring sites, eight event sampling sites were located throughout the watershed (Table 1, Figure 2) to help locate highest nutrient inflows. Event sample sites were located at road crossings of tributary streams and ditches. Samples were collected on May 17 and July 5, 1994.

Table 1. Sampling Station Locations, Weyauwega Lake, 1994 - 1995.

REGULAR MONITORING

Site	Depth
0301	10.0 feet
0302	3.0 feet

EVENT MONITORING

Site	Description
O3E1	Main channel of the Waupaca River at Reek Road
O3E2	Ditch West of Reek Road on north side of Waupaca River
O3E3	Intermittent creek draining to the northwest corner of the intersection of Zastrow and Haire River Roads
O3E4	Intermittent creek at County AA (Haire River Road)
O3E5	Overland flow South of Haire River Road
ST2	Storm sewer outfall near boat landing
ST3	Storm sewer outfall (brown clay pipe) near Ace building
ST4	Storm sewer outfall (24" pipe) near Legion Hall

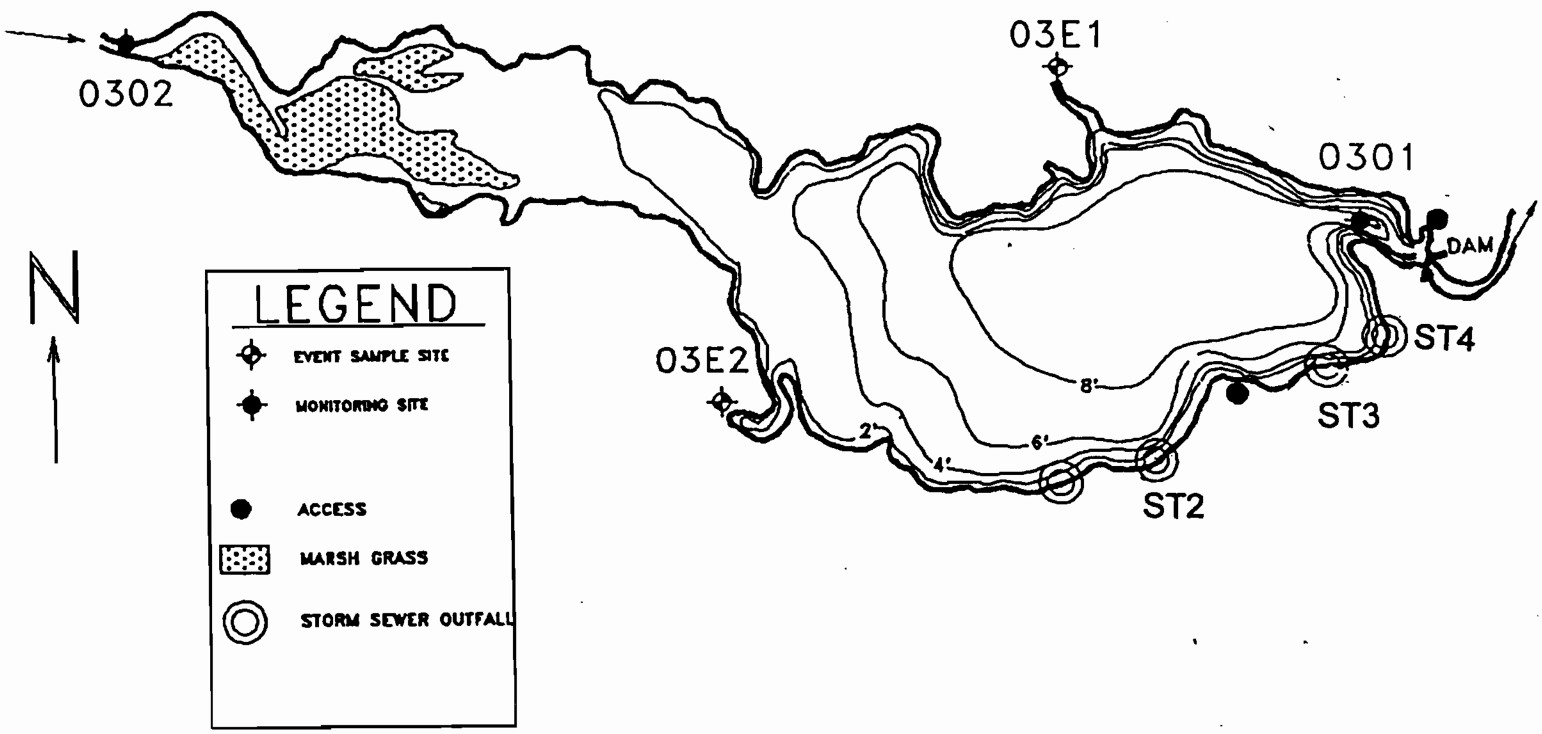

Figure 2. Sample Sites, Weyauwega Lake, 1994 - 1995.

Aquatic Plant Control

Aquatic plant surveys were conducted in Phase I to assess the types and amounts of plants in Weyauwega Lake. Phase II aquatic plant activities included assessment of aquatic plant control techniques. Control methods evaluated included aquatic herbicides, mechanical harvest, benthic barriers (screening), and SCUBA cutting (clear and selective).

Sediment Mapping

Sediment mapping was undertaken to estimate the quantity and location of sediment accumulations. An aluminum pole, marked with one foot increments, was used as a measuring device. A number of transects were established running north-south while one transect went the length of the pond (east-west, Fig. 3). Along each transect the measuring device was used to first, measure the depth of the water, and second, to measure the depth of soft sediment by pushing the device down until hard substrate was reached.

Sediment Sampling

As water enters Weyauwega Lake from upstream sources, its velocity decreases and water-borne dediments are deposited. These factors have resulted in a rapid "filling in" rate in the original stream channel and on the extensive shallow shelf areas adjacent to the channel.

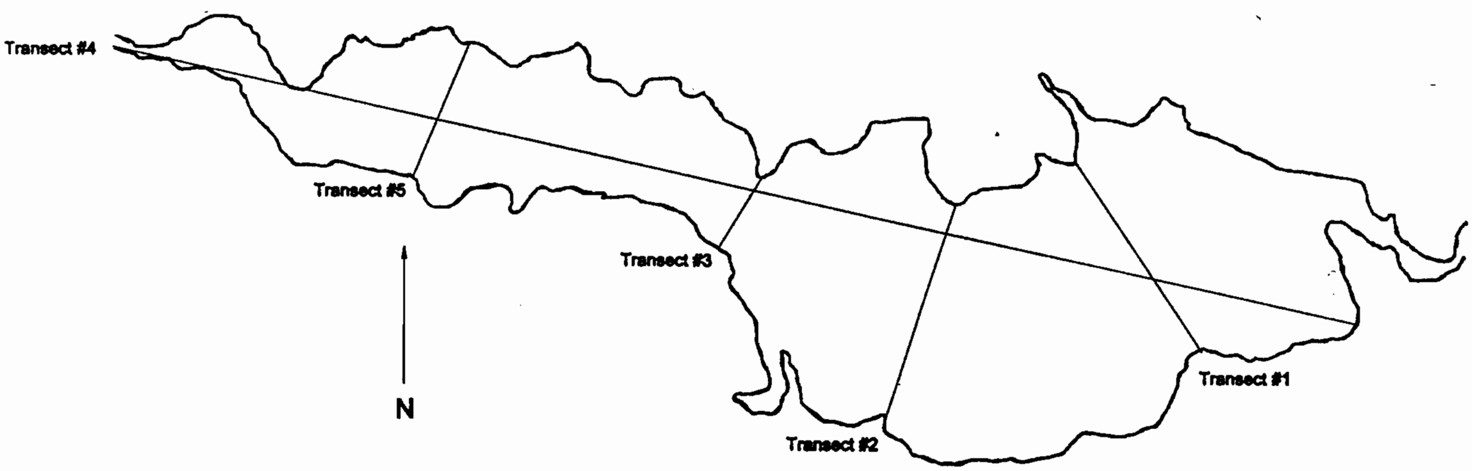

Figure 3. Sediment Profile Transect Locations, Weyauwega Lake, Waupaca County, 1994.

To address the condition, activities included an initial feasibility study for sediment removal. Two sediment samples were collected for analysis - one from near the Waupaca River inlet and another at the deepest point of the lake. The samples were analyzed for their composition and for the presence of toxic/hazardous materials including heavy metals. The analyses were conducted by IPS and Enviroscan of Rothschild, Wisconsin.

Public Involvement Program

Public involvement activities were coordinated to inform and educate the WLCC about lake management in general and specifics regarding the Weyauwega Lake resource. Activities included news releases, IPS newsletters, meeting attendance and presentations to the WLCC. A summary of public involvement activities is outlined in Appendix I.

FIELD DATA DISCUSSION

Watershed Characteristics

The Weyauwega Lake watershed is estimated to be 3,831 acres or 2% of the entire TWRPW (4). Land use for the Weyauwega Lake subwatershed was determined during the 1994 - 1995 inventory to be: non-irrigated agriculture, 1,839 acres (48%); irrigated agriculture, 0 acres (0%); forested, 1,111 acres (29%); wetland (including surface water), 575 acres (15%); and developed areas, 306 acres (8%) (4).

There were 220 landowners who had livestock operations in the TWRPW, of which 168 (76%) had more than 20 animal units and 52 (24%) had 20 or fewer animal units. Sixty-two percent of the barnyards were surface drained; 38% were internally drained (4).

Groundwater

Nitrate was identified as a contaminant of concern in the Wolf River Basin Plan (5) and was targeted for analyses in the TWRPW Project groundwater appraisal. Sources of nitrate include fertilizers, animal feedlots, sewage drainage fields, municipal and industrial wastewater, urban drainage and decaying plant debris. Underground soil types, bedrock structure and the direction of groundwater flow may have an influence on when and where nitrates are found.

Nitrates occur naturally in many types of food, but high levels in drinking water pose a health threat to infants less than six months of age. The threat is a acute, meaning there could be harmful effects directly from consuming nitrate-polluted water. Nitrates interfere with the blood's ability to carry oxygen and symptons of suffocation or "blue baby syndrome" can occur. This problem does not affect older children or healthy adults. Research is underway to determine if nitrates pose any long-term health risks.

Relative to other subwatersheds in the TWRPW Project, residential well samples in the Waupaca-Weyauwega subwatershed had one of the highest average nitrate levels [5.31 milligrams per liter (mg/l)] (Table 2). Seventeen percent of the Waupaca-Weyauwega subwatershed well samples were betweem 2.0 and 10.0 mg/l; nitrate levels over 2 mg/l are generally considered indicative of human impact on groundwater. Wells with nitrate levels less than 5mg/l should be retested every few years. If the nitrate levels are between 5 and 10 mg/l, well owners should test their water for nitrates more frequently, perhaps annually, to monitor fluctuations in nitrate concentrations. The State Laboratory of Hygiene as well as private laboratories certified by the Department of Natural Resources can test water for the presence of nitrates.

Four well samples (6%) in the Waupaca-Weyauwega subwatershed were over the health standard of 10 mg/l (4).

Table 2. Well Nitrate Data by Subwatershed for the Tomorrow/ Waupaca River Priority Watershed Project, 1995.

Subwatershed	No. of Samples	>2 mg/l	>10 mg/l	>20 mg/l	Average
Upper Tomorrow	258	168	66	20	6.82
Spring Creek	275	154	39	5	4.71
Chain O' Lakes	389	136	30	2	2.59
Crystal River	266	117	22	5	3.27
Waupaca/ Weyauwega	63	15	11	4	5.31
	=====	=====	=====	=====	=======
Total	1,251	590	168	36	4.54
Percent	100%	47%	13%	3%	

This widespread occurence of nitrates suggest that there are multiple sources of nitrate in the watershed. The most likely sources of the widespread nitrate condition are nitrogen fertilizers applied to crops and manure applied to croplands and lost from storage and barnyards. The distribution of wells over the 10 ppm health standard indicate there are significant sources or multiple sources having significant impact in various locations throughout the watershed (4).

Water Quality

In-lake phosphorus (ave. = 0.035, median = 0.028, σ = 0.020 mg/l) (Tables 3 and 4) and inlet phosphorus (ave. = 0.036, median = 0.034, σ = 0.020 mg/l) were well below expected levels for impoundments (ave. = 0.064, median = 0.035, σ = 0.100 mg/l), drainage lakes (ave. = 0.040, median = 0.025, σ = 0.064) and lakes in the central region of Wisconsin (ave. = 0.020, median = 0.012, σ = 0.021) (6). NOTE: Some total phosphorus data are indicated to have exceeded the recommended holding time before analysis. A study has shown, however, that phosphorus data remains accurate for samples analyzed well after the 28 day holding time (7).

In-lake total nitrogen levels were significantly higher (ave. = 3.15, median = ,σ = 1.07) than expected levels for impoundments (ave. = 1.06, median = 0.94, σ = 0.54), drainage lakes (ave. = 0.95, median = 0.83, σ = 0.55), and lakes in the central region of Wisconsin (ave. = 0.72, median = 0.69, σ = 0.31) (6). Inlet total nitrogen levels (ave. = 3.24, median = , σ = 0.90) were slightly higher than those in-lake; the difference was primarily attributable to higher NO_2 + NO_3 nitrogen in the samples (Table 4).

In-lake regular monitoring data (1994 - 1995) indicated a trend of highest total phosphorus at times of highest overland runoff

Table 3. Water Quality Parameters, Station 0301, Lake Weyauwega, January 1994 - September 95.

PARAMETER	SAMPLE[1]	DATE								
		01/27/94	06/28/94	07/25/94	09/07/94	02/09/95	05/16/95	07/25/95	08/24/95	09/27/95
Secchi (feet)		NR[2]	8.8	> 10.0	> 10.0	NR	6.0	> 10.5	6.2	7.8
Cloud Cover (percent)		100	100	50	40	100	70	5	100	80
Temperature (degrees Celsius)	S	0.23	22.28	20.81	16.91	NR	17.30	26.52	NR	13.47
	B	1.60	22.25	20.43	16.54	NR	16.11	24.92	NR	13.19
pH (surface units)	S	6.42	7.31	7.27	7.16	NR	8.50	8.68	7.8	7.80
	B	6.88	7.30	7.28	7.16	NR	8.31	8.05	7.6	7.55
D.O. (mg/l)	S	11.07	NR	5.79	7.39	NR	10.68	8.85	6.90	8.75
	B	10.60	NR	6.20	7.39	NR	10.70	7.91	4.80	8.66
Conductivity (umhos/cm)	S	387	363	388	360	NR	380	393	316	413
	B	375	363	391	361	NR	379	408	333	412
Laboratory pH (surface units)	S	NR	NR	NR	NR	NR	8.67	NR	NR	NR
	B	NR	NR	NR	NR	NR	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	NR	NR	NR	NR	NR	182	NR	NR	NR
	B	NR	NR	NR	NR	NR	NR	NR	NR	NR
Total Solids (mg/l)	S	NR	NR	NR	NR	NR	246	NR	NR	NR
	B	NR	NR	NR	NR	NR	NR	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.4	NR	NR	NR	0.4	0.6	NR	NR	NR
	B	0.6	NR	NR	NR	0.4	0.6	NR	NR	NR
Ammonia Nitrogen (mg/l)	S	0.148	NR	NR	NR	0.106	ND[3]	NR	NR	NR
	B	0.159	NR	NR	NR	0.096	ND	NR	NR	NR
NO_2 + NO_3 Nit. (mg/l)	S	2.97	NR	NR	NR	3.58	1.49	NR	NR	NR
	B	2.99	NR	NR	NR	3.57	1.51	NR	NR	NR
Total Nitrogen (mg/l)	S	3.37	NR	NR	NR	3.98	2.09	NR	NR	NR
	B	3.59	NR	NR	NR	3.97	2.11	NR	NR	NR
Total Phosphorus (mg/l)	S	0.016	0.056	0.048[4]	0.028[4]	0.016	0.026	0.028	0.073	0.020
	B	0.029	0.057	0.048[4]	0.028[4]	0.016	0.025	0.039	0.091	0.017
Dissolved Phos. (mg/l)	S	0.011	0.041	0.028	0.015	0.005	0.003	0.013	0.047	0.002
	B	0.010	0.038	0.031	0.019	0.006	0.003	0.021	0.062	0.004
Nit/Phos Ratio	S	210.60	--	--	--	248.75	80.38	--	ND	--
	B	123.79	--	--	--	248.12	84.40	--	ND	--
Chlorophyll a (ug/l)	S	NR	5.84	3.34	2.54	NR	3.3	0.3	5.31	1.44

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

Table 4. Water Quality Parameters, Station 0302, Weyauwega Lake, January 1994 - September 1995.

PARAMETER	SAMPLE[1]	DATE 01/27/94	06/28/94	07/25/94	09/07/94	02/09/95	05/16/95	07/25/95	08/24/95	09/27/95
Secchi (feet)		> 3.0	> 3.0	> 3.0	NR[2]	> 5.0	> 3.0	4.0	3.1	2.8
Cloud Cover (percent)		100	100	100	40	100	80	5	100	10
Temperature (degrees Celsius)	M	1.60	21.98	19.25	16.90	NR	18.4	24.33	NR	13.06
pH (surface units)	M	6.88	NR	7.74	7.57	NR	8.67	8.29	7.8	7.56
D.O. (mg/l)	M	10.60	8.86	8.66	10.00	NR	14.2	7.23	6.5	8.22
Conductivity (umhos/cm)	M	375	368	399	358	NR	378	415	336	418
Laboratory pH (surface units)	M	NR	NR	NR	NR	NR	8.73	NR	NR	NR
Total Alkalinity (mg/l)	M	NR	NR	NR	NR	NR	183	NR	NR	NR
Total Solids (mg/l)	M	NR	NR	NR	NR	NR	256	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	M	0.6	NR	NR	NR	0.4	0.6	NR	NR	NR
Ammonia Nitrogen (mg/l)	M	0.159	NR	NR	NR	0.096	0.034	NR	NR	NR
NO_2 + NO_3 Nit. (mg/l)	M	2.99	NR	NR	NR	3.52	1.62	NR	NR	NR
Total Nitrogen (mg/l)	M	3.59	NR	NR	NR	3.92	2.22	NR	NR	NR
Total Phosphorus (mg/l)	M	0.029	0.040	0.037[3]	0.024[3]	0.016	0.034	0.048	0.082	0.018
Dissolved Phos. (mg/l)	M	0.010	0.019	0.016	0.006	0.005	0.002	0.026	0.040	0.002
Nit./Phos Ratio	M	123.79	--	--	--	100	330	--	--	--
Chlorophyll a (ug/l)	S	NR	4.17	3.39	0.024	NR	NR	1.03	NR	NR

[1] M = mid-depth; [2] NR = no reading; [3] holding time exceeded by SLOH

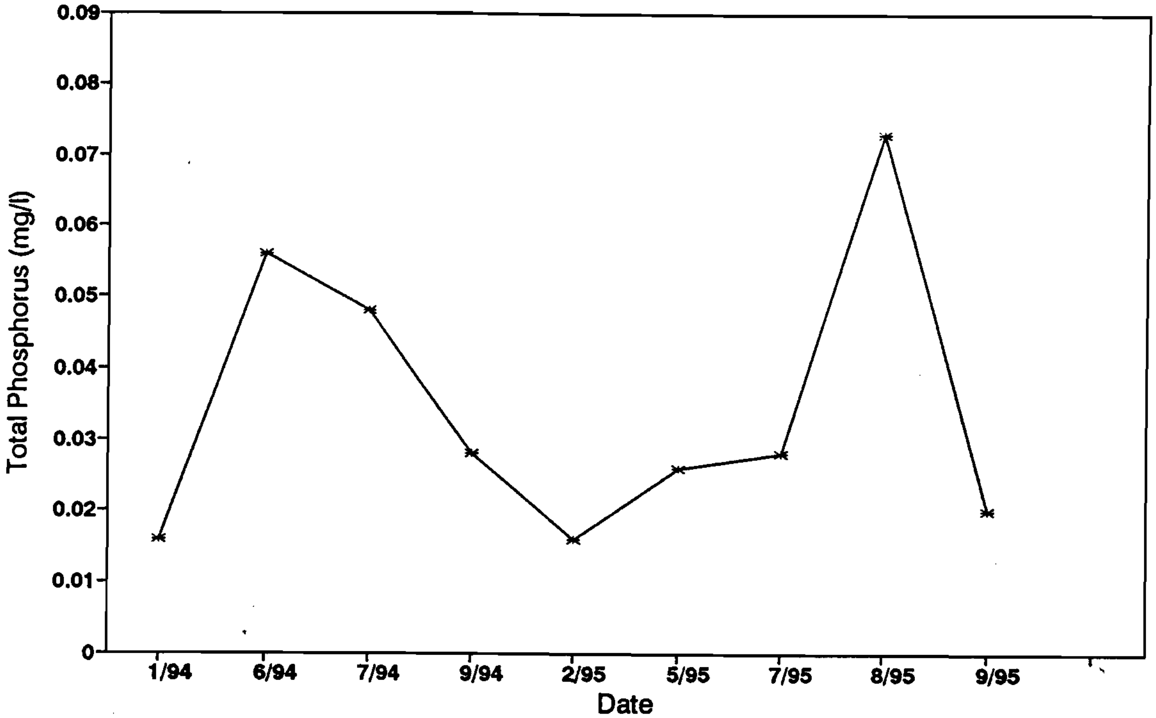

Figure 4. Surface Total Phosphorus Trends for Weyauwega Lake, 1994 - 1995.

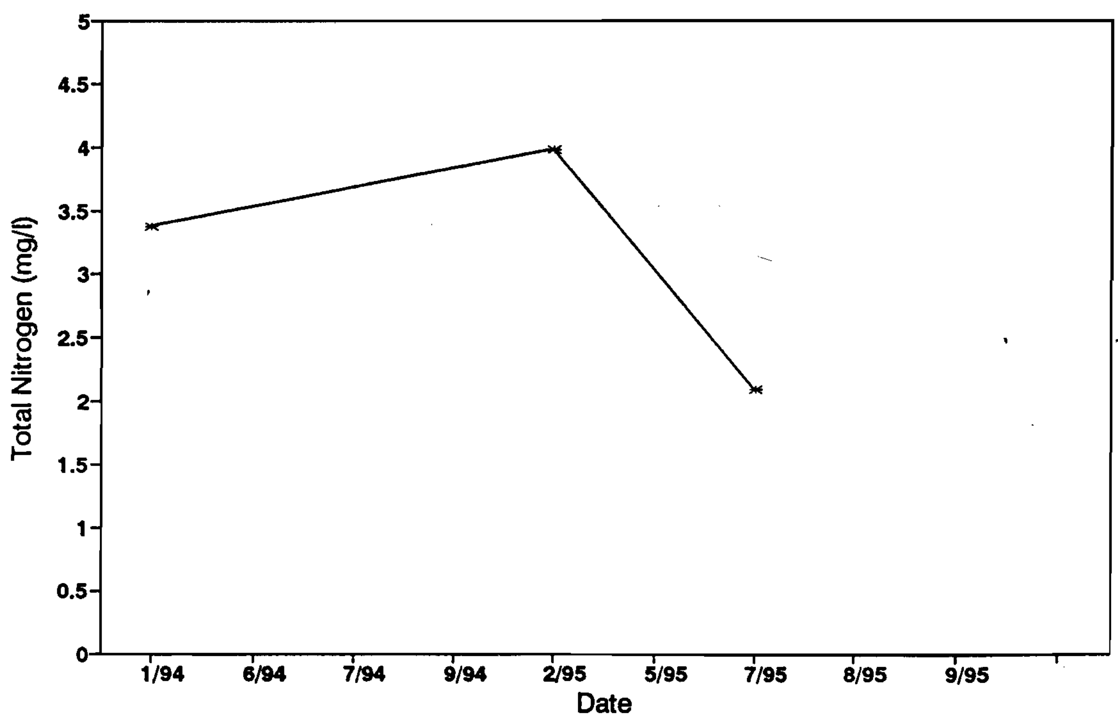

Figure 5. Surface Total Nitrogen Trends for Weyauwega Lake, 1994 - 1995.

(Spring) with lowest total phosphorus during Winter (Figure 8). The trend for total nitrogen was highest levels during times of highest groundwater input (Winter).

Event monitoring indicated significantly higher total phosphorus levels for Site 03E3 (on July 5, 1.70 mg/l) and Site 03E2 (0.650) (Tables 5 and 6). The average for all sites was 0.066 mg/l (σ = 0.035) and 0.051 mg/l (σ = 0.580) for May and July, respectively.

Highest total nitrogen levels were observed at Site 03E2 (July) and Site 03E3 (May). Total nitrogen levels for all sites averaged 3.30 mg/l (σ = 1.75) and 2.52 mg/l (σ = 2.12) for the May and July sample dates, respectively. Higher than expected total nitrogen levels (for impoundments) were observed at a number of event sample sites are most likely attributable to high background nitrate levels in groundwater.

Other indicators of lake eutrophication status include light penetration and algal production. Numerous summarative indices have been developed, based on a combination of these and other parameters, to assess or monitor lake eutrophication or aging. The Trophic State Index (TSI) developed by Carlson (8) utilizes Secchi transparency, chlorophyll a, and total phosphorus. As with most indices, application is generally most appropriate on a relative and trend monitoring basis. This particular index does not account for natural, regional variability in total phosphorus levels nor in Secchi

Table 5. Event Water Quality Parameters, Weyauwega Lake, May 17, 1994.

PARAMETER	SAMPLE SITE 03E1	03E2	03E3	03E4	03E5
TKN (mg/l)	0.9	1.8	2.0	0.6	1.1
NH_4-N (mg/l)	0.028	0.077	0.098	0.043	0.035
NO_2+ NO_3-N (mg/l)	ND[1]	1.69	3.55	1.80	3.05
Total N (mg/l)	0.928	3.49	5.55	2.4	4.15
Total P (mg/l)	0.10	0.07	0.10	0.03	0.03
Diss. P (mg/l)	NS[2]	NS	NS	NS	NS
N/P Ratio	9.28	49.86	55.5	80.0	138.3

[1] ND = not detectable; [2] NS = no sample collected

Table 6. Event Water Quality Parameters, Weyauwega Lake, July 5, 1994.

PARAMETER	SAMPLE SITE 03E1	03E2	03E3	ST2	ST3	ST4
TKN (mg/l)	2.3	3.1	3.3	0.8	0.4	1.2
NH_4-N (mg/l)	0.083	0.114	1.12	0.212	0.182	0.208
NO_2+ NO_3-N (mg/l)	0.037	3.16	0.253	0.203	0.172	0.210
Total N (mg/l)	2.34	6.26	3.55	1.003	0.572	1.41
Total P (mg/l)	0.372	0.65	1.70	0.147	0.202	0.41
Diss. P (mg/l)	0.212	0.126	0.930	0.040	0.038	0.044
N/P Ratio	6.28	9.63	2.09	6.82	2.83	3.44

transparency reduction unrelated to algal growth (e.g. that associated with color).

TSI numbers for Weyauwega Lake with respect to in-lake surface total phosphorus (Figure 6) indicate a eutrophic classification. TSI numbers varied between oligotrophic and mesotrophic for chlorophyll a readings. Secchi depth TSI trends were biased high by readings "to bottom" on some sample dates but generally indicated an oligotrophic classification. A statistical summary of 100 Wisconsin impoundments indicated an average chlorophyll a reading of 22.3 $\mu g/l$ (median = 11.0 $\mu g/l$, standard deviation = 27.2 $\mu g/l$), compared to the 1994-1995 in-lake average of 3.15 $\mu g/l$ (median = 3.5, σ = 1.97 $\mu g/l$) for Weyauwega Lake.

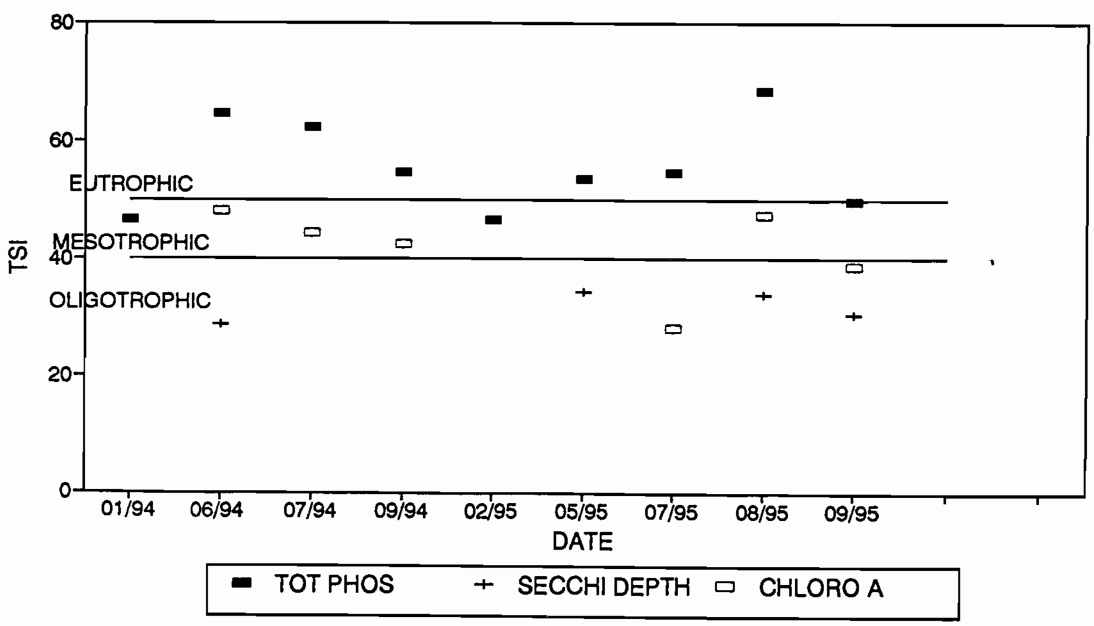

Figure 6. Trophic State Index for Secchi Depth, Total Phosphorus and Chlorophyll a, Weyauwega Lake, 1994 - 1995.

Aquatic Plant Control

Aquatic herbicide treatment, mechanical harvest, dredging, benthic barriers, installation of floating platforms, rototilling and SCUBA cutting were identified and discussed relative to their applicability to Weyauwega Lake in the Phase I report. These, along with biological alternatives, are compared relative to effectiveness and other concerns in Table 7.

Table 7. Comparison of Aquatic Plant Control Alternatives for Weyauwega Lake, Waupaca County, WI.

	MECHANICAL HARVESTING	AQUATIC HERBICIDES	DREDGE	ROTOTILL	SCUBA	BOTTOM SCREENS	DRAWDOWN	BIOLOGICAL
Effects on Ecosystem	Removes plant material, some small fish	possible residual effects	removes preferred habitat, disturbs sediment	disturbs sediments	removes plant material	covers plants	decreased water quality downstream, possible fishery effects	needs more research
Effective Large-scale	yes	yes	yes	yes	no	no	yes	yes
Effective Small-scale	no	yes	yes	no	yes	yes	no	no
Species Selective	possibly	possibly	yes	no	yes	no	no	yes
Removes Nutrients	yes	no	yes	no	yes	no	no	no
WDNR Acceptability	high-minimal environmental impacts	medium-permit required	low-many environmental impacts	medium-sediment impacts	high-minimal impacts	medium-for small areas permit required	medium-limited success	low-many unknowns
Public Acceptability	high-immediate benefits	medium/low-many "anti-chemical" advocates	medium	medium/low-new technology	high-immediate effects	medium-difficult to maintain	medium/high-will allow frontage clean-up	low

Table format taken from "Minnesota Aquatic Plant Control Draft Reconnaissance Report," August 1989.

Sediment Sampling

Two grab samples, each comprised of four core (1.5 inch diameter plastic) samples of the sediment (maximum top five inches), were taken from each site, composited in a stainless steel pail, and homogenized with a stainless steel spoon. The samples were put into glass jars provided by the analytical laboratory, sealed with tape, labeled (i.e., coded) and packed on ice in the field. All sample collection equipment was detergent washed and acid (10% HNO_3) rinsed before sampling at each site.

Samples were maintained on ice and shipped on ice via overnight express to the analytical laboratory. Enviroscan, Inc. of Rothschild, Wisconsin (WDNR Certification No. 737053130) conducted the analyses for total solids, chromium, lead, mercury and cyanide following EPA methods 160.3/6010/7471A/9012. EPA methods 8080A (pesticide analysis) was also conducted (Tables 8 and 9). All analyses was conducted in accordance with Enviroscan Quality Assurance Program.

Results for the sediment samples taken in 1995 were generally below the reporting limit. Exceptions to this were noted for chromium and mercury at site 1A and for chromium at site 2A.

Table 8. Sediment Collection Analysis, Sample 1A, Weyauwega Lake, August 1995.

	UNITS	REPORTING LIMIT	RESULT
EPA 160.3			
Total Solids	%	-	74.3
EPA 6010			
Chromium	mg/kg	0.58	1.98
Lead	mg/kg	6.70	X
EPA 7471A			
Mercury	mg/kg	0.027	0.077
EPA 9012			
Cyanide	mg/kg	0.13	X
EPA 8080A			
PCB - 1016	mg/kg	0.54	X
PCB - 1221	mg/kg	0.54	X
PCB - 1232	mg/kg	0.54	X
PCB - 1242	mg/kg	0.54	X
PCB - 1248	mg/kg	0.54	X
PCB - 1254	mg/kg	0.54	X
PCB - 1260	mg/kg	0.54	X
Aldrin	mg/kg	0.0054	X
a - BHC	mg/kg	0.0054	X
b - BHC	mg/kg	0.0054	X
d - BHC	mg/kg	0.0054	X
g - BHC (Lindane)	mg/kg	0.0054	X
Chlordane	mg/kg	0.54	X
4,4' -DDD	mg/kg	0.027	X
4,4' -DDE	mg/kg	0.009	X
4,4' -DDT	mg/kg	0.027	X
Dieldrin	mg/kg	0.009	X
Endosulfan I	mg/kg	0.009	X
Endosulfan II	mg/kg	0.009	X
Endosulfan Sulfate	mg/kg	0.027	X
Endrin	mg/kg	0.009	X
Endrin Aldehyde	mg/kg	0.027	X
Heptachlor	mg/kg	0.0054	X
Heptachlor Epoxide	mg/kg	0.0054	X
Toxaphene	mg/kg	0.54	X

X = Analyzed but not detected.
Results calculated on a dry-weight basis.

Table 9. Sediment Collection Analysis, Sample 2A, Weyauwega Lake, August 1995.

	UNITS	REPORTING LIMIT	RESULT
EPA 160.3			
Total Solids	%	-	72.4
EPA 6010			
Chromium	mg/kg	0.59	2.31
Lead	mg/kg	6.90	X
EPA 7471A			
Mercury	mg/kg	0.028	X
EPA 9012			
Cyanide	mg/kg	0.14	X
EPA 8080A			
PCB - 1016	mg/kg	0.55	X
PCB - 1221	mg/kg	0.55	X
PCB - 1232	mg/kg	0.55	X
PCB - 1242	mg/kg	0.55	X
PCB - 1248	mg/kg	0.55	X
PCB - 1254	mg/kg	0.55	X
PCB - 1260	mg/kg	0.55	X
Aldrin	mg/kg	0.0055	X
a - BHC	mg/kg	0.0055	X
b - BHC	mg/kg	0.0055	X
d - BHC	mg/kg	0.0055	X
g - BHC (Lindane)	mg/kg	0.0055	X
Chlordane	mg/kg	0.55	X
4,4' -DDD	mg/kg	0.028	X
4,4' -DDE	mg/kg	0.01	X
4,4' -DDT	mg/kg	0.028	X
Dieldrin	mg/kg	0.01	X
Endosulfan I	mg/kg	0.01	X
Endosulfan II	mg/kg	0.01	X
Endosulfan Sulfate	mg/kg	0.028	X
Endrin	mg/kg	0.01	X
Endrin Aldehyde	mg/kg	0.028	X
Heptachlor	mg/kg	0.0055	X
Heptachlor Epoxide	mg/kg	0.0055	X
Toxaphene	mg/kg	0.55	X

X = Analyzed but not detected.
Results calculated on a dry-weight basis.

Sediment Mapping

Sediment deposition in Weyauwega Lake overall averaged 5.49 feet for all five transects (Figures 7-11). On a longitudinal basis sediment depth was relatively consistent in a downstream progression. Transectionally, sediment depth was greater in shallower shelf areas (less flow, abundant macrophytes) when compared to sediment depth within the original channel.

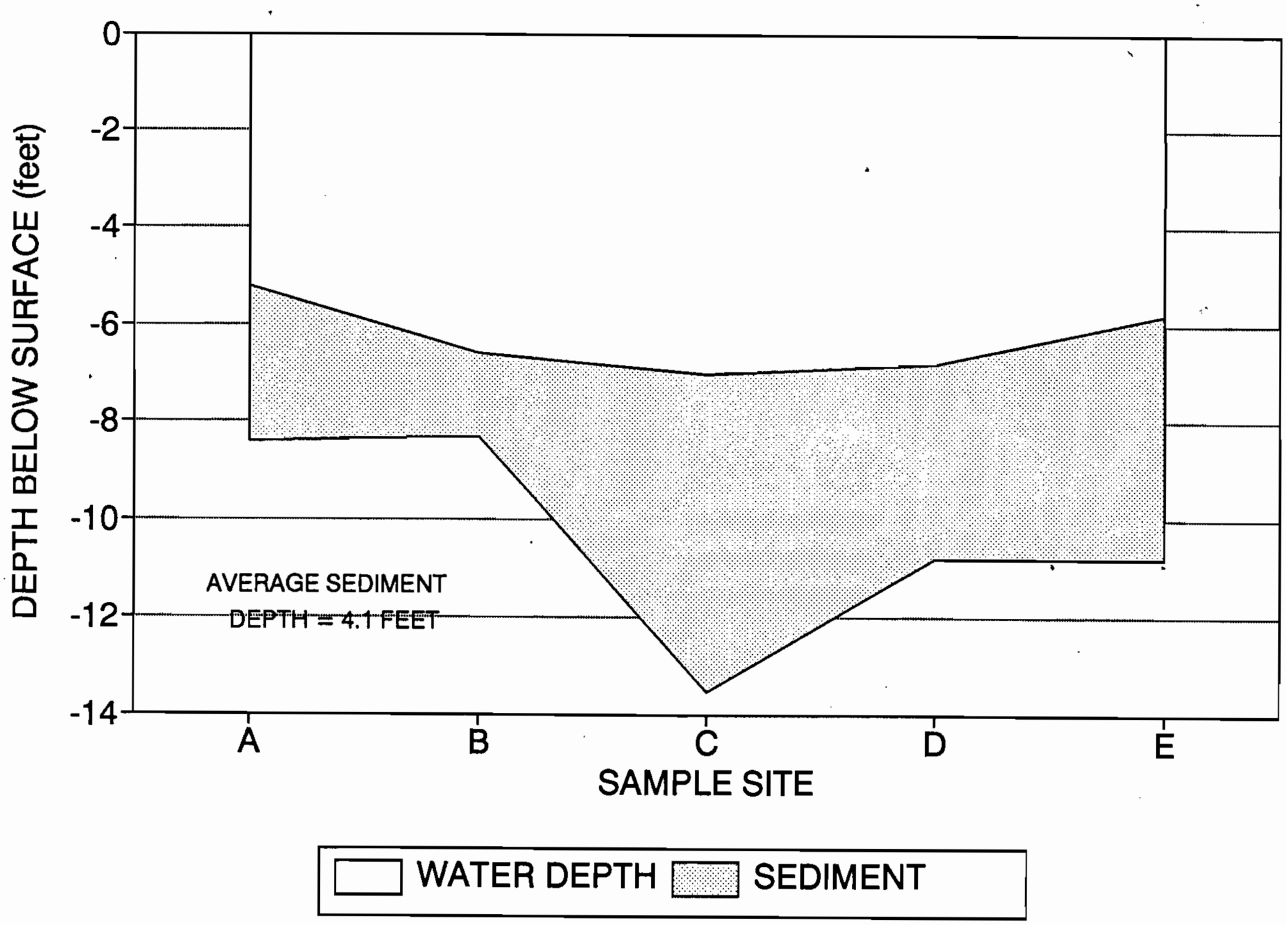

Figure 7. Sediment Profile (points A-E orientated North to South), Transect #1.

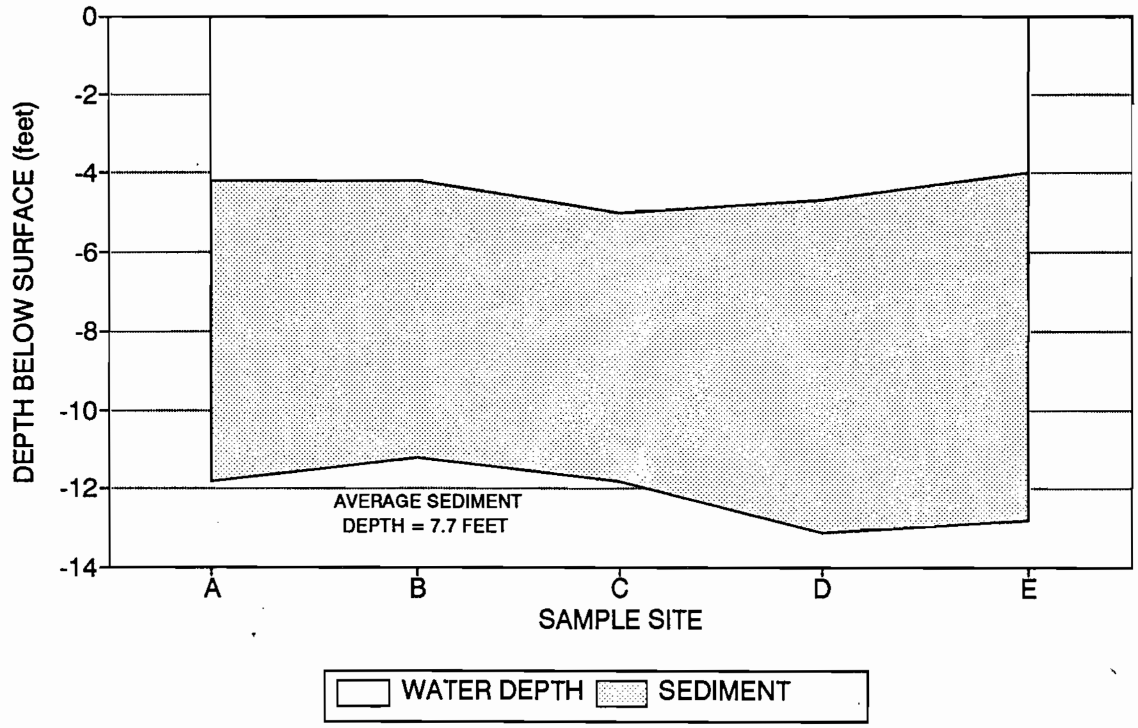

Figure 8. Sediment Profile (points A-D orientated North to South), Transect #2.

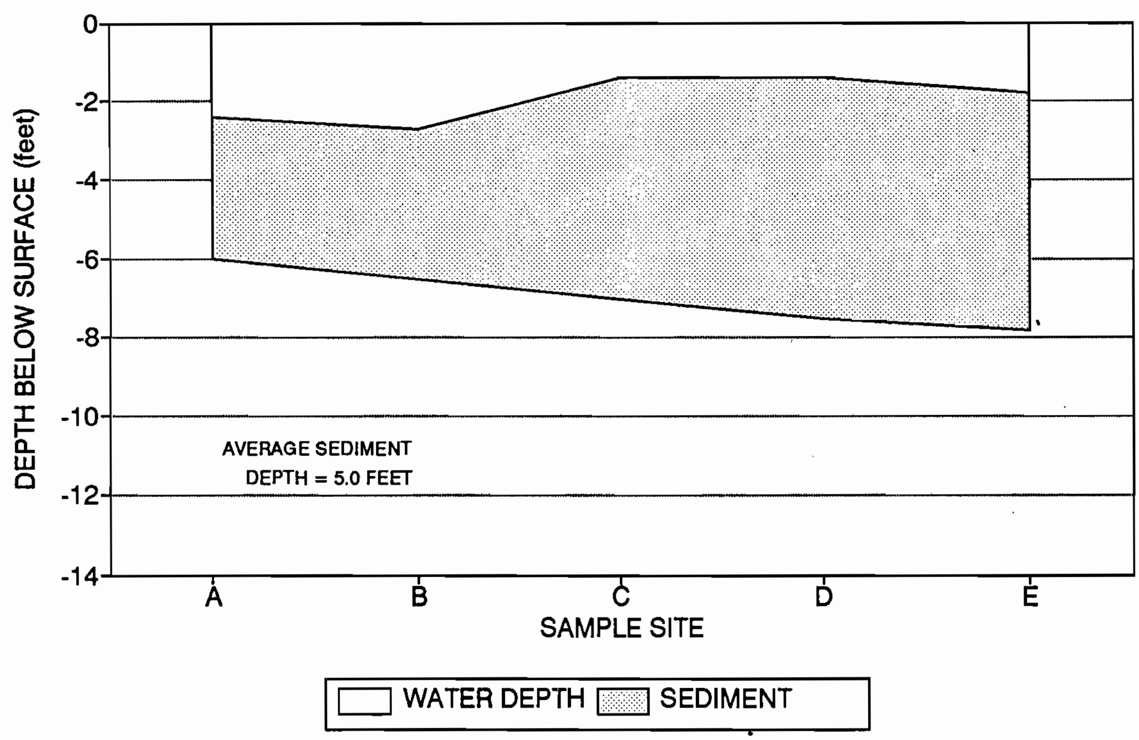

Figure 9. Sediment Profile (points A-E orientated North to South), Transect #3.

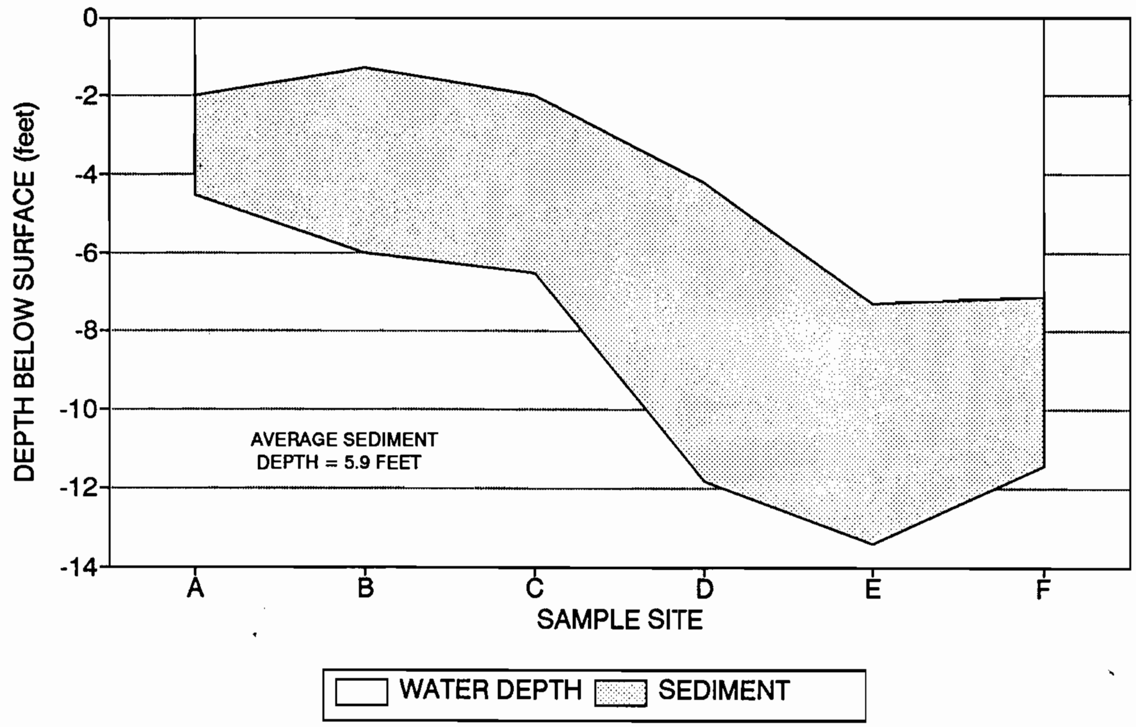

Figure 10. Sediment Profile (points A-E orientated East to West), Transect #4.

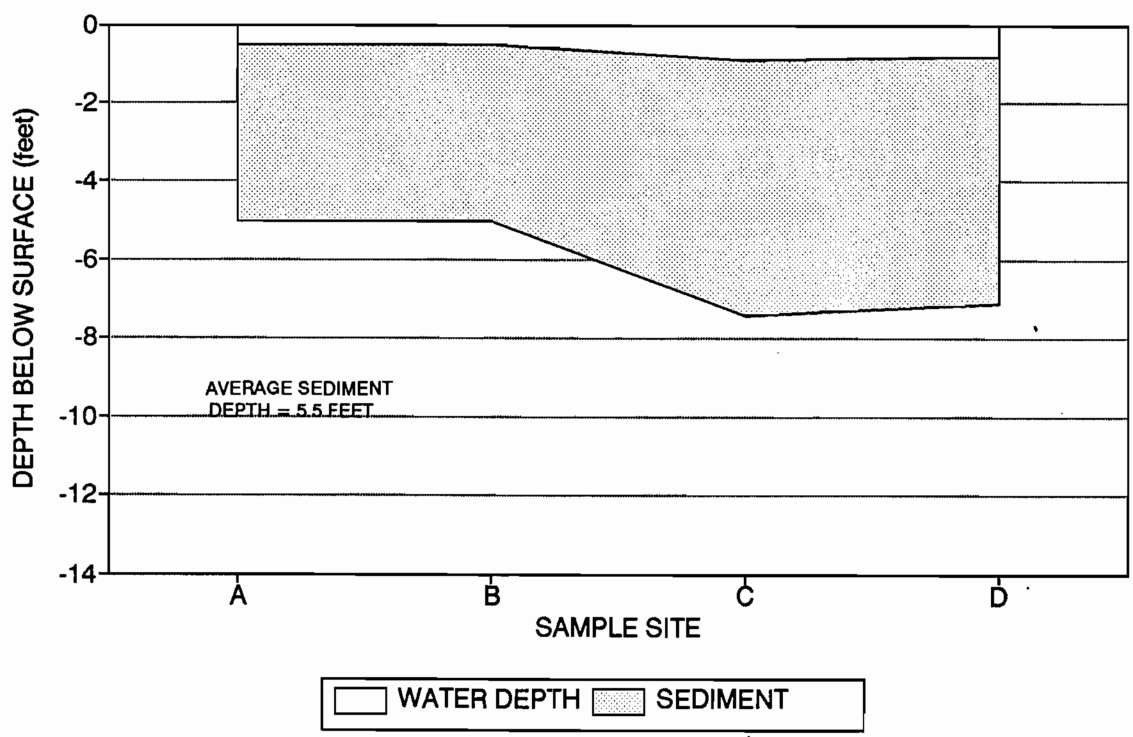

Figure 11. Sediment Profile (points A-E orientated North to South), Transect #5.

MANAGEMENT ALTERNATIVES DISCUSSION

Water Quality and Sedimentation

Weyauwega Lake, as an impoundment, has basin characteristics which make it prone to sedimentation, non-point source runoff and changing water quality. Water quality is good but macrophyte growth has increased and is dominated by a few species at potentially nuisance levels. Sedimentation is probably significant and may be severe, especially in the upstream reaches of the impoundment. The silt contributes to the weed problem by providing absorbed nutrients such as phosphorus which can lead to algae blooms and excessive rooted aquatic vegetation.

Before drastic management measures are taken to reclaim or "rejuvenate" the resource, steps must be taken to reduce sediment and nutrient inputs to the extent possible and/or practical. Efforts should be made to identify runoff or erosion prone areas and control nutrient and sediment inflows on a watershed-wide basis. Major emphasis should be given to implementation of BMP's to reduce these loadings and inputs within the drainage basin. Applicable practices for the Weyauwega Lake watershed include: streamside management zones, range and pasture management, maintenance of natural waterways, conservation tillage, and any techniques related to erosion control from forested lands. Common sense approaches are relatively easy and can be very effective in minimizing inputs.

Yard practices can minimize both nutrient and sediment inputs. Lawn fertilizers should be used sparingly, if at all. If used, the land owner should use phosphate-free fertilizers and apply small amounts more often instead of large amounts at one or two times. Composting lawn clippings and leaves away from the lake can reduce nutrient inputs to the lake. If leaves are burned, it should be done in an area where the ash cannot wash directly into the lake (9), or indirectly to the lake via roadside ditches.

Creation of a buffer strip with diverse plants at least 20 feet wide immediately adjacent to the lake can control wave erosion, trap soil eroded from the land above, increase infiltration (to filter nutrients and soil particles), and shade areas of the lake to reduce macrophyte growth (especially on south shores) and provide fish cover (9). Clearly, upland management and stabilization of buffers between agricultural land uses, housing developments, and the lake or streams will reduce sediment entry into the pond. Placement of a low berm in this area can enhance effectiveness of the buffer strip by further retarding runoff during rainfalls.

Macrophytes

Management of macrophyte populations is often a major objective for lakes and particularly shallow impoundments. Macrophytic growth can positively affect the resource through fish forage and wildlife production/protection, shoreline stabilization and nutrient uptake. Nuisance levels of macrophytes, however, can cause organic sediment build-up, preclude development of desirable diverse plant populations, reduce aesthetics, reduce DO (potential fishkills), impair recreational use and contribute to the development of stunted panfish populations. Macrophyte management should be carefully implemented and may consider different use areas of the lake. Numerous methods of macrophyte control and management are available ranging from radical habitat alteration to more subtle habitat manipulation and are discussed below relative to Weyauwega Lake applicability..

Dredging is a drastic and costly form of habitat alteration. Before any dredge plan is developed or implemented on Weyauwega Lake, the lake bottom must be studied (chemical and physical features) and steps must be taken to ensure the dredging will be cost-effective (i.e., last as long as possible). Only when erosion and nutrient control measures are implemented (to the extent practical) on a watershed-wide basis, should a dredging plan be considered. A dredge plan should involve as little sediment removal as possible to create access and edge (removal to a depth at which macrophyte growth would be retarded due to reduced sunlight). A basic plan for Weyauwega Lake could involve dredging a relatively small area in the upstream reach (wildlife/fish production/protection zone) as a catchment basin for future sedimentation and a larger area in the lower reaches adjacent to deepest areas for increased access and edge.

Chemical treatment for macrophyte control has been shown to eradicate some undesirable species and leave others intact. The WDNR strongly discourages the use of chemicals because of nutrient release, oxygen depletion, sediment accumulation, bioaccumulation and other unknown environmental hazards including invasion potential from nuisance exotics. Chemical effects are nondiscriminate and may harm desirable or beneficial plant populations. Chemical use in the past has shown no lasting effect on controlling plant populations and should not be considered for Weyauwega Lake at this time.

Aquatic plant screens have been shown to reduce plant densities in other lakes and may be applicable in near-shore areas here. A fiberglass screen or plastic sheet is placed and anchored on the sediment to prevent plants from growing. This may also make some sediment nutrients unavailable for algal growth. Screens should be removed each fall and cleaned in order to last a number of years. Screens are generally used in small areas of concern, e.g., around beaches, landings or piers.

Installation of floating platforms (black plastic attached to restrict plant growth and help to open corridors for swimming or boat navigation. Shading is usually required for three weeks to two months to impact nuisance plant growth (10). A drawback is that the area cannot be used while the platform is in place. This control technique is not recommended for Weyauwega Lake at this time.

Remaining control methods consist, in one form or another, of macrophyte harvest. It is a commonly used technique which can be applied on a widespread or localized basis. Its efficiency, based on method of harvest, can vary substantially with depth and lake basin configuration. Several conditions should be considered with respect to macrophyte harvest. Macrophyte growth on Weyauwega Lake is dense and widespread; even intense harvest efforts will probably not manage all areas of concern in the impoundment. Milfoils, coontail and common waterweed all spread easily by fragmentation; strong consideration should be given to the potential of these species to become even more dominant by becoming better established where competing macrophytes have been removed. Macrophyte harvesting is typically conducted with a mechanical harvester which cuts the vegetation and removes (harvests) it onto a platform for out-lake disposal. Given the precautions regarding potential nuisance species dispersal and the ability of some plants to survive and spread when detached from the substrate, harvest practices may even enhance the nuisance macrophyte problem through seed dispersal, fragmentation or incomplete removal. Harvest is, however, area selective, relatively inexpensive and removes nutrients from the lake system.

SCUBA assisted harvest has also been shown to selectively manage macrophytes. It can be used in deeper areas and to target only specific species or nuisance growth areas. This method is labor intensive, but has effectively reduce nuisance plant levels for up to two years (10). Because unlimited areas are available for potential macrophyte management in Weyauwega Lake, SCUBA assisted harvest may be a viable option for specific problem areas.

Raking weeds (using an ordinary garden rake) in the near shore zone can be a very effective localized plant control method when done on a regular basis. A concentrated effort on individual problem areas would reduce efforts expended on other control methods. This option appears viable to improve aesthetics.

A newer technique of rototilling sediments to destroy plant roots appears to be effective in controlling plant growth for relatively longer period than harvesting. The process is about a the same cost per hour as a contracted macrophyte harvester (11). A potential problem is disturbance of the sediments and resuspension of nutrients or toxics.

Any macrophyte management efforts should be proceeded or accompanied by landowner/resource user education and watershed-wide best management practices (BMP's) to reduce nutrient and sediment inflows. Macrophyte management, in addition to enhancing the aesthetic aspects of Weyauwega Lake will also, at least marginally, improve the fish habitat.

BASELINE CONCLUSIONS

Physical characteristics of the impoundment make Weyauwega Lake prone to sedimentation, prolific aquatic plant growth, non-point source nutrient inflows, and variable water quality affected by that of parent river flow conditions.

In-lake nutrient levels were less than expected for natural lakes in the region and less than average for impoundments. This, coupled with comparitively low chlorophyll a and good transparency, suggested that nutrients are probably being bound in sediments, utilized by the extensive macrophyte assemblages or rapidly flowing through the system.

Weyauwega Lake habitat supports widespread, nuisance aquatic plant growth. Recreational use of the resource is restricted by widespread and abundant macrophytic growth throughout much of the open-water season. Continued development of current weed conditions will also have negative impact on the lake fishery (loss of spawning areas, increased risk of dissolved oxygen depletion, etc.). Adequate water quality, nutrients and predominantly soft, shallow shelf areas make conditions in Weyauwega Lake (like many other impoundments) conducive to nuisance aquatic plant growth. Event monitoring indicated storm sewer sites and feeder creeks contributing relatively significant phosphorus and/or nitrogen concentrations.

Sedimentation seems to be significant in areas of the impoundment. Sediment sampling results determined sediments are clean in regards to heavy metals and pesticides. Levels were, however, above the reporting limit for chromium and mercury at site 1A and for chromium at site 2A.

Waupaca County has well established areas of Eurasian milfoil and Purple loosestrife which may serve as sources for these exotic and harmful species. Introduction of these plants to Weyauwega Lake via resource users carries a high potential. Public education regarding recognition and preventative measures to stop their spread must be encouraged. Eradication/control strategies, in the eventuality that any exotic becomes established, must be developed.

MANAGEMENT RECOMMENDATIONS

Weyauwega Lake is greatly influenced by the activities that take place within the watershed since it receives a significant amount of surface inflow. Residents should be aware of the potential effects of watershed uses on their resources. They should be strongly encouraged to keep abreast of and support the TWRPW project. Residents in the Weyauwega watershed should have private wells tested for nitrates and/or pesticide levels and groundwater samples should be collected at various points to determine areas of concern.

Future management should target areas of concern; efforts relative to erosion control and surface runoff reduction, manure containment, fertilizer management and stream fencing should be emphasized.

The feasibility of stormwater discharge reduction and/or redirection away from Weyauwega Lake must be persued as a major Phase II, recommendation. These efforts should be coordinated with other ongoing projects/iniatives aimed at elimination of untreated stormwater discharge to the system.

Water quality monitoring should be continued to track trends, develop a better nutrient budget for the impoundment and to detect major disturbances within the watershed. Monitoring should include regular (quarterly) sampling of the inlet, deepest point and event sampling of similar sites. Self-help secchi monitoring should be continued; rainfall monitoring should be initiated.

Mechanical harvest (determined to be most cost efficient) should be initiated for widespread aquatic plant control in the downstream portion of the impoundment; small channels in upstream portions (especially around islands and piers) should also be harvested. Management for wetland habitat (with side benefits of nutrient removal) should be considered for the upstream reach. Areas harvested (especially channels) should be buoyed or identified on a map and made available at access points. Screening and SCUBA/hand removal should be encouraged for small localized areas where harvester access is limited.

Drawdown may be considered for Weyauwega Lake. Drawdown will allow control of some aquatic plants, but more importantly will allow landowners to more effectively manage frontage areas.

Land purchase may be pursued for wetland protection near the impoundment and/or throughout the watershed. Wetland protection will help to increase awareness and protect water quality. Signs should be posted at access points informing lake users of

Eurasian Water Milfoil, Purple Loosestrife and Zebra Mussels. A sign reading "remove weeds from trailer" should be painted on the main ramp.

Identified purple loosestrife stands should be treated as soon as it is practical to do so; localized growth areas or individual plants should be treated first and more extensive growth areas later. It is best to treat plants before flowering (May to mid June). Plants are treated by cutting the top off and spraying the remainder with a Roundup-surfactant mix; plants in standing water should be treated with a Rodeo-surfactant mix. Chemicals can be applied using hand spray bottles or larger chemical sprayers. Sites should be revisited in subsequent years to treat remnant individuals.

Local townships, Waupaca County and the State of Wisconsin, should take a cooperative effort in protection of the Weyauwega Lake resource by the regulation of land uses and land use practices. Efforts should continue to utilize the funds available from the Tomorrow/Waupaca River Priority Watershed Project to implement long term conservation practices.

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