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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**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

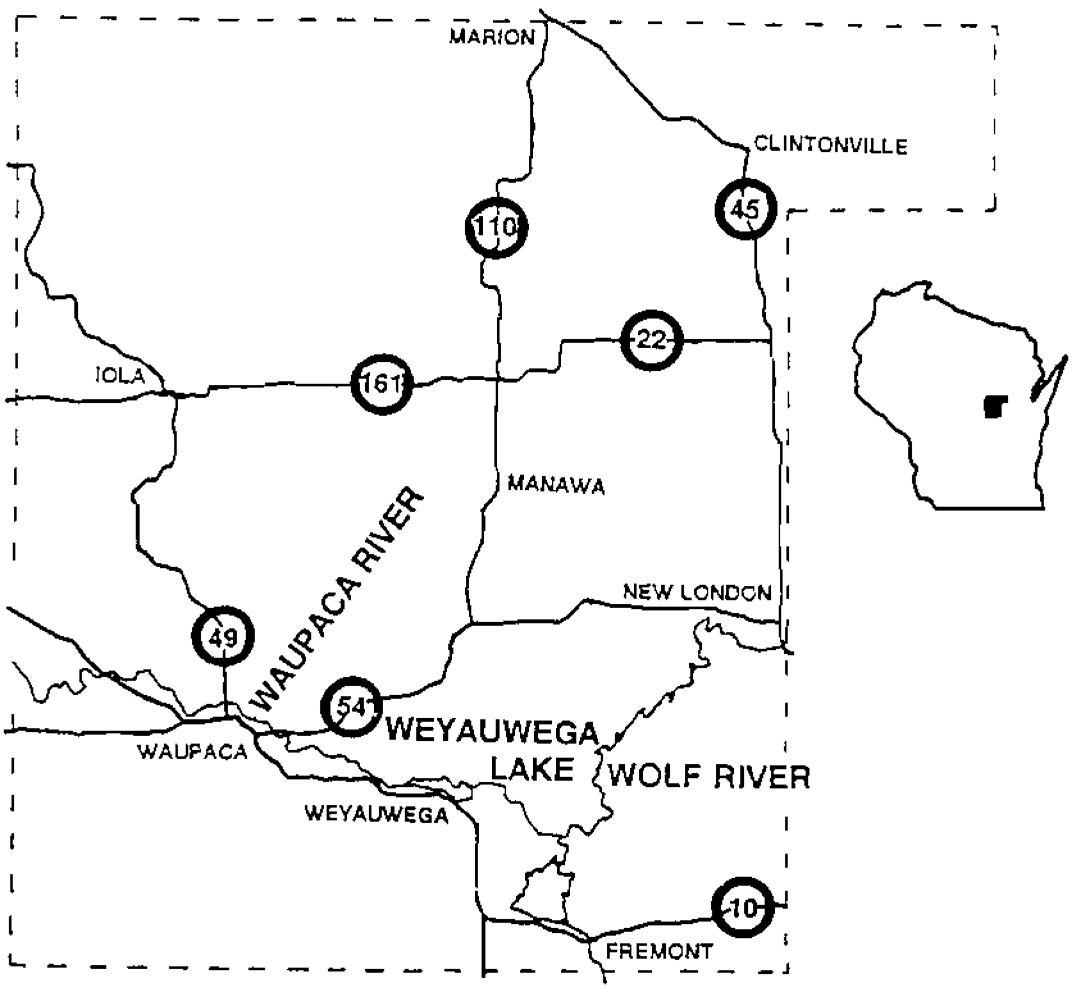



Figure 1. Location Map, Weyauwega Lake, Waupaca County, WI.

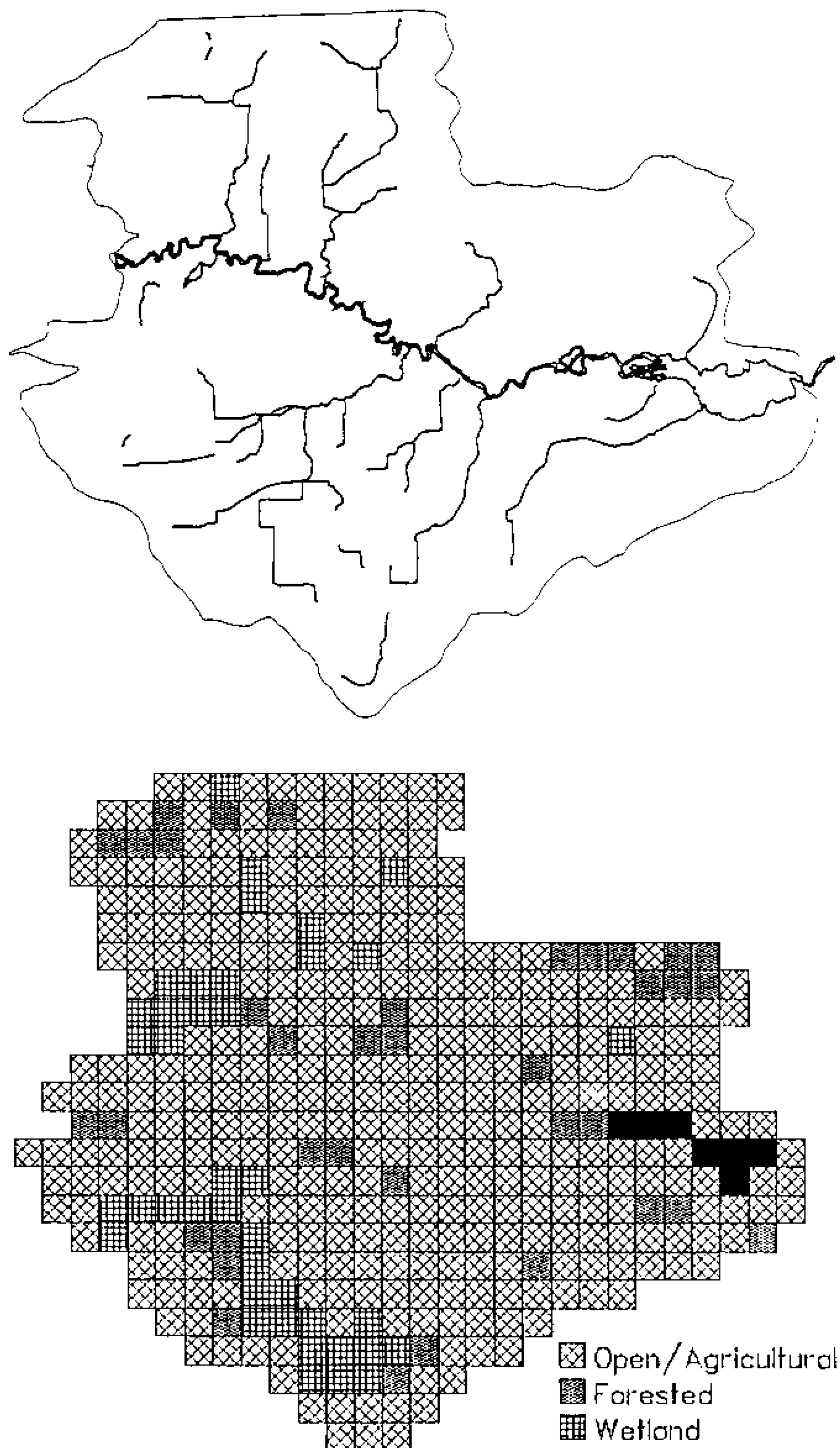
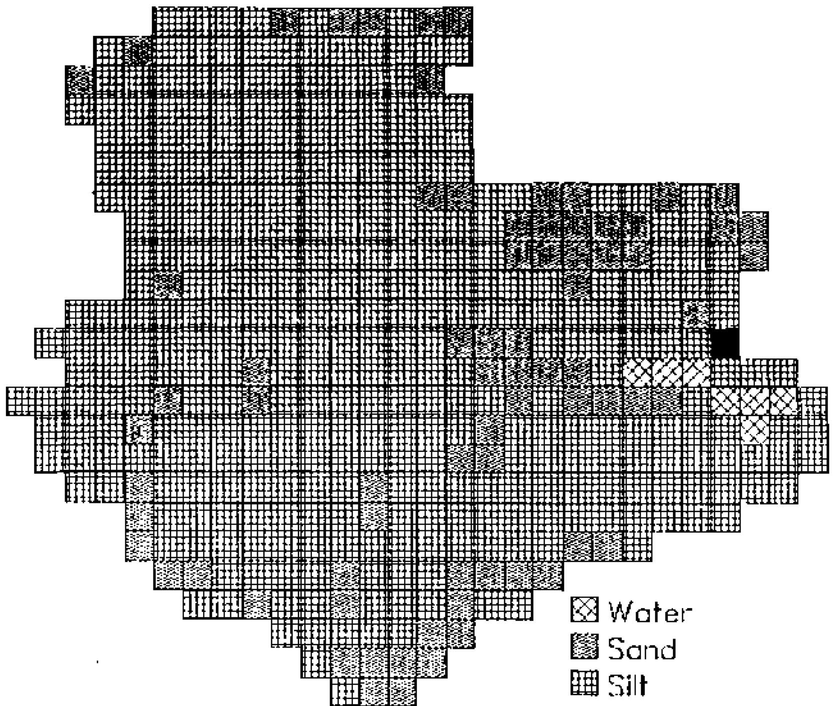



Figure 2. Some Physical Characteristics of the Weyauwega Lake Subwatershed.



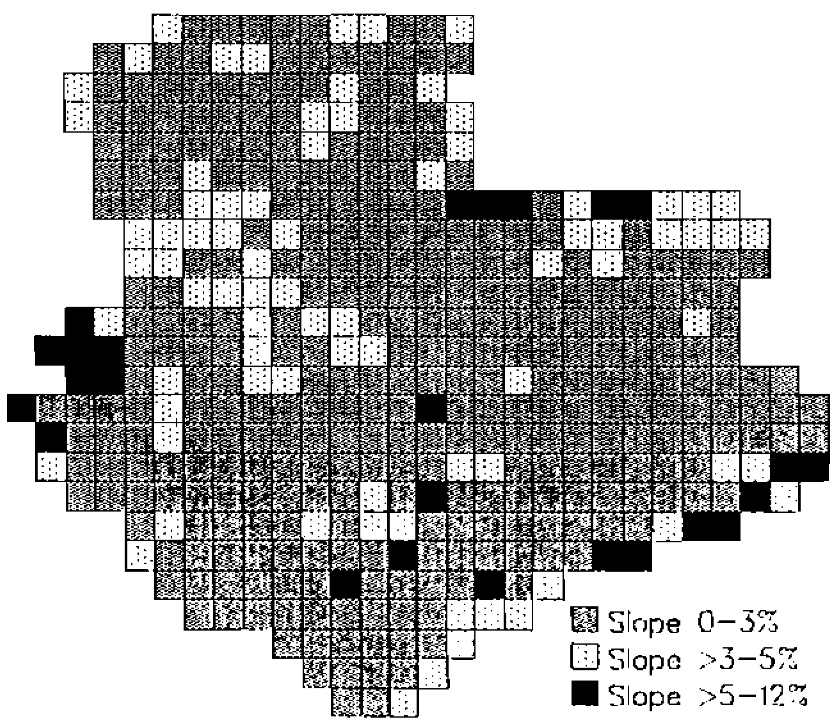




Figure 2 (continued). Some Physical Characteristics of the Weyauwega Lake Subwatershed.

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"<br>88° 57' 43" | 44° 19' 34"<br>88° 57' 40" | 18 | 144 | 1/2 |
| B | 44° 19' 34"<br>88° 57' 11" | 44° 19' 28"<br>88° 57' 04" | 18 | 268 | 1/2 |
| C | 44° 19' 32"<br>88° 56' 49" | 44° 19' 16"<br>88° 56' 56" | 155 | 195 | 1/2/3 |
| D | 44° 19' 39"<br>88° 56' 36" | 44° 19' 19"<br>88° 56' 26" | 180 | 167 | 1/2/3 |
| E | 44° 19' 30"<br>88° 56' 11" | 44° 19' 28"<br>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)

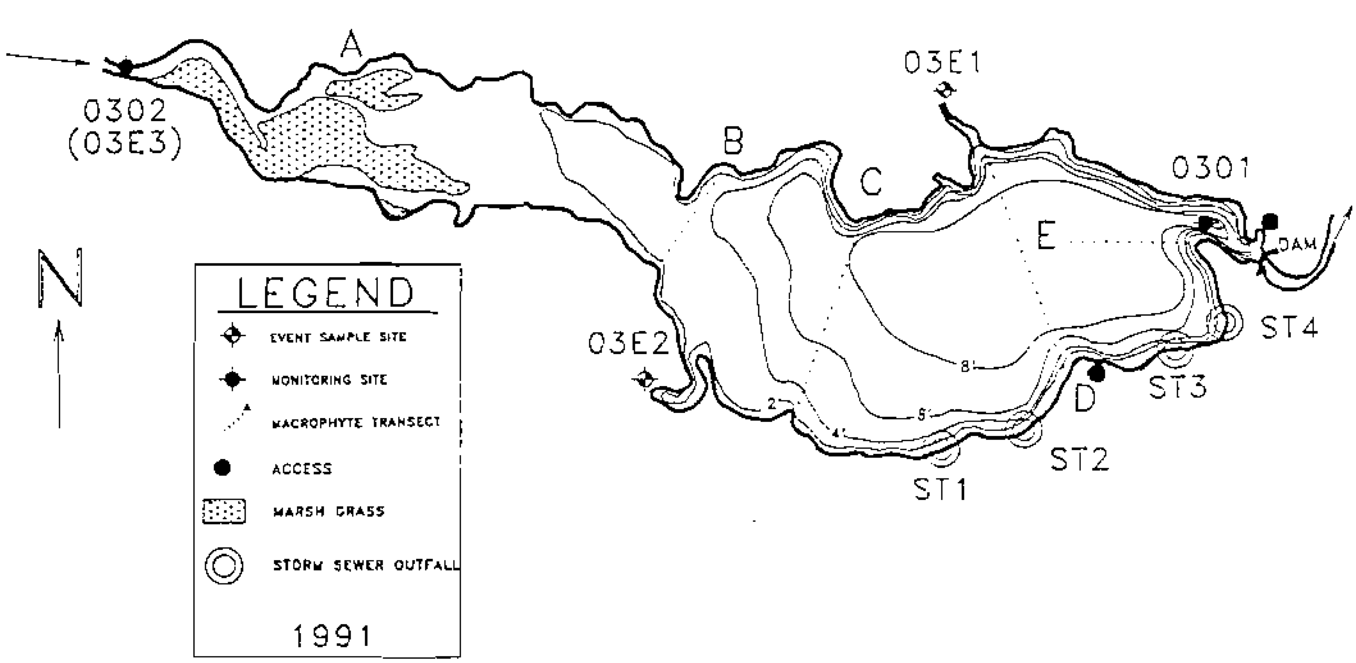



Figure 3. Sampling Sites, Weyauwega Lake, Waupaca County, WI, 1991 - 1992.

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 ($\sigma$) = 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, $\sigma$ = 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, ($\sigma$) = 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, $\sigma$ = 0.100 mg/l) and well below that for impoundments with 0-14 day residence times (ave. = 0.094, median = 0.075, $\sigma$ = 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

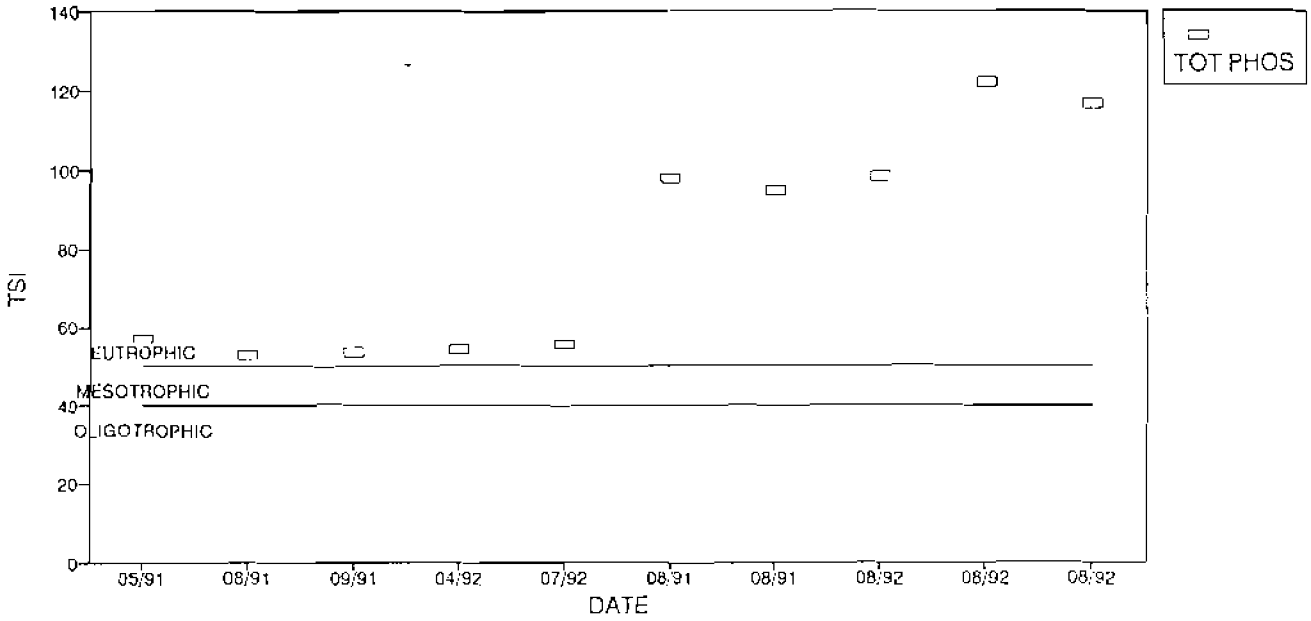



Figure 4. Trophic State Index for Total Phosphorus, Weyauwega Lake.

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 =

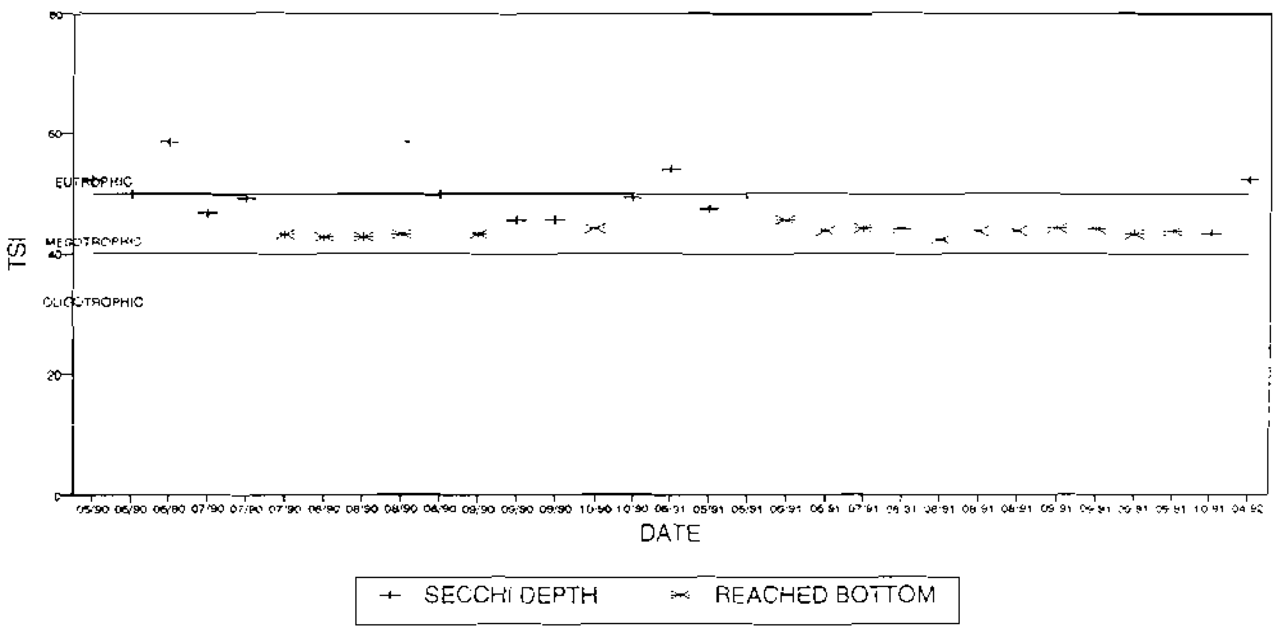



Figure 5. Trophic State Index for Secchi Depth, Weyauwega Lake.

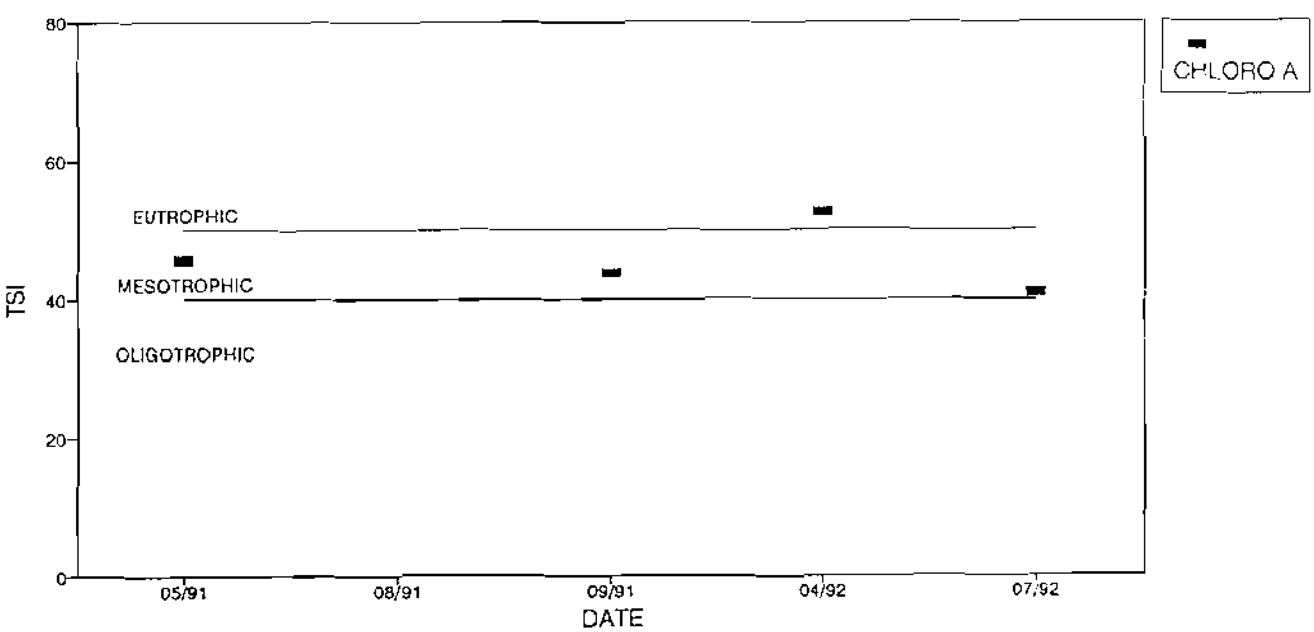



Figure 6. Trophic State Index for Chlorophyll a, Weyauwega Lake.

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 | 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 | 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.

| CODE | 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 | 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 | 1 JUNE | 1 SEP | 2 JUNE | 2 SEP | 3 JUNE | 3 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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APPENDIX II
**HISTORIC WATER QUALITY DATA**
Weyauwega Lake, Waupaca County, WI
Secchi Readings: 05/90 - 10/91
Lake Center
(Source: WDNR Self Help Data)

CHANNEL SITE

| DATE | SECCHI DEPTH (ft) |
|---|---|
| 05-30-90 | 5.5 |
| 06-13-90 | 6.5 |
| 06-27-90 | 3.5 |
| 07-11-90 | 8.25 |
| 07-18-90 | 7.0 |
| 07-27-90 | >10.5 |
| 08-01-90 | >10.75 |
| 08-08-90 | >10.75 |
| 08-15-90 | >10.5 |
| 08-23-90 | 6.5 |
| 09-05-90 | >10.5 |
| 09-13-90 | 9.0 |
| 09-26-90 | 9.0 |
| 10-11-90 | >10.0 |
| 10-17-90 | 7.0 |
| 05-25-91 | 5.0 |
| 05-30-91 | 6.5 |
| 06-12-91 | >9.0 |
| 06-20-91 | >10.25 |
| 07-24-91 | >10.0 |
| 08-01-91 | >11.0 |
| 08-14-91 | >10.25 |
| 08-29-91 | >10.25 |
| 09-04-91 | >10.0 |
| 09-13-91 | >10.5 |
| 09-27-91 | >10.25 |
| 10-11-91 | 10.5 |

> Entries = TO BOTTOM

MID - LAKE SITE

| DATE | SECCHI DEPTH (ft) |
|---|---|
| 05-30-90 | 4.5 |
| 06-13-90 | 6.0 |
| 06-27-90 | 3.0 |
| 07-11-90 | 7.0 |
| 07-18-90 | 5.0 |
| 07-27-90 | >8.0 |
| 08-01-90 | >7.5 |
| 08-08-90 | >7.0 |
| 08-15-90 | >7.5 |
| 08-23-90 | 7.0 |
| 09-05-90 | >8.0 |
| 09-13-90 | 6.5 |
| 09-26-90 | 6.5 |
| 10-11-90 | >8.0 |
| 10-17-90 | 5.5 |
| 05-25-91 | 6.75 |
| 05-30-91 | 7.0 |
| 06-12-91 | >8.5 |
| 06-20-91 | >8.0 |
| 07-24-91 | >8.0 |
| 08-01-91 | >7.0 |
| 08-14-91 | >7.25 |
| 08-29-91 | >7.25 |
| 09-04-91 | >7.0 |
| 09-13-91 | >7.75 |
| 09-27-91 | >8.25 |
| 10-11-91 | >8.25 |

# APPENDIX VI
## Review of Best Management Practices (BMP's)(1)

**Conservation Tillage:** A farming practice that leaves stalks or stems and roots intact in the field after harvest. Its purpose is to reduce water runoff and soil erosion compared to conventional tillage where the topsoil is mixed and turned over by a plow. Conservation tillage is an umbrella term that includes any farming practice that reduces the number of times the topsoil is mixed. Other terms that are used instead of conservation tillage are (1) minimum tillage where one or more operations that mixed the topsoil are eliminated; and (2) no-till where the topsoil is left essentially undisturbed.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Fair to excellent, decreases sediment input to streams and lakes. (40-90% reduced tillage, 50-95% no tillage). |
| b) Nitrogen (N) | Poor, no effect on nitrogen input to streams and lakes. |
| c) Phosphorus (P) | Fair to excellent, can reduce the amount of phosphorus input to streams and lakes. (40-90% reduced tillage, 50-95% no tillage). |
| d) Runoff | Fair to excellent, decreases amount of water running off fields carrying sediment and phosphorus. |
| 2. Capital Costs | High, because requires purchase of new equipment by farmer. |
| 3. Operation and Maintenance | Less expensive than conventional tillage. Potential increase in herbicide costs. Potential increase in net farm income. |
| 4. Longevity | Good, approximately every five years the soil has to be turned over. |
| 5. Confidence | Fair to excellent. |
| 6. Adaptability | Good, but may be limited in northern areas that experience late cool springs, or in heavy, poorly drained soils. |
| 7. Potential Treatment Side Effects | Potential increase in herbicide effects and insecticide contamination of surface and groundwater. Nitrogen contamination of groundwater. |
| 8. Concurrent Land Management Practices | Consider fertilizer management and integrated pest management. |

**Integrated Pest Management:** Pests are any organisms that are harmful to desired plants, and they are controlled with chemical agents called pesticides. Integrated pest management considers factors such as how much pesticide is enough to control a problem, the best method of applying the pesticides, the appropriate time for application and the safe handling, storage and disposal of pesticides and their containers. Other considerations include using resistant crop varieties, optimizing crop planting time, optimizing time of day application, rotating crops and biological controls.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | No effect, but pesticides attached to soil particles can be carried to streams and lakes. |
| b) Nitrogen (N) | No effect. |
| c) Phosphorus (P) | No effect. |
| d) Runoff | No effect, but water is the primary route for transporting pesticides to lakes and streams. |
| 2. Capital Costs | No effect. |
| 3. Operation and Maintenance | Farming cost, potential reduction in pesticide costs and an increase in net farm income. |
| 4. Longevity | Poor, as pesticides are applied one or more times per year to address different pests and different crops. |
| 5. Confidence | Fair to excellent, reported pollutant reductions range from 20-90%. |
| 6. Adaptability | Methods are generally applicable wherever pesticides are used: forest, farms, homes. |
| 7. Potential Treatment Side Effects | Potential for ground and surface water contamination. Toxic components may be available to aquatic plants and animals. |
| 8. Concurrent Land Management Practices | See crop rotation, conservation tillage. |

# APPENDIX VI
## Review of Best Management Practices (BMP's)
(continued)

**Street Cleaning:** Streets and parking lots can be cleaned by sweeping which removes large dust and dirt particles or by flushing which removes finer particles. Sweeping actually removes solids so pollutants do not reach receiving waters. Flushing just moves the pollutants to the drainage system unless the drainage system is part of the sewer system. When the drainage system is part of the sewer system, the pollutants will be treated as wastes in the sewer treatment plant.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Poor, not proven to be effective. |
| b) Nitrogen (N) | Poor, not proven to be effective. |
| c) Phosphorus (P) | Poor, not proven to be effective. |
| d) Runoff | No effect. |
| 2. Capital Costs | High, because it requires the purchase of equipment by community. |
| 3. Operation and Maintenance | Unknown but reasonable vehicular maintenance would be expected. |
| 4. Longevity | Poor, have to sweep frequently throughout the year. |
| 5. Confidence | Poor. |
| 6. Adaptability | To paved roads, might not be considered a worthwhile expenditure of funds in communities less than 10,000. |
| 7. Potential Treatment Side Effects | Unknown. |
| 8. Concurrent Land Management Practices | Detention/Sedimentation basins. |

**Streamside Management Zones (Buffer strips):** Considerations in streamside management include maintaining the natural vegetation along a stream, limiting livestock access to the stream, and where vegetation has been removed, planting buffer strips. Buffer strips are strips of plants (grass, trees, shrubs) between a stream and an area being disturbed by man's activities that protects the stream from erosion and nutrient impacts.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Good to excellent, reported to reduce sediment from feedlots on 4% slope by 79%. |
| b) Nitrogen (N) | Good to excellent, reported to reduce nitrogen from feedlots on 4% slope by 84%. |
| c) Phosphorus (P) | Good to excellent, reported to reduce phosphorus from feedlots on 4% slope by 67%. |
| d) Runoff | Good to excellent, reported to reduce runoff from feedlots on 4% slope by 67%. |
| 2. Capital Costs | Good, moderate costs for fencing material to keep out livestock and for seeds for plants. |
| 3. Operation and Maintenance | Excellent, minimal upkeep. |
| 4. Longevity | Excellent, maintains itself indefinitely. |
| 5. Confidence | Fair, because of the lack of intensive scientific research. |
| 6. Adaptability | May be used anywhere. Limitations on types of plants that may be used between geographic areas. |
| 7. Potential Treatment Side Effects | With trees, shading may increase the diversity and number of organisms in the stream with the possible reduction of algae. |
| 8. Concurrent Land Management Practices | Conservation tillage, animal waste management, livestock exclusion, fertilizer management, pesticide management, ground cover maintenance, proper construction, use, maintenance of haul roads and skid trails. |

# APPENDIX VI
## Review of Best Management Practices (BMP's)
## (continued)

**Contour Farming:** A practice where the farmer plows across the slope of the land. This practice is applicable on farm land with a 2-8 percent slope.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Good on moderate slopes (2 to 8 percent slopes), fair on steep slopes (50 percent reduction). |
| b) Nitrogen (N) | Unknown. |
| c) Phosphorus (P) | Fair. |
| d) Runoff | Fair to good, depends on storm intensity. |
| 2. Capital Costs | No special effect. |
| 3. Operation and Maintenance | No special effect. |
| 4. Longevity | Poor, it must be practiced every time the field is plowed. |
| 5. Confidence | Poor, not enough information. |
| 6. Adaptability | Good, limited by soil, climate, and slope of land. May not work with large farming equipment on steep slopes. |
| 7. Potential Treatment Side Effects | Side effects not identified. |
| 8. Concurrent Land Management Practices | Fertilizer management, integrated pesticide management, possibly streamside management. |

**Contour Stripcropping:** This practice is similar to contour farming where the farmer plows across the slope of the land. The difference is that strips of close growing crops or meadow grasses are planted between strips of row crops like corn or soybeans. Whereas contour farming can be used on 2-8 percent slopes, contour stripcropping can be used on 8-15 percent slopes.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Good, 8 to 15 percent slopes, provides the benefits of contour plowing plus buffer strips. |
| b) Nitrogen (N) | Unknown, assumed to be fair to good. |
| c) Phosphorus (P) | Unknown, assumed to be fair to good. |
| d) Runoff | Good to excellent. |
| 2. Capital Costs | No special effect unless farmer cannot use the two crops. |
| 3. Operation and Maintenance | No special effect. |
| 4. Longevity | Poor, must be practiced year after year. |
| 5. Confidence | Poor, not enough information. |
| 6. Adaptability | Fair to good, may not work with large farming equipment on steep slopes. |
| 7. Potential Treatment Side Effects | Side effects not identified. |
| 8. Concurrent Land Management Practices | Fertilizer management, integrated pesticide management. |

# APPENDIX VI
## Review of Best Management Practices (BMP's)
(continued)

**Range and Pasture Management:** The objective of range and pasture management is to prevent overgrazing because of too many animals in a given area. Management practices include spreading water supplies, rotating animals between pastures, spreading mineral and feed supplements or allowing animals to graze only when a particular plant food is growing rapidly.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Good, prevents soil compaction which reduces infiltration rates. |
| b) Nitrogen (N) | Unknown. |
| c) Phosphorus (P) | Unknown. |
| d) Runoff | Good, maintains some cover which reduces runoff rates. |
| 2. Capital Costs | Low, but may have to develop additional water sources. |
| 3. Operation and Maintenance | Low. |
| 4. Longevity | Excellent. |
| 5. Confidence | Good to excellent. Farmer must have a knowledge of stocking rates, vegetation types, and vegetative conditions. |
| 6. Adaptability | Excellent. |
| 7. Potential Treatment Side Effects | None identified. |
| 8. Concurrent Land Management Practices | Livestock exclusion, riparian zone management and crop rotation. |

**Crop Rotation:** Where a planned sequence of crops are planted in the same area of land. For example, plow based crops are followed by pasture crops such as grass or legumes in two to four year rotations.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Good when field is in grasses or legumes. |
| b) Nitrogen (N) | Fair to good. |
| c) Phosphorus (P) | Fair to good. |
| d) Runoff | Good when field is in grasses or legumes. |
| 2. Capital Costs | High if farm economy reduced. Less of a problem with livestock which can use plants as food. |
| 3. Operation and Maintenance | Moderate, increased labor requirements. May be offset by lower nitrogen additions to the soil when corn is planted after legumes, and reduction in pesticide application. |
| 4. Longevity | Good. |
| 5. Confidence | Fair to good. |
| 6. Adaptability | Good, but some climatic restrictions. |
| 7. Potential Treatment Side Effects | Reduction in possibility of groundwater contamination. |
| 8. Concurrent Land Management Practices | Range and pasture management. |

# APPENDIX VI
## Review of Best Management Practices (BMP's)
## (continued)

**Terraces:** Terraces are used where contouring, contour strip cropping, or conservation tillage do not offer sufficient soil protection. Used in long slopes and slopes up to 12 percent; terraces are small dams or a combination of small dams and ditches that reduce the slope by breaking it into lesser or near horizontal slopes.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Fair to good. |
| b) Nitrogen (N) | Unknown. |
| c) Phosphorus (P) | Unknown. |
| d) Runoff | Fair, more effective in reducing erosion than total runoff volume. |
| 2. Capital Costs | High initial costs. |
| 3. Operation and Maintenance | Periodic maintenance cost, but generally offset by increased income. |
| 4. Longevity | Good with proper maintenance. |
| 5. Confidence | Good to excellent. |
| 6. Adaptability | Fair, limited to long slopes and slopes up to 12 percent. |
| 7. Potential Treatment Side Effects | If improperly designed or used with poor cultural and management practices, they may increase soil erosion. |
| 8. Concurrent Land Management Practices | Fertilizer and pesticide management. |

**Animal Waste Management:** A practice where animal wastes are temporarily held in waste storage structures until they can be utilized or safely disposed. Storage units can be constructed or reinforced concrete or coated steel. Wastes are also stored in earthen ponds.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Not applicable. |
| b) Nitrogen (N) | Good to excellent. |
| c) Phosphorus (P) | Good to excellent. |
| d) Runoff | Not applicable. |
| 2. Capital Costs | High because of the necessity of construction and disposal equipment. |
| 3. Operation and Maintenance | Unknown. |
| 4. Longevity | Unknown. |
| 5. Confidence | Fair to excellent if properly managed. |
| 6. Adaptability | Good. |
| 7. Potential Treatment Side Effects | The use of earthen ponds can possibly lead to groundwater contamination. |
| 8. Concurrent Land Management Practices | Fertilizer management. |

# APPENDIX VI
## Review of Best Management Practices (BMP's)
## (continued)

**Nonvegetative Soil Stabilization:** Examples of temporary soil stabilizers include mulches, nettings, chemical binders, crushed stone, and blankets or mats from textile material. Permanent soil stabilizers include coarse rock, concrete, and asphalt. The purpose of soil stabilizers is to reduce erosion from construction sites.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Excellent. |
| b) Nitrogen (N) | Poor. |
| c) Phosphorus (P) | Poor. |
| d) Runoff | Poor on steep slopes with straw mulch, otherwise good. |
| 2. Capital Costs | Low to high, depending on technique applied. |
| 3. Operation and Maintenance | Moderate. |
| 4. Longevity | Generally a temporary solution until a more permanent cover is developed. Excellent for permanent soil stabilizer. |
| 5. Confidence | Good. |
| 6. Adaptability | Excellent. |
| 7. Potential Treatment Side Effects | No effect on soluble pollutants. |
| 8. Concurrent Land Management Practices | Runoff detention/retention. |

**Porous Pavement:** Porous pavement is asphalt without fine filling particles on a gravel.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Good. |
| b) Nitrogen (N) | Good. |
| c) Phosphorus (P) | Good. |
| d) Runoff | Good to excellent. |
| 2. Capital Costs | Moderate, slightly more expensive than conventional surfaces. |
| 3. Operation and Maintenance | Potentially expensive, requires regular street maintenance program and can be destroyed in freezing climates. |
| 4. Longevity | Good, with regular maintenance (i.e., street cleaning), in southern climates. In cold climates, freezing and expansion can destroy. |
| 5. Confidence | Unknown. |
| 6. Adaptability | Excellent. |
| 7. Potential Treatment Side Effects | Groundwater contamination from infiltration of soluble pollutants. |
| 8. Concurrent Land Management Practices | Runoff detention/retention. |

# APPENDIX VI
## Review of Best Management Practices (BMP's) (continued)

**Flood Storage (Runoff Detention/Retention):** Detention facilities treat or filter out pollutants or hold water until treated. Retention facilities provide no treatment. Examples of detention/retention facilities include ponds, surface basins, underground tunnels, excess sewer storage and underwater flexible or collapsible holding tanks.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Poor to excellent, design dependent. |
| b) Nitrogen (N) | Very poor to excellent, design dependent. |
| c) Phosphorus (P) | Very poor to excellent, design dependent. |
| d) Runoff | Poor to excellent, design dependent. |
| 2. Capital Costs | Dependent on type and size. Range from $100 to $1,000, per acre served, depending on site. These costs include capital costs and operational costs. |
| 3. Operation and Maintenance | Annual cost per acre of urban area served has ranged from $10 to $125 depending on site. |
| 4. Longevity | Good to excellent, should last several years. |
| 5. Confidence | Good, if properly designed. |
| 6. Adaptability | Excellent. |
| 7. Potential Treatment Side Effects | Groundwater contamination with retention basins. |
| 8. Concurrent Land Management Practices | Porous pavements. |

**Sediment Traps:** Sediment traps are temporary structures made of sandbags, straw bales, or stone. Their purpose is to detain runoff for short periods of time so heavy sediment particles will drop out. Typically, they are applied within and at the periphery of disturbed areas.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Good, coarse particles. |
| b) Nitrogen (N) | Poor. |
| c) Phosphorus (P) | Poor. |
| d) Runoff | Fair. |
| 2. Capital Costs | Low. |
| 3. Operation and Maintenance | Low, require occasional inspection and prompt maintenance. |
| 4. Longevity | Poor to good. |
| 5. Confidence | Poor. |
| 6. Adaptability | Excellent. |
| 7. Potential Treatment Side Effects | None identified. |
| 8. Concurrent Land Management Practices | Agricultural, silviculture or other construction best management practices could be incorporated depending on situation. |

# APPENDIX VI
## Review of Best Management Practices (BMP's) (continued)

**Surface Roughening:** On construction sites, the surface of the exposed soil can be roughened with conventional construction equipment to decrease water runoff and slow the downhill movement of water. Grooves are cut along the contour of a slope to spread runoff horizontally and increase the water infiltration rate.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Good. |
| b) Nitrogen (N) | Unknown. |
| c) Phosphorus (P) | Unknown. |
| d) Runoff | Good. |
| 2. Capital Costs | Low, but requires timing and coordination. |
| 3. Operation and Maintenance | Low, temporary protective measure. |
| 4. Longevity | Short-term. |
| 5. Confidence | Unknown. |
| 6. Adaptability | Excellent. |
| 7. Potential Treatment Side Effects | None identified. |
| 8. Concurrent Land Management Practices | Nonvegetative soil stabilization. |

**Riprap:** A layer or loose rock or aggregate placed over a soil surface susceptible to erosion.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Good, based on visual observations. |
| b) Nitrogen (N) | Unknown. |
| c) Phosphorus (P) | Unknown. |
| d) Runoff | Poor. |
| 2. Capital Costs | Low to high, varies greatly. |
| 3. Operation and Maintenance | Low. |
| 4. Longevity | Good, with proper rock size. |
| 5. Confidence | Poor to good. |
| 6. Adaptability | Excellent. |
| 7. Potential Treatment Side Effects | In streams, erosion may start in a new, unprotected place. |
| 8. Concurrent Land Management Practices | Streamside (lake) management zone. |

# APPENDIX VI
## Review of Best Management Practices (BMP's)
## (continued)

**Interception or Diversion Practices:** Designed to protect bottom land from hillside runoff, divert water from areal sources of pollution such as barnyards or to protect structures from runoff. Diversion structures are represented by any modification of the surface that intercepts or diverts runoff so that the distance of flow to a channel system is increased.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Fair to good (30 to 60 percent reduction). |
| b) Nitrogen (N) | Fair to good (30 to 60 percent reduction). |
| c) Phosphorus (P) | Fair to good (30 to 60 percent reduction). |
| d) Runoff | Poor, not designed to reduce runoff but divert runoff. |
| 2. Capital Costs | Moderate to high, may entail engineering design and structures. |
| 3. Operation and Maintenance | Fair to good. |
| 4. Longevity | Good. |
| 5. Confidence | Poor to good, largely unknown. |
| 6. Adaptability | Excellent. |
| 7. Potential Treatment Side Effects | None identified. |
| 8. Concurrent Land Management Practices | Since the technique can be applied under multiple situations (i.e., agriculture, silviculture, construction) appropriate best management practices associated with individual situations should also be applied. |

**Grassed Waterways:** A practice where broad and shallow drainage channels (natural or constructed) are planted with erosion-resistant grasses.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Good to excellent (60 to 80 percent reduction). |
| b) Nitrogen (N) | Unknown. |
| c) Phosphorus (P) | Unknown. |
| d) Runoff | Moderate to good. |
| 2. Capital Costs | Moderate. |
| 3. Operation and Maintenance | Low, but may interfere with the use of large equipment. |
| 4. Longevity | Excellent. |
| 5. Confidence | Good. |
| 6. Adaptability | Excellent. |
| 7. Potential Treatment Side Effects | None identified. |
| 8. Concurrent Land Management Practices | Conservative tillage, integrated pest management, fertilizer management, animal waste management. |

# APPENDIX VI
## Review of Best Management Practices (BMP's)
## (continued)

**Maintain Natural Waterways:** This practice disposes of tree tops and slash in areas away from waterways. Prevents the buildup of damming debris. Stream crossings are constructed to minimize impacts on flow characteristics.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Fair to good, prevents acceleration of bank and channel erosion. |
| b) Nitrogen (N) | Unknown, contribution would be from decaying debris. |
| c) Phosphorus (P) | Unknown, contribution would be from decaying debris. |
| d) Runoff | Fair to good, prevents deflections or constrictions of stream water flow which may accelerate bank and channel erosion. |
| 2. Capital Costs | Low, supervision required to ensure proper disposal of debris. |
| 3. Operation and Maintenance | Low, if proper supervision during logging is maintained, otherwise $160-$800 per 100 ft stream. |
| 4. Longevity | Good. |
| 5. Confidence | Good. |
| 6. Adaptability | Excellent. |
| 7. Potential Treatment Side Effects | None identified. |
| 8. Concurrent Land Management Practices | Proper design and location of haul and skid trails; Streamside management zones. |

**Haul Roads and Skid Trails:** This practice is implemented prior to logging operations. It involves the appropriate site selection and design of haul road and skid trails. Haul roads and skid trails should be located away from streams and lakes. Recommended guidelines for gradient, drainage, soil stabilization, and filter strips should be followed. Routes should be situated across slopes rather than up or down slopes. If the natural drainage is disrupted, then artificial drainage should be provided. Logging operations should be restricted during adverse weather periods. Other goods practices include ground covers (rock or grass) closing roads when not in use, closing roadways during wet periods, and returning main haul roads to prelogging conditions when logging ceases.

| CRITERIA | REMARKS |
|---|---|
| 1. Effectiveness | |
| a) Sediment | Good if grass cover is used on haul roads (45 percent reduction); Excellent if crushed rock is used as ground cover (92 percent reduction). |
| b) Nitrogen (N) | Unknown. |
| c) Phosphorus (P) | Unknown. |
| d) Runoff | Unknown. |
| 2. Capital Costs | High, grass cover plus fertilizer $5.37/100 ft roadbed, crushed rock (6 in) $179.01/100ft roadbed. |
| 3. Operation and Maintenance | High, particularly with grass which may have to be replenished routinely and may not be effective on highly traveled roads. |
| 4. Longevity | Unknown. |
| 5. Confidence | Good for ground cover, poor for nutrients. |
| 6. Adaptability | Good. |
| 7. Potential Treatment Side Effects | Potential increase in nutrients to water course if excess fertilizers are applied. |
| 8. Concurrent Land Management Practices | Maintain natural waterways. |