Corbett Lake Management Plan

Ladysmith, Wisconsin

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Prepared for City of Ladysmith

1.0 Introduction

Corbett Lake is a 33-acre basin located on the southwest side of the City of Ladysmith (see Figures 1 and 2). Contributing watershed areas to the lake have been significantly reduced by human activity. Formerly several square miles of rural land drained to Corbett Lake. However, due to human intervention early this century much of the watershed draining to Corbett Lake was diverted away from the City of Ladysmith. Today the 0.3 square mile (192-acres) Corbett Lake watershed lies entirely within the City limits and includes portions of the downtown area (primarily commercial and light industrial land uses) and residential areas adjacent to the lake. The lake drains via a bee hive inlet and buried pipe to the Flambeau River.

Since Corbett Lake lies within the City of Ladysmith it is very accessible by City residents including both adult and children walkers and bikers. A City park (Falge Park) extends across much of the north shore of the lake. The park includes a short trail, playground equipment, picnic areas and boat launch. At various times in the last 15 years, crappie, bluegill, largemouth bass, walleye, rainbow trout, and fathead minnows have been stocked in the lake. At the present time, residents enjoy fishing along the shores of the lake for pan fish and bass although the fish have become stunted in recent years. A new City of Ladysmith/Rusk County library is located adjacent to Falge Park on a hillside overlooking a bay of Corbett Lake. The library is expected to increase the recreational use of Corbett Lake as library patrons will sometimes use the adjacent park.

Corbett Lake has a maximum depth of 12 feet and an average depth of 4 feet (see Figure 3). The lake's northern portion the lake adjacent to the library is the relatively deep area while the remainder is generally 6 feet deep or less. In August open water is found almost exclusively in the lake's northern bay adjacent to the library. Elsewhere macrophytes dominate the lake with just an occasional small patch of open water being present. The Upper Chippewa River Basin Water Quality Management Plan (Wisconsin Department of Natural Resources, 1996) indicates that Corbett Lake has limited fishery potential. However, based on the ability of City residents to catch pan fish and bass in the past, the City of Ladysmith believes the lake to have significant potential for producing fish which residents will enjoy catching (A. Christianson, personal communication).

Corbett Lake has a summer, fall, and winter dissolved oxygen problem primarily due to its generally shallow morphometry. In response to this problem, the City of Ladysmith operates a cascade aeration system located at the northeast side of the island in Falge Park.

1.1 History of the Corbett Lake Watershed

A forest and wetland dominated rural watershed formerly drained into Corbett Lake. The natural watershed of Corbett Lake extended upstream northwesterly to Tulca Lake, known locally as Dump lake. About 1916, the majority of the Corbett Lake surface water drainage was diverted away from the approximately 66-acre lake as it existed at that time (Terrill, undated). A ditch was constructed to drain water in wetlands west and north of Ladysmith. The ditch began at Bruno Lake and flowed into Dump Lake. The drainage ditch then ran southeast from Dump Lake towards Ladysmith. Near the western limit of the City, the ditch was turned south with runoff waters entering the Flambeau River near the present Mt. Scenario College. The remaining portion of the natural inlet channel to Corbett Lake between the ditch and the lake was diverted west into the drainage ditch. Shortly thereafter, the outlet to Corbett Lake was also modified and normal water levels in the lake were further reduced. Since that time the extent of the Corbett Lake watershed has remained approximately the same; however, the City of Ladysmith has grown considerably such that all runoff entering the lake is now of urban origin.

1.2 Project Overview

Issues and problems which have been addressed during development of the Corbett Lake Management Plan include the following:

- Improve lake water quality;
- Manage pollutants in urban runoff entering the lake;
- Reestablish the lake's natural watershed;
- Control macrophytes;

- Protect and improve fisheries habitat;
- Increase recreational opportunities; and
- Protect and improve wildlife habitat.

The overall goal of the project is to improve Corbett Lake's water quality. Phases 1 and 2 of the project involved a basic data collection program to build the water quality and physical characteristic database needed to support water quality management decisions for Corbett Lake. The results of Phase 1 and 2 were presented in a previous report (SEH, 1999).

The quality of Corbett Lake has been degraded by the loss of a major portion of the contributing watershed area. The effectiveness and feasibility of reestablishing some of the Corbett Lake watershed as a means of improving water quality was investigated as part of Phase 1, including collecting water level data needed to analyze the feasibility of reestablishing some watershed areas.

Macrophytes are present in many areas of the lake and one goal of the City is to control macrophyte growth, particularly in areas adjacent to the eastern deeper area of Corbett Lake. This may involve dredging some areas on the eastern side to deepen the lake further or a program of harvesting the macrophytes. An analysis of the benefits and feasibility of dredging and macrophyte harvesting are part of the project.

The City of Ladysmith believes a descent fishery can be reestablished in the lake. Over the last several years, pan fish have become stunted which may relate to water quality degradation. The City desires to take steps to reverse this trend.

Improving recreational opportunities at Corbett Lake is another important goal. With improved water quality and fishery, the City would reestablish a fishing pier at Falge Park. Another potential recreation improvement would be to construct a boardwalk over wetland areas found at the west end of the park.

Another project opportunity would be to enhance wildlife habitat. For instance, it may be possible to use sediments removed during dredging to build small islands at the western end of the lake.

1.3 History of the Project

Phase 1 work at Corbett Lake was supported by Lake Management Planning Grants number LPL-460 and LPL-491. The first phase focused on collecting basic data for Corbett Lake which addressed the first three project overview issues. The two main data collection tasks supported by the Lake Management Planning grant LPL-460 were as follows:

1. Obtain basic water quality data from two locations within the lake. Lake samples were collected once per month for the months of May, June, July, August, and September 1997. Qualitative observations on macrophyte, algae, and zooplankton populations were noted when the samples were collected.
2. Corbett Lake subwatershed boundaries were delineated in the field along with inflow points, drainage areas, and land use.

The second grant, LPL-491, allowed a topographic profile to be obtained between Corbett Lake and the drainage diversion ditch west of Ladysmith which conveys runoff from formerly draining to the lake. A series of staff gages were set between the lake and the diversion ditch. Water surface elevation readings were collected at least twice a month. The profile and water surface elevation data collected by this effort provided an interpretation of the feasibility of reestablishing some the lake's natural watershed.

Phase 2 of the project has also been completed through support from Lake Management Planning Grant LPL-512. Work tasks in Phase 2 included development of a preliminary annual water budget, creation of a bathymetric map and sounding of soft sediment depth.

Phase 3 of the project involves the following activities:

1. Conducting a feasibility analysis and obtaining cost data for candidate lake management activities.
2. Develop a lake management plan for Corbett Lake.

The Lake Management Planning Grant LPL-584 is supporting Phase 3 of the project. This report contains the results of Phases 1, 2, and 3 of the project including the Corbett Lake Management Plan.

2.0 Data Collection Results

A variety of environmental data was collected during the first two phases of the Corbett Lake project including water quality, water level, bathymetery and soft sediment thickness. The results of these data collection efforts are presented in this section of the report.

2.1 Lake Bathymetery and Soft Sediment Thickness

The bathymetric map (Figure 3) was prepared following a January 1998 lake survey. Overall, the lake is relatively shallow with the primary exception being the recently dredged bay adjacent to the Rusk County Library. The remainder of the lake is generally 6 feet or less in depth.

Soft sediments were also probed over the eastern half of the lake. The thickness of the soft sediments ranged from 1 or 2 feet near shore to 15 feet in the center of the lake. Over 100,000 cubic yards of soft sediment was found in the eastern half of the lake. Visual inspection of upper layers of the sediment indicate a primary source of the material is the macrophytes present in the lake.

2.2 Macrophytes

Qualitative observations were also made of macrophytes (rooted aquatic plants) and algae (microscopic plants) present in the lake. Appendix A contains the listing of macrophytes observed growing in Corbett Lake. A moderately diverse macrophyte community was found. In general, macrophytes dominate most of the relatively shallow lake. Qualitatively, algae were not observed to be a problem though algae could be observed growing within the macrophyte beds.

2.3 Lake Water Quality

Lake water quality samples were collected at the two stations shown on Figure 2 on a monthly basis for the period from May 1997 to September 1997. Sample station 1 (CL-01) was at the deepest point of the lake and both surface and bottom samples were obtained. Only a surface sample was collected at station 2 (CL-02). Table B-1 in Appendix B presents the raw water quality data obtained. The laboratory report sheets for the data are found in Appendix C.

Table 1 below summarizes the water chemistry data. Total phosphorus (TPHOS) and chlorophyll a (CHLA) concentrations are chemical measurements of biomass productivity and lake water quality state (trophic status). It is important to note the water column data for TPHOS and CHLA do not measure the amount of these materials found within the macrophytes.

Table 1
Corbett Lake Water Quality Data
Sample Site Summary

Parameter	Unit	CL-01 (Surface)		CL-01 (Bottom)		CL-02 Surface	
		Mean	Range	Mean	Range	Mean	Range
Chlorophyll a	ug/l[1]	11.16	5.4-20.3	NA[2]	--	6.74	3.85-10.6
Ammonia-Nitrogen	mg/l[3]	.005	nd(3)[4]-.015	.067	nd-.248	.007	nd(3)-.019
Nitrate-Nitrogen[5]	mg/l	.002	nd(4)-.01	.020	.01-.033	.002	nd(4)-.01
Total Kjeldahl Nitrogen	mg/l	.658	.6-.71	2.48	0.9-6.68	.73	.65-.8
Total Phosphorus	mg/l	.029	.012-.041	.102	.047-.161	.024	.02-.033
Dissolved Reactive Phosphorus	mg/l	.001	nd(3)-.004	.002	nd(3)-.007	.001	nd(3)-.002
Chloride	mg/l	86	80.7-90	104	81.5-140	86	83.2-89.1
pH	SU[6]	7.2	6.04-8	6.4	5.8-6.7	7.2	6.0-7.6
Specific Conductance	µs/cm[7]	302	268-329	378	346-455	296	267-327
Dissolved Oxygen	mg/l	7.6	4.94-9.4	0.20	.11-.62	3.6	0.6-10.1
Redox Potential	MV[8]	292	278-303	134	94-222	345	301-386
Seechi Depth	ft	6.0	4.5-8.4	NA	--	4.2	3.6-4.6

1) Micrograms per liter
2) Not applicable
3) Milligrams per liter
4) Not detected, number of times not detected in parenthesis if more than once
5) Nitrate plus nitrite nitrogen
6) Standard units
7) Microsiemens per centimeter
8) Millivolts

Lakes are often classified qualitatively by trophic status, which is a measure of water quality and productivity. Pristine clear lakes with low productivity are called oligotrophic. Lakes with high productivity and/or degraded water quality are called eutrophic lakes. Lakes with an intermediate quality or level of productivity are called mesotrophic.

Seechi depth is a measurement of the transparency which is often used in combination with total phosphorus and chl a concentrations to determine lake trophic status. In Corbett Lake, seechi depth at Station CL-02 was measured outside of the macrophyte beds. Here 4 out of 5 measurements represent the seechi disk lying on the bottom. In the densest parts of the macrophyte beds the seechi depth measurement would be much lower. Seechi depth measured at Station Cl-01 represents the lake transparency that could be expected in the absence of the macrophytes (4.5 to 8.4 feet). The mean seechi disk transparency of 6 feet at Station Cl-01 was slightly below the average for 282 lakes sampled in northwestern Wisconsin by the Wisconsin Department of Natural Resources (Lillie and Mason, 1983).

With regard to limiting nutrient levels, TPHOS concentrations are seen to be relatively low though the amount found within the macrophytes is unknown and may in fact be high. CHLA concentrations indicate moderate biomass productivity in the water column. The TPHOS and CHLA concentrations in Corbett Lake are typical of the means (0.026

mg/l and 12.4 µg/l, respectively) for the lakes monitored by Lillie and Mason (1983). From a more descriptive perspective, Corbett Lake's quality would be considered fair to good.

TPHOS, CHLA, and seechi depth measurements taken together indicate Corbett Lake may be classified as mildly eutrophic, since it lies just within the range for eutrophic lakes as defined by Carlson Trophic State Index (Carlson, 1977). As strictly defined, the Carlson Trophic State Index does not apply to macrophyte dominated lakes. However, the eutrophic classification fits with the nature of the lake, which is shallow over much of the basin and dominated by macrophytes.

Nutrient enrichment does not necessarily cause nuisance macrophyte or "weed" growth. High macrophyte biomass is typical, however, for lake basins like Corbett Lake where the lake is generally shallower than the seechi depth, where calm relatively clear water predominate with nutrient rich moderately organic soils. High nutrient concentrations in the water column usually trigger algae blooms, a phenomenon not observed at Corbett Lake. Algae are a minor component of the productivity of Corbett Lake.

The presence of the macrophytes leads to the most important water quality constraint associated with Corbett Lake: low dissolved oxygen levels. Dissolved oxygen depletion was found in all months samples were taken (May to September 1997). In May, only the deeper water of the bay (Station CL-01) near the library was experiencing dissolved oxygen depletion (Figure 4). By June, however, the dissolved oxygen level measured at Sample Point CL-02 indicates that dissolved oxygen was becoming depleted throughout most of the lake (Figure 4 and Table A-1). On average, the dissolved oxygen concentration at Station CL-02 was 3.6 mg/l, which indicates a substantial oxygen deficit occurs much of the time throughout the lake since, for the average water temperature of this station, the water potentially could hold 9 mg/l of dissolved oxygen.

The dissolved oxygen profiles depicted on Figure 4 indicate the cascading aerating is providing some relief from the oxygen depletion which occurs in Corbett Lake. The aerator's effect is on the upper meter of the lake water with little aeration of deeper water occurring.

Nitrogen, another important nutrient, was found to be primarily in the organic form (total kjeldahl nitrogen), which is consistent with the macrophyte dominated nature of the lake. Nitrogen was not found at concentrations which would be considered excessive.

An elevated chloride level (140 mg/l) was found in the bottom sample at Sample Point CL-01 for the May 1997 sample. Finding an elevated chloride concentration at depth is an indication that urban runoff is influencing the quality of the lake water. Furthermore, the average chloride level of 86 mg/l observed in Corbett Lake is extremely high. Of the 282 lakes monitored by Lillie and Mason (1973), the average chloride concentration was 2 mg/l. From a statewide perspective this same study of 660 lakes indicated an average concentration of 4 mg/l with a 57 mg/l as an observed maximum. Also of note, turbid water from storm water discharges was observed entering Corbett Lake in March 1998.

2.4 Water Level Measurements

Water levels were measured at three locations to make an initial determination of the feasibility of diverting water back into Corbett Lake from the drainage ditch on the west side of Ladysmith. Measurements were made at Corbett Lake, in the wetland on the west side of Highway 27 that lies between Corbett Lake and the drainage ditch, and at the point where the drainage ditch turns south towards Mt. Scenario College (Figure 1). The water level data is found in Appendix D.

Figure 5 depicts the water levels at these locations for the May to November 1997 period. The most important result of the water level measurements is the water level in the ditch is always significantly lower than the Corbett Lake water level. On average, the water level in the ditch was 1118.3 feet in elevation or 1.9 feet below the Corbett Lake water level, which averaged 1120.2 feet in elevation. For the most part, the water level at the intermediate wetland was higher than that of Corbett Lake. This indicates that intermediate wetland lies on the drainage divide between the ditch and Corbett Lake and it would take a pump station to divert water from the ditch into Corbett Lake.

There is a wood duck nesting box mounted on a steel pole at the point where the drainage ditch turns south towards Mt. Scenario College. An obvious high water mark could be seen on the steel pole, and an elevation of 1121 feet was measured for the high water mark. One explanation for the high watermark is as follows: during spring break up the ditch, as it turns south towards Mt. Scenario College, may be partially plugged with ice and allowing water to pond near this point. During these limited times water potentially could flow east from the drainage ditch into Corbett Lake.

A 30-inch diameter culvert crossing exists under Highway 27 where the old inflow channel to Corbett Lake previously existed. The west invert of this culvert is the highest, having an invert elevation of 1119.66-feet. Since visually, other than State Highway 27, there are no other barriers to water flow east towards Corbett Lake from the drainage ditch, it is quite possible that a limited amount of water occasionally flows into Corbett Lake from the drainage ditch during flood periods. The amount of water that may enter Corbett Lake from the drainage ditch is not likely to be significant to the long term quality of the lake.

2.5 Water Budget

A monthly water budget has been prepared for Corbett Lake and is presented in Table 2. The hydrology of the lake is limited by the 0.3 square mile watershed. For instance, evaporation exceeds surface inflows throughout the summer. Significant inflows to the lake occur only during the spring snow melt period and fall. The net runoff to the lake is estimated to be only 6 inches over the watershed, which is only 18 percent of the total estimated rainfall for the watershed. The water level data indicate groundwater inflows or outflows are not significant to the water budget of Corbett Lake. For instance, during dry periods the water level of the lake drops to the invert elevation of the outlet, but does not drop below this elevation as would occur if groundwater outflow rates were significant.

Table 2
Corbett Lake Water Budget

Month	Average Precipitation[1] (in)	Surface Water Runoff[2] (in)	Groundwater Inflow (in)	Average Lake Evaporation[3] (in)	Net Inflow (in)	Groundwater Outflow (in)	Surface Water Outflow (in)
January	1.00	0.79	0	0	0.79	0	0
February	0.78	0.58	0	0	0.58	0	0
March	1.71	0.69	0	0	0.69	0	3.06
April	2.71	1.49	0	4.18	0	0	0
May	3.65	2.32	0	4.52	0	0	0
June	4.46	3.06	0	4.89	0	0	0
July	3.72	2.38	0	4.31	0	0	0
August	4.48	3.08	0	3.05	0	0	0
September	4.44	3.04	0	2.21	0.83	0	0.83
October	2.52	1.33	0	0	1.33	0	1.33
November	1.80	0.75	0	0	0.75	0	0.75
December	1.22	1.01	0	0	1.01	0	0
Annual Total	32.49	20.52	0.00	23.16	5.98	0.00	5.97

1) From NOAA Climatological Data Report for 1996, Holcombe Wisconsin gage.
2) Calculated using SCS runoff volume computation methods.
3) From NOAA Technical Report NWS 34, December 1982.

2.6 Fish Stocking

Fish have been stocked in Corbett Lake a number of times starting in 1947 through this year as shown by the Wisconsin Department of Natural Resources (WDNR) stocking record in Appendix E. Bluegill, crappie, largemouth bass, walleye, rainbow trout and fathead minnows have been stocked in the lake.

3.0 Discussion

The following discussion addressed potential measures for improving the quality of Corbett Lake.

3.1 Improving Water Quality

3.1.1 Increasing the Watershed Size

Reestablishing the natural watershed by diverting water from the unnamed drainage ditch west of Ladysmith back into Corbett Lake is not practical because the lake water surface is 1.5 to 2 feet higher than typical water levels in the unnamed ditch. A pump station could be installed to pump the water from the unnamed drainage ditch under State Highway 27 to Corbett Lake. However, given that macrophytes and low dissolved oxygen are the main water quality problems, there are better approaches to improving lake water quality.

3.1.2 Aeration

Adding more aerators to the lake should be considered as a high priority for water quality improvement. The cascading aerator in place is providing some relief to the upper part of the lake near the aerator, but much of the lake continues to suffer from low dissolved oxygen concentrations. Fisheries habitat in Corbett Lake is very limited by the low dissolved oxygen. Additional aeration will increase the area of the lake habitable by fish and may reduce the potential for algae to become a nuisance.

Aerating oxygen poor bottom waters would be the best approach to improving these concentrations in the lake. This approach creates an artificial circulation in the lake by bringing bottom waters to the surface allowing oxygen introduced from the atmosphere to be distributed throughout the water column. This technique will result in uniform temperatures from top to bottom, which can be expected to occur naturally much of the time given the shallow nature of Corbett Lake. A uniform vertical temperature distribution in the lake would not affect the ability of the lake to produce pan fish or largemouth bass. A secondary benefit of using bottom aerators is an enhancement of the decomposition of organic sediments, which would likely lead to a gradual deepening of the lake near a diffuser.

Figure 6 shows proposed diffuser location for a 11 diffuser bottom aeration system. The diffusers are all in the eastern half of the lake basin where the water is generally deeper. The existing cascade aerator would be removed once the bottom aerators are installed.

There are a wide variety of bottom aerators available. A standard test, named the standard aeration efficiency (SAE) test, has been developed for measuring the efficiency of an aerator. SAE numbers are a fair comparison when comparing similar equipment. The test is a measure of the amount of oxygen transferred into the water per the amount of energy used. The correct aeration system for a particular application is chosen according to type, SAE, capital cost and anticipated maintenance cost. The estimated range of capital and installation cost for the proposed bottom aeration system for Corbett Lake is $10,000 to $12,000.

There will be maintenance issues and costs associated with the bottom aerator system. The proposed system requires two 1-horsepower compressors which will need 115 volt power. Presently, the 1.5-horsepower pump for the cascade aerator has an annual power cost of approximately $1,000 per year. Since the cascade aerator will be removed this cost can be transferred to the bottom aerator system.

The compressors will also need periodic replacement of the vanes, air filters, and bearings. Typically, the vanes would be replaced once per year at $90 per compressor, the air filter would be replaced once every six months at $13 per compressor, and the bearings would be replaced every three to five years at approximately $25 per compressor.

Occasionally the diffuser would need to be cleaned. Generally they are checked every five years and cleaned with a weak acid solution as needed. A pressure gage at the compressor helps to indicate the need for maintenance if the indicated air pressure gradually rises over time which signals blockage in an air line or at a diffuser.

3.1.3 Nutrients and Solids

Nitrogen and phosphorus, key nutrients to lake productivity and nuisance algae, are not found in the lake at excessive concentrations. The focus of water quality improvements other than improving dissolved oxygen levels should be on reducing solids being discharged to the lake from urban areas.

There are several opportunities for construction of simple biofiltration treatment systems to remove suspended solids from storm water prior to the discharge into Corbett Lake. The best opportunity is on the east side of the lake where a storm sewer enters the lake from the area of Corbett's Third Addition near the corner of Second Street South and First Street South. It may be possible to enhance the ditch between the storm sewer and the lake at this location to provide a biofiltration system for storm water treatment.

On the north side of Corbett Lake where a storm sewer discharges from Fourth Street South towards the lake is another point where biofiltration of storm water may be feasible. The primary constraint of this location is the relatively steep lake side slope which would need to be accommodated by the system.

Snow removal stockpile areas should be reviewed to make sure these stockpiles do not drain to Corbett Lake. Deicers and associated pollutants in snow removed from roads can be a source of water quality problems. The elevated chloride levels in Corbett Lake reflect this problem. To protect Corbett Lake it would be best to stockpile snow at locations that do not drain to the lake. For instance, use of the snow removal stockpile area on the east side of Corbett Lake should be discontinued.

3.2 Lake Restoration

Corbett Lake has an over abundance of marcrophystes (aquatic plants). Macrophytes can improve a lake's environment in the following ways:

1. Enhancing the aesthetic appearance.
2. Provide food for waterfowl, furbearers, and other wildlife.
3. Used as cover for fish.
4. Substrate for periphyton (attached algae) and macroinvertebrates.
5. Take up some excess phosphorus and nitrogen from the lake's nutrient budget.

The goal of lake restoration methods discussed here is to control macrophytes to a more optimum level to enhance these benefits.

3.2.2 Dredging

Macrophytes dominate much of the Corbett Lake Basin because of the shallow nature of the lake. Because of the dense macrophyte growth and shallow lake depths, dredging has been investigated as a means of improving water quality. reducing sediment accumulation, providing macrophyte control and improving fishery habitat. Deepening a portion of the east basin to a depth of 12 to 14 feet would provide another macrophyte free area in the lake. The proposed dredging could be accomplished with an irregular shape to create more drop offs and edge area that would be used by fish. The best result would be obtained by placing a bottom aerator in the newly dredged area.

Two dredging construction methods have been investigated including mechanical and hydraulic dredging. Mechanical dredging would involve an excavator mounted on a barge, with the excavator being used to reach to the lake bottom, scooping sediments up and then depositing the sediments on another barge. Mechanically dredged sediments would be brought ashore by either pumping them from the sediment barge to a tank truck or pulling a full barge up to shore and off loading it into dump trucks. Ultimately the sediments, whether in slurry or solid form, would need to be taken to a land spreading, composting or landfill location.

Hydraulic dredging of sediments involves using a large suction pump mounted on a barge to remove sediments and pump them to a settling basin disposal site. A field review of potential settling basin sites for hydraulic dredging of Corbett Lake was completed and the nearest location was identified on the south side of the Flambeau River in the City of Ladysmith industrial park.

For mechanical and hydraulic dredging methods, a cost estimate was prepared for small and moderate size projects. For this analysis, a small project was taken to be dredging 8,000 cubic yards of sediments and increasing the depth 5 feet over an area one acre in size. Similarly a moderately size project was defined as dredging 25,000 cubic yards over a three acre area.

Both methods of dredging would cost $10 per cubic yard or more, plus engineering and permit costs. It was estimated the small project would cost a minimum of $100,000 and the moderate project a minimum of $300,000. Dredging is thus seen to be an expensive lake management option. Furthermore, there is no State grant program which would support dredging at Corbett Lake. However, dredging would provide a significant improvement to the lake by reducing the area of macrophyte growth and increasing the area of deeper water habitat.

3.2.3 Macrophyte Harvesting

Another option for controlling macrophytes is mechanical harvesting. Corbett Lake has an overabundance of aquatic macrophytes (submerged and emergent vegetation) which is causing stunting in the bluegill population. The small bluegills in Corbett Lake are not of preferred harvestable size and they will not grow larger unless their population densities are reduced.

Fisheries research has shown that predators, like northern pike and largemouth bass, are not as effective in feeding with increased densities of aquatic vegetation. Feeding rates of predators are optimized in cover that holds high densities of prey while still providing adequate space for predator fish to maneuver and capture prey.

Predation and cover density affects growth and feeding of bluegill. Small bluegill under four inches in total length tend to restrict their activities to areas having dense macrophyte growth, while larger bluegill which are less susceptible to fish predation tend to occupy areas away from dense macrophyte cover where food is easier to obtain.

Other studies have shown that macrophyte cover restricts the ability of bluegill to use invertebrate food sources, and that growth rates of bluegill are best at intermediate levels of macrophyte density. Bluegills typically eat invertebrates such as aquatic insects, worms, snails, copepods, amphipods, and small crayfish. When older, bluegills will also eat small minnows and some plant material.

One effective way to reduce the high stunted bluegill population in Corbett Lake is to increase predation by largemouth bass and northern pike through harvesting and removal of aquatic macrophyte cover over a major portion of the lake basin. Such control of stunted bluegill populations can be accomplished in lakes with dense macrophyte cover through mechanical harvesting of the aquatic vegetation. Mechanical harvesting is similar in cost to herbicide treatment for large areas.

Mechanical harvesting can also be used to selectively harvest areas within macrophyte beds to create areas for boating and fishing, and to enhance habitat for predator fish. Improvements of fish condition and growth have been observed in bluegill and largemouth bass following mechanical harvesting of vegetation in lakes.

We propose mechanical harvesting of all aquatic macrophytes in the northeast and extreme western portions of the basin in water from 1 to 8 feet in depth over an area of about 15 acres. The harvesting would affect approximately 40 percent of the surface of Corbett Lake. Figure 7 depicts where aquatic macrophytes would be harvested. The mechanical harvesting would be done in a waterscaping pattern where bays or areas near shore remain vegetated. This would allow the macrophyte cover to continue at levels which improve ecological relationships between invertebrates and predator panfish or pan fish and predator fish.

Harvesting in the first year would be performed by a contractor in mid-July to remove as much biomass of the dominant floating macrophyte population of Corbett Lake. Those species include:

Common Name	Scientific Name
White Water Lily	Nymphaea tuberosa
Yellow Water Lily	Nuphar variegatum
Water Shield	Brasenia schreberi

According to one contractor, the above floating attached species are best harvested in mid-July in the Ladysmith area because of their growth habits. The plants should be harvested when fully mature in order to most effectively decimate these plants.

The cost of mechanical harvesting by a contractor would be approximately $250 per acre. The total cost for harvesting the 15 acres would be approximately $3,750. The waste vegetation would be removed from the lake and dumped at the boat landing for disposal to a local compost area or landfill by the City's waste hauler. The cut vegetation must be removed from the water because otherwise the organic decomposition of the weeds will cause a depression in dissolved oxygen levels which could cause a fish kill.

After the first year, we recommend that the City purchase an electric weed cutter for approximately $1,500. City staff would then cut and remove the weeds in the 15-acre area for the next two years just before Memorial Day weekend, and just before Independence Day weekend in order to fully decimate the macrophyte population. We anticipate that two City staff perform each aquatic plant harvesting over two 8-hour working days. Information on the electric weed cutters is found in Appendix F.

An alternative approach that may be easier for the City is to contract the weed cutting work for up to the first 3 years. A 3-year contract could lead to lower annual costs through the bid process and minimize the amount of work needing to be completed by City personnel.

In later years, less frequent macrophyte harvesting will be needed. We anticipate that starting in the fourth year only one harvest in late June will be required.

3.3 Algal Control using Copper Sulfate

It is possible that eliminating a large part of the macrophyte community may lead to a algae bloom in Corbett Lake. This possibility results from the same levels of phosphorus reaching the lake after macrophyte harvesting and the available phosphorus causing a algae bloom instead of being used by the aquatic plant community. SEH does not anticipate algae blooms to occur since the measured phosphorus concentrations in the lake were relatively low throughout the May to September period of testing. The algae present in the lake may be more visible after macrophyte harvesting, since they would be less hidden by the macrophytes.

The most likely impact of an algae bloom would be on the transparency of the lake. For instance, swimmable water is defined as Secchi disk transparency being 6 feet or more in lakes such as Corbett Lake. An algal bloom may impact transparency to the point where the bay near the library is perceived to be swimming impaired by City residents. If in the future algae booms became a problem in the bay near the library. the City may desire to conduct occasional algae control, especially to maintain swimmable water.

If Secchi disk transparency does fall below 5 to 6 feet in June and July, it may be desirable to implement algal control measures using copper sulfate. The following level of effort would be needed to accomplish the algae control.

The average depth of the 15 acres being treated as shown on the bathymetric map is approximately 6 feet deep. The proper dosage of copper sulfate for this area of Corbett lake would be 3 pounds per surface acre, or 45 pounds of copper sulfate crystals. Copper sulfate can be purchased for approximately \$300 per 25 pounds.

The best way to apply the copper sulfate is via the boat and burlap method as outlined below:

1. Arrange for one boat and motor.
2. Construct a rectangular frame of 2-inch lumber about 12 inches wide and long enough to extend across the center of the boat and 12 to 18 inches beyond one side. Nail an additional cross piece about a foot from each end of the frame to form a square to which the mouth of a burlap bag can be fastened.
3. Nail a burlap bag inside the square at each end of the frame so that the bottom of the bag will drag in the water. Supply the boat with a 1-pound coffee can or its equivalent for transferring copper sulfate crystals into the burlap bags.
4. Distribute the total amount of chemical to be applied to the lake to the boat. At the start, about three pounds of large-crystal copper sulfate should be placed in the bag and more copper sulfate should be added as it dissolves.
5. Remove the bag from the water when the boat is not moving. The boat should be washed carefully when the treatment is finished since copper sulfate is eventually corrosive to metals and paint.
6. Copper sulfate dust is irritating to the eyes so proper care should be taken that none reaches the eyes.

Effectiveness of plankton algae treatments varies with weather conditions, uniformity of application and other factors. On some lakes a single treatment per summer (usually in early July) gives satisfactory algal control. Other lakes may require three or more treatments. Treatment of algae one year will have no suppressive effect on algae the next year. In general, treatments have greatest chance for success when made in clear weather with light wind to aid in the mixing of the water. Early morning treatments are more effective than those made in the afternoon.

A principal precaution in treatment of plankton algae, other than application of correct dosage, is to make the treatment before the growth becomes extremely heavy. Plan early for treatment. If treatment is made when a heavy bloom is present, decay of a large amount of dead algae may deplete oxygen in the water causing a kill of fish and other aquatic animals. Do not wait to treat until there are heavy scums along shore. Treat while the algae are still dispersed throughout the water. The water should not be used for swimming for 24 hours after treatment.

3.4 Implementing Minimum Size Limits for Predator Fish

The concept of minimum size limits protects larger predator fish up to a certain age and size which helps to balance the fish population size and community structure. The minimum size limit causes angling and natural mortality to be lowered among younger year classes of fish which protects a large portion of the natural reproduction capacity of these fish if the minimum size limit is properly imposed.

For example, the following minimum size limits if imposed on Corbett Lake would protect the following fish species up to the following ages:

Fish	Minimum Size Limit	Age at Minimum Size Limit
Northern Pike	24"	5
Largemouth Bass	15"	6

After bottom aerators are installed pike and largemouth bass could be stocked in the lake. Minimum size limits for these fish could then be used to help accomplish the goal of providing an enhanced fishery for Corbett Lake. The City would need to work with the Department of Natural Resources to legally establish the minimum size limit.

4.0 Recommendations

It is recommended the following lake management measures, given in order of priority, be taken:

1. Install a system of lake bottom aerators at a cost of approximately $12,000. The WDNR Lake Protection Grant program may support the capital and construction cost of the aerators.
2. Retain a contractor to mechanically harvest the recommended area for one year at a cost of approximately $3,750

3. After the first year, mechanically harvest macrophytes in the recommended area for two years. The weed harvesting during years 2 and 3 could either be done by a contractor or by City staff. The City could purchase a small hand held weed harvestor at a cost of approximately $1,500 to accomplish the ongoing maintenance harvesting. It is likely the City would need to purchase or rent a boat bigger than currently available at the treatment plant to haul cut weeds to the boat landing.
4. Pursue implementation of a minimum size limit for predator fish stocked in Corbett Lake.
5. Discontinue investigation of lake dredging.
6. Discontinue consideration of diverting water into the lake from the drainage ditch west of Highway 27.
7. Establish biofiltration treatment of storm water entering the lake from urban areas.
8. Discontinue snow disposal on east side of lake

5.0 References

Christianson, Alan, 1997, personal communication from City of Ladysmith Administrator.

Cooke, Welch, Peterson and Newroth, 1993, *Restoration and Management of Lakes and Reservoirs*, Lewis.

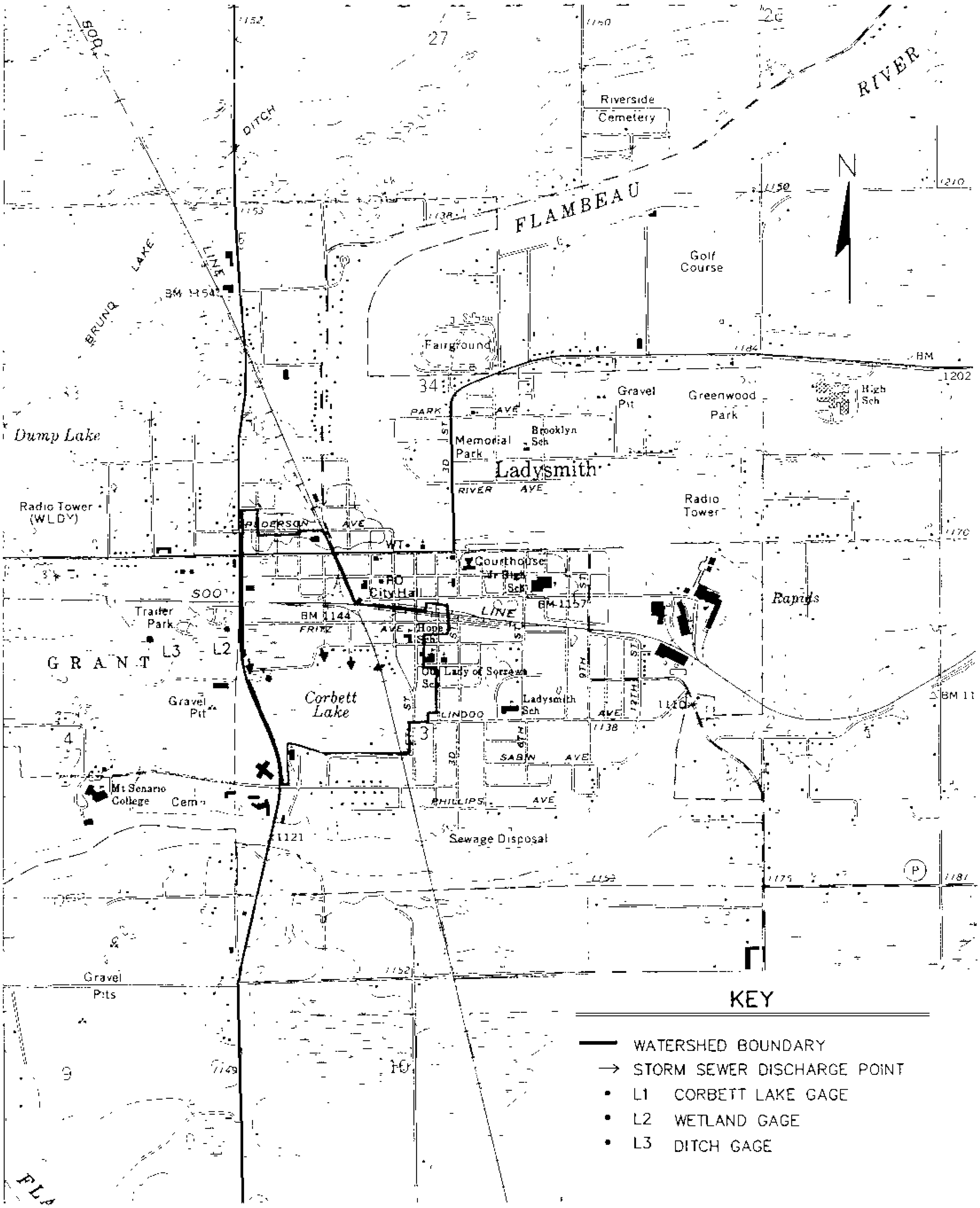
Cross, T. and R. Davis, 1992, *Macrophyte Removal to Enhance Bluegill, Largemouth and Northern Pike Populations*, Minnesota Department of Natural Resources, Investigative Report Number 415.

Lille, Richard A. and John W. Mason, 1983, *Limnological Characteristics of Wisconsin Lakes*, Technical Bulletin No. 138, Wisconsin Department of Natural Resources.

SEH, January 1999, *Corbett Lake Phase 1 and 2 Report*.

Terrill, John, unknown date, *Tails, Trails and Tails* Article on Corbett Lake in Ladysmith News.

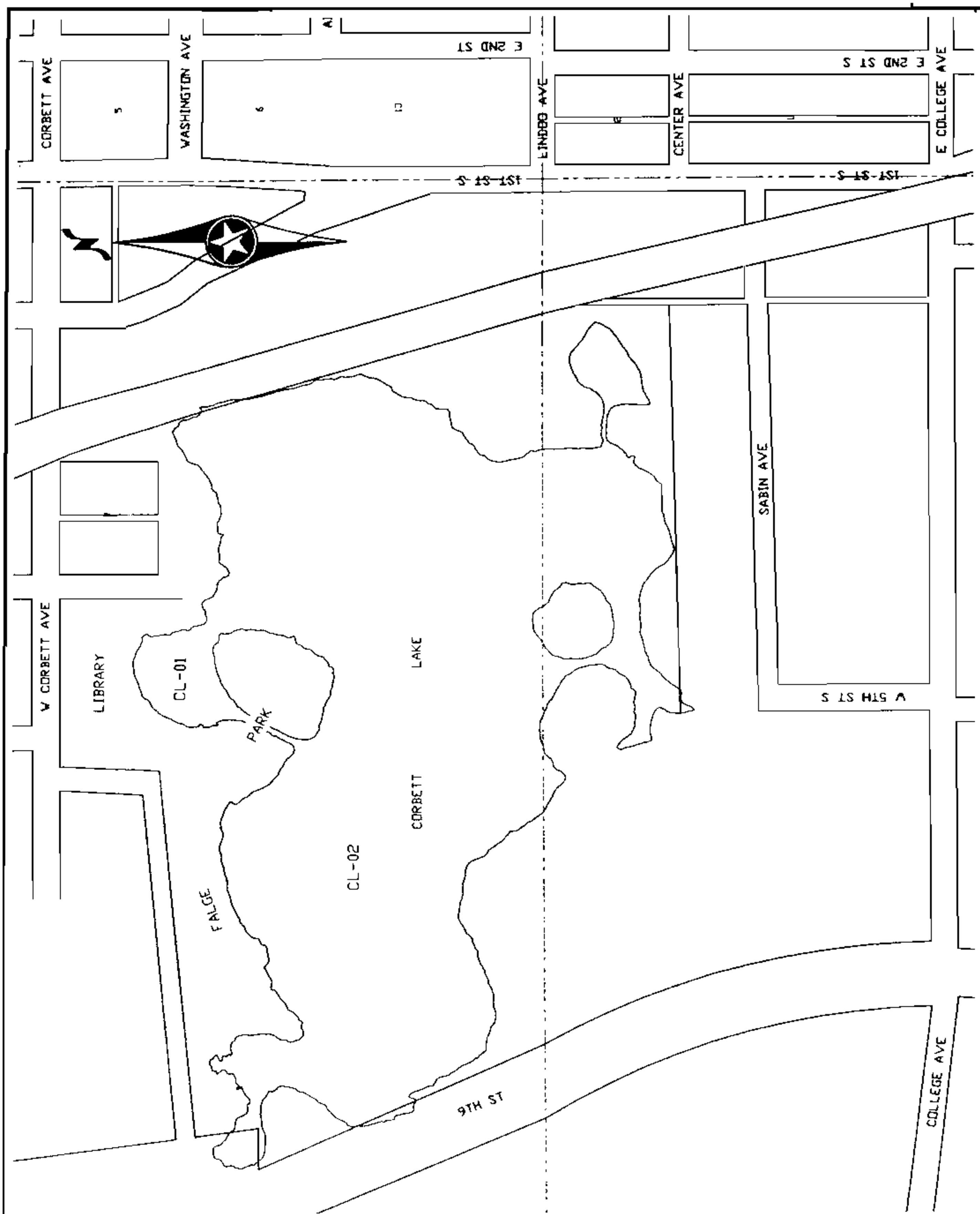
Figures



SEH

GENERAL LOCATION MAP

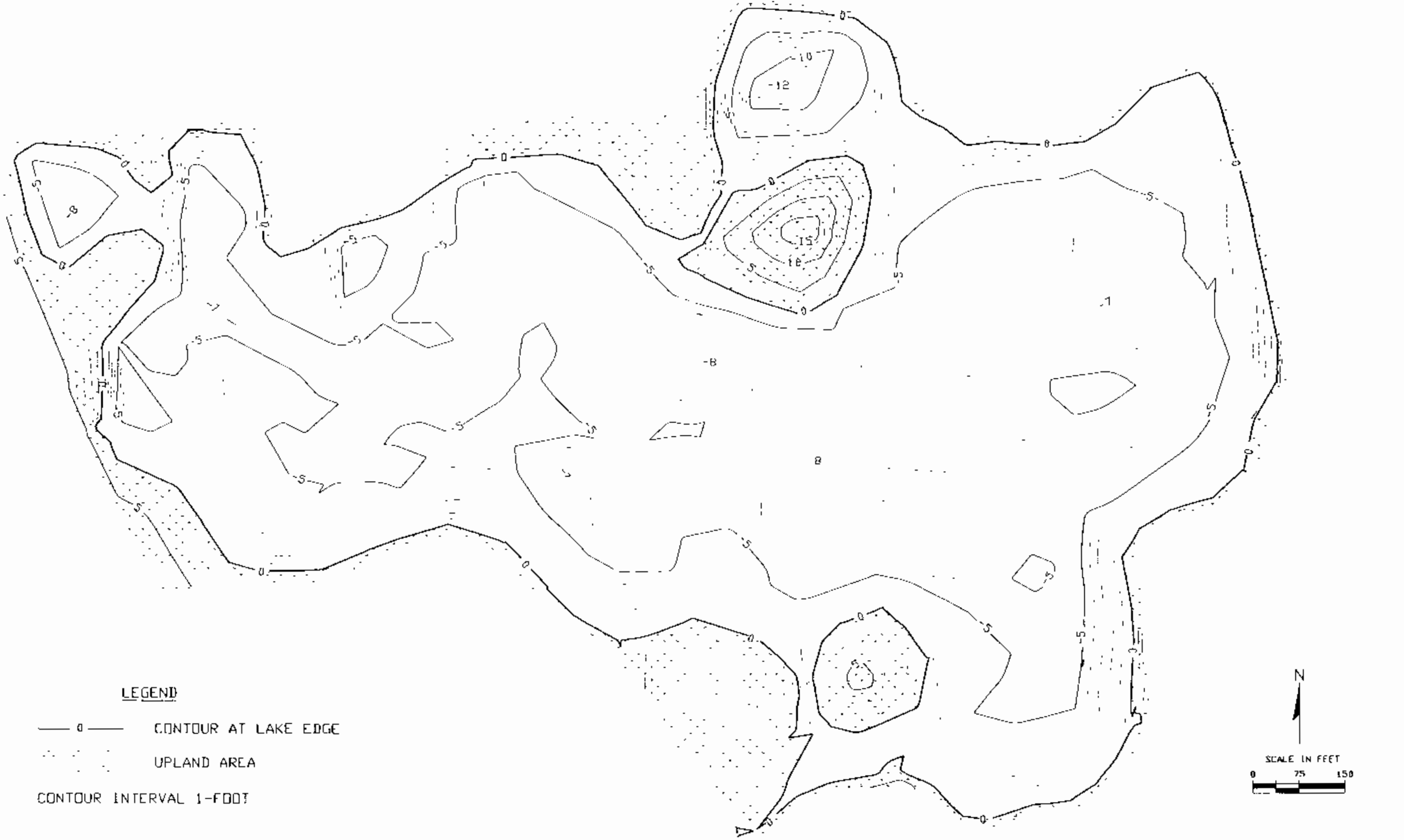
FILE NO	FIGURE
LADYS9706	1
DATE	
04/03/98	



SEH

CORBETT LAKE BASIN

FILE NO.	FIGURE
LADYS9706	2
DATE	
01/22/96	

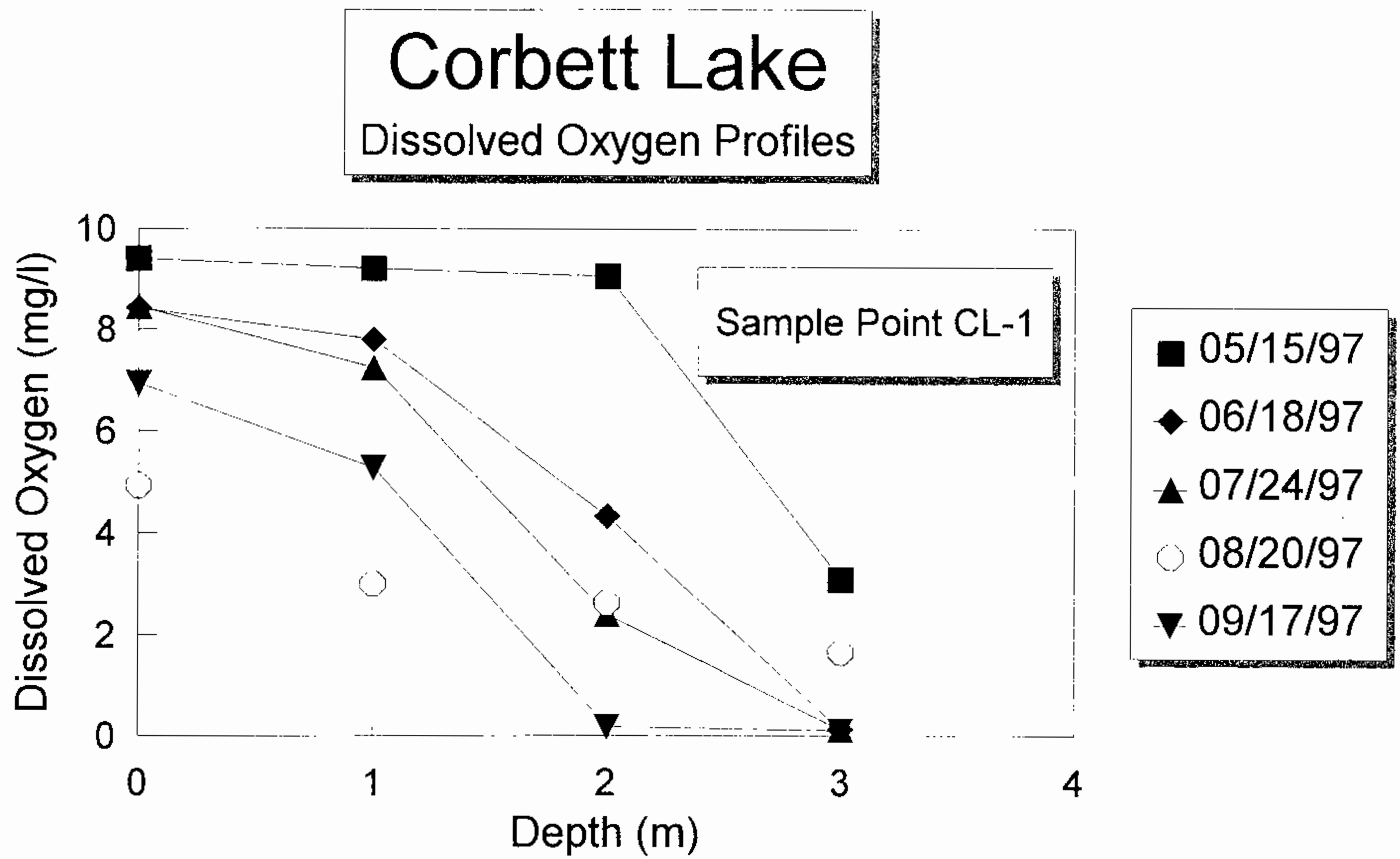


SEH ENGINEERS ■ ARCHITECTS ■ PLANNERS

BATHYMETRIC MAP

CORBETT LAKE
LADYSMITH, WI

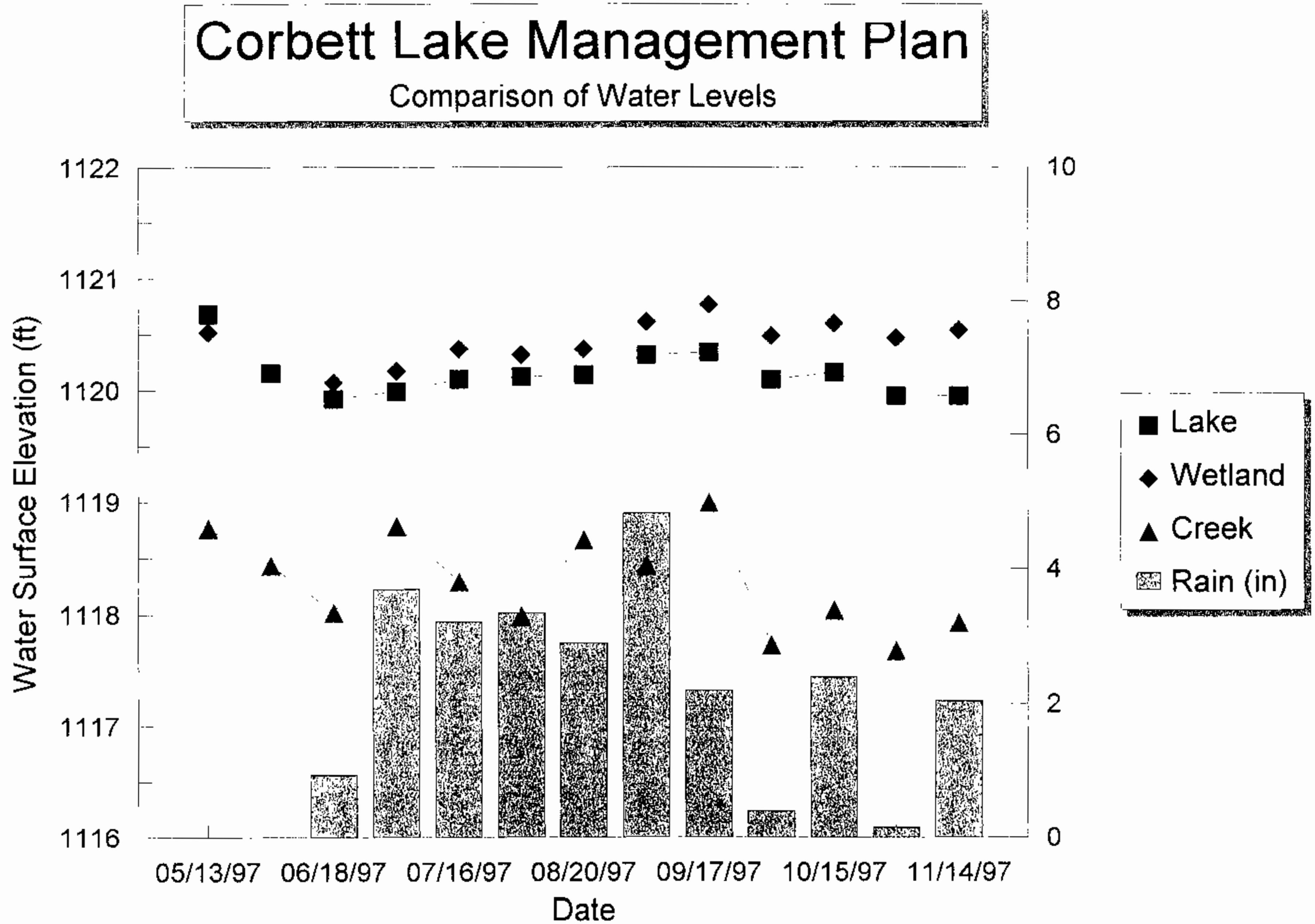
FILE NO	FIGURE
LADYS9706	3
DATE	
3/26/98	



SEH ENGINEERS ARCHITECTS PLANNERS

DISSOLVED OXYGEN PROFILES

FILE NO.	FIGURE
LADYS9706	4
DATE	
03/26/98	



ENGINEERS ARCHITECTS PLANNERS

COMPARISON OF WATER LEVELS

FILE NO.	FIGURE
LADYS9706	5
DATE	
03/26/98	

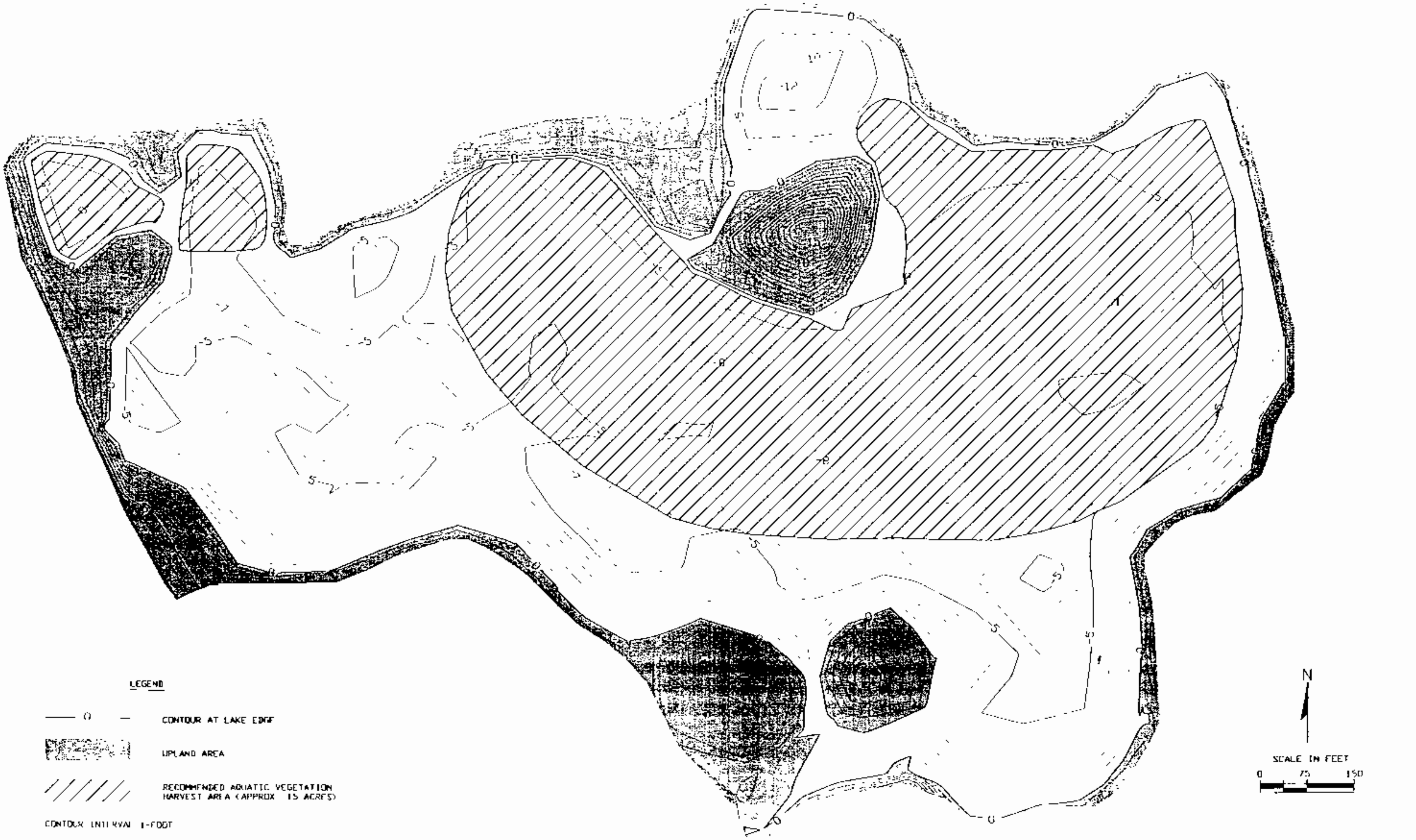
PROPOSED BOTTOM AERATOR (DIFFUSER) LOCATIONS

CORBETT LAKE
LADYSMITH, WI

FILE NO. LADYS9706.02

DATE

FIGURE 6



SEH

RECOMMENDED AQUATIC VEGETATION
HARVEST AREA

CORBETT LAKE
LADYSMITH, WI

FILE NO. LADYS9706.02
DATE 6/26/99
FIGURE 7

Corbett Lake Water Quality Data Summary — Table A-1

Sample Location: CL-01

Parameter	Units	Date 05/15/97	05/15/97 Notes	06/18/97	06/18/97 Notes	07/24/97	07/24/97 Notes	08/20/97	08/20/97 Notes	09/17/97	09/17/97 Notes	Mean
chlorophyll a	ug/l	13 1	1	6 32	2	5 37		20 3	6	10 7		11 158
ammonia	mg/l	nd		nd		0 01	less than	0.015	6	nd		0 005
nitrate+nitrite nitrogen	mg/l	nd		nd		0 01	less than	nd	6	nd		0 002
total kjeldahl nitrogen	mg/l	0 7		0 68	3	0 6		0 71	6	0 6		0 658
total phosphorus	mg/l	0 041		0 025	4	0.012		0 040	6	0 027		0 029
dissolved reactive phosphorus	mg/l	nd		0 004		nd		0 002	6	nd		0 001
Chloride	mg/l	86 2		90				80 7				85 633
Temperature	C	11.43		21 1		22.43		18 26		19 71		18 586
pH		7 56		6 74		7 84		8		6.04		7 236
pH - lab		7 44		7 43								
Alkalinity	mg/l	21		20								
Specific Conductance	uS/cm	317		329		304		290		268		301 600
Dissolved Oxygen	Percent Saturation	88 1										
Dissolved Oxygen	mg/l	9 4		8 43		8 46		4 94		6 93		7 632
TDS		0 203										
Redox	mV	295		299		278		284		303		291 800
Secchi Depth	ft	4 5		8 4		7 1		4 7		5 1		5 960

Sample Location: CL-01d

Parameter	Units	Date 05/15/97	05/15/97 Notes	06/18/97	06/18/97 Notes	07/24/97	07/24/97 Notes	08/20/97	08/20/97 Notes	09/17/97	09/17/97 Notes	Mean
chlorophyll a	ug/l											
ammonia	mg/l	nd		0 038		0 036		0 013	6	0.248		0 067
nitrate+nitrite nitrogen	mg/l	0 03		0 013		0 013		0 01	6	0.033		0 020
total kjeldahl nitrogen	mg/l	1.7		6 68	3	1.2		0.9	6	1.9		2 476
total phosphorus	mg/l	0 161		0.115	4	0 069		0 047	6	0.117		0 102
dissolved reactive phosphorus	mg/l	nd		0 007		nd		0 001	6	nd		0 002
Chloride	mg/l	140		89 1				81 5				103 533
Temperature	C	10 43		17 34		17.8		17 3		16 14		15 802
pH		6 42		6 4		6 68		6.67		5 8		6 394
pH - lab		6 51		7 2								
Alkalinity	mg/l	33		26								
Specific Conductance	uS/cm	455		342		375		346		372		378 000
Dissolved Oxygen	Percent Saturation	3 2										
Dissolved Oxygen	mg/l	0 2		0 14		0 11		0 62		0 11		0 236
TDS		0 315										
Redox	mV	94		222		101		135		116		133 600

Sample Location: CL-02 — CL-02

Parameter	Units	Date 05/15/97	05/15/97 Notes	06/18/97	06/18/97 Notes	07/24/97	07/24/97 Notes	08/20/97	08/20/97 Notes	09/17/97	09/17/97 Notes	
chlorophyll a	ug/l	7 8	1	10 6	2	4 19	5	3.85	5,6	7 27		6 742
ammonia	mg/l	nd		0.019		nd	less than	0 015	6	nd		0 007
nitrate+nitrite nitrogen	mg/l	nd		nd		nd	less than	0.01	6	nd		0 002
total kjeldahl nitrogen	mg/l	0 8		0 7	3	0 8		0.65	6	0 7		0 730
total phosphorus	mg/l	0 033		0 02	4	0 02		0.023	6	0 025		0 024
dissolved reactive phosphorus	mg/l	nd		0 002		nd		0.001	6	nd		0 001
Chloride	mg/l	85 8		89.1		83 2						86.033
Temperature	C	11 2		20.25		21 25		16 74		17 46		17.380
pH		7 61		7 3		7.58		7 53		5 97		7 198
Specific Conductance	uS/cm	307		327		297		283		267		296 200
Dissolved Oxygen	Percent Saturation	94 8										
Dissolved Oxygen	mg/l	10 13		3 74		1 24		0.6		2 13		3 568
TDS		0 196										
Redox	mV	301		326		344		370		386		345 400
Secchi Depth	ft	4 2		4 6		4 2		3 6		4 3		4 180

Notes
1 Holding time exceeded by 17 days, result approx
2 Holding time exceeded by 15 days, result approx
3 Holding time exceeded by 5 days, result approx
4 Matrix Q.C exceeded, spike recovery = 111 1%
5 Low absorbance, result approx
6 Ice melted, result approx

Table D-1
Corbett Lake Water Level Measurements

Water Surface Elevation (ft)

	Lake Gage 1	Wetland Gage 2	Creek Gage 3	Difference G1 - G3	Average Difference
Elevation Top of Staff (ft)	1122.92	1122.55	1120.79		
Elevation Bot of Staff (ft)	1119.59	1119.22	1117.46	(ft)	(ft)
Date	Lake	Wetland	Creek		
05/13/97	1120.68	1120.52	1118.76	1.92	
06/04/97	1120.15	1120.16	1118.43	1.72	
06/18/97	1119.92	1120.07	1118.01	1.91	
07/02/97	1119.99	1120.17	1118.78	1.21	
07/16/97	1120.1	1120.37	1118.28	1.82	
08/06/97	1120.12	1120.32	1117.98	2.14	
08/20/97	1120.14	1120.37	1118.66	1.48	
09/03/97	1120.32	1120.62	1118.43	1.89	
09/17/97	1120.34	1120.77	1118.99	1.35	
10/02/97	1120.1	1120.49	1117.72	2.38	
10/15/97	1120.16	1120.6	1118.03	2.13	
10/29/97	1119.95	1120.47	1117.67	2.28	
11/14/97	1119.95	1120.54	1117.92	2.03	1.87
average	1120.15		1118.28		

See Figure 1 for gage locations