LPL-194

THUNDER LAKE PLANNING GRANT

INVENTORY
&
RECOMMENDATIONS

COMPLETED BY

THUNDER LAKE
PROTECTION & REHABILITATION
DISTRICT

&

RAND ATKINSON
AQUATIC RESOURCES, INC.

IN COOPERATION WITH
WISCONSIN DEPARTMENT OF NATURAL RESOURCES
LAKE PLANNING GRANT PROGRAM

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INTRODUCTION

The future health of Thunder Lake is dependent on area residents working together to alleviate the problems identified and described in this planning grant inventory and document. Water level stabolization is the key management component that must be addressed at this time for the future welfare of the Thunder Lake ecosystem.

The past erosion of the bogs on the shoreline of Thunder Lake from increased water levels and wave action has freed an abundance of nutrients. These nutrients are available for fish and aquatic plant growth but also causes the water quality problems the lake community now faces.

The future of Thunder Lake is dependent on the stabolizing these nutrients again and reducing the amount of oxygen they utilize under the ice. Every effort must be made to recapture the nutrients either by trapping wind blow sediments directly or channelize suspended nutrients into fish, waterfowl, wildlife, and a diversity of aquatic plants. The aquatic ecosystem at the present time is making every effort to do this on it's own but our management is needed to correct the disruptions recognized in this document.

The lake community will be one to benefit from their own actions if they follow the recommendations below. Recreational use benefits can include: a sustainable fishery, a diverse and manageable aquatic plant community for increased waterfowl use and navigation, and better water clarity for aesthetics. The monetary value of your property is reflected in the quality of your lake.

ACKNOWLEDGEMENTS

A special thanks to the Thunder Lake District who cares enough for their lake to take the project of this grant on. Past Chairman, Tom Truog, was a great cooperator, leader, and contact in getting this momentous task completed. Thanks to all the members who were active in every aspect of gathering data: Dave Smith in contributing seechi disc information, history, and equipment. Mark Goldsworthy, John Sampson, and Barb Pauls for cranberry operation details. Greg & Ingrid Weinfurter for your recent leadership and use of Press Express in printing this report.

Thank you Task Force personnel for the review, information, and guidance that includes those listed above and DNR personnel including: Bob Young, Ron Eckstein, Ron Theis, Duke Andrews, and Mike Coshen. Also, thank you town chairman, Richard Van Kirk for your time and facilities for many meetings. Much of our work is just beginning now that we have direction.

Rand Atkinson, Aquatic Resources, Inc

LAND RESOURCES OF THE THUNDER LAKE WATERSHED

Geology and Watershed Characteristics

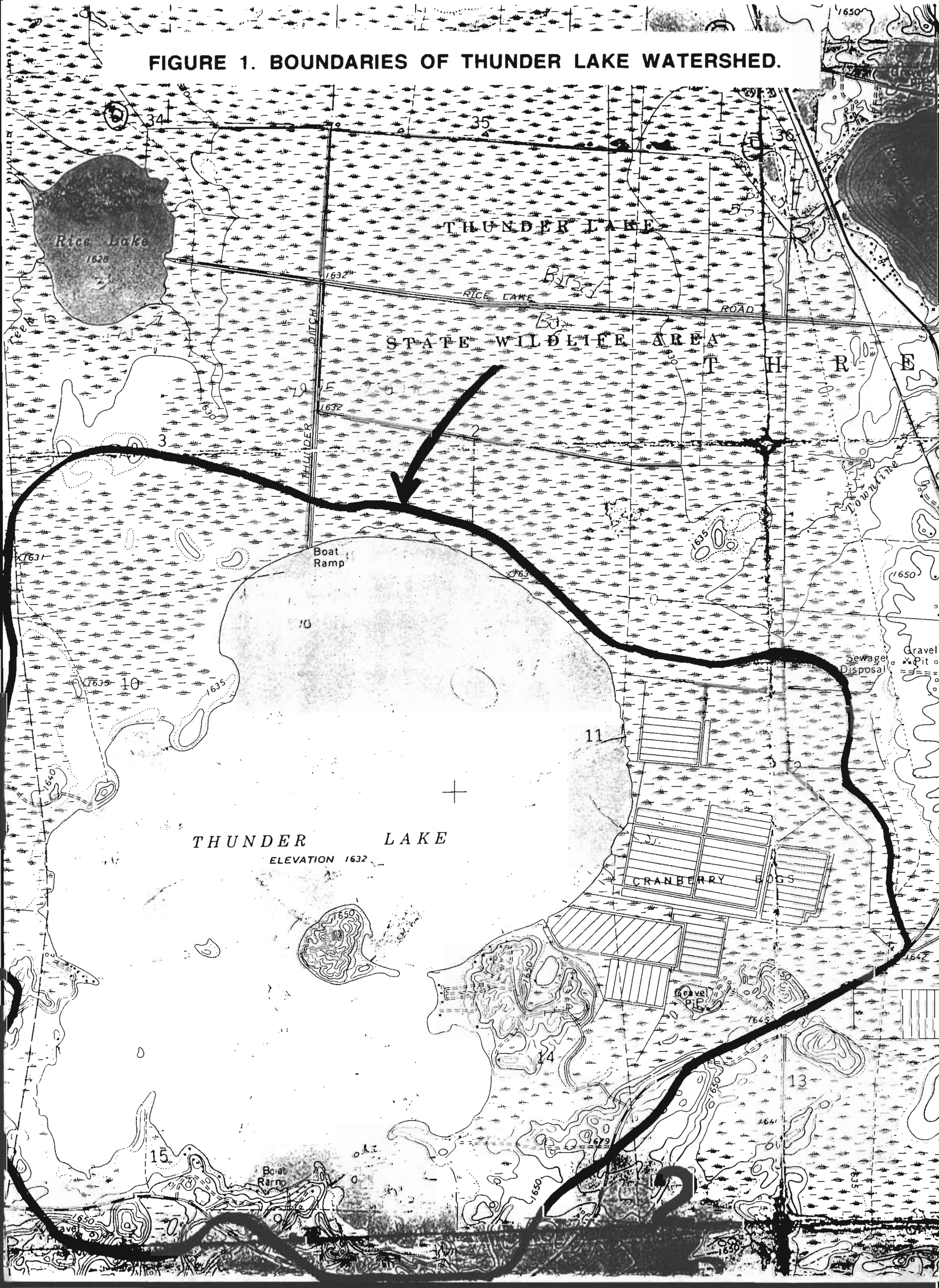
Thunder Lake is an 1800 acre impoundment whose shoreline is bordered by an upland watershed to the south, southwest and southeast. Extensive marsh areas surround the rest of the lake to the east,west and north. The soils and the underlying glacial materials that makeup the upland and marsh areas of the watershed have determine the history of the Thunder Lake area.

The level to steep terrain bordering the south shoreline of Thunder Lake was formed by glacial outwash which is stratified sand and gravel, gravelly sand, and sand that was carried, sorted and deposited by glacial melt water. These materials were carried southwest by the Chippewa Lobe of theWisconsin Glacier as it advanced from the northeast. As this lobe stopped advancing and began to melt these materials were subsequently sorted and deposited by streams flowing from the melting ice. This action deposited these materials in irregular patterns and depressions to form nearly level to steep hills surrounding kettles, shallow pits, and potholes. Many of these depression areas are connected toThunder Lake through narrow wetland corridors. Other land depressions collect water and slowly release ground water through unblocked glacial outwash materials beneath the soil to Thunder Lake and it's wetlands.

The wetland areas that surround Thunder Lake on three sides are also underlain by glacial outwash but is primarily sand that was deposited to form a large plain area surrounded by the higher ground described above. Adjacent to the upland terrain a basin area formed in this plain that became the open waters of Thunder Lake.

Thunder Lake's watershed to the south and west is easily defined by the hilly terrain with many streams flowing away to the south and west (Figure 1). The watershed is approximately 2,230 acres, which is primarily lowlands. Direction of ground water movement adjacent to Thunder Lake was evaluated in a1980 study to develop a nutrient budget for the lake. Groundwater in peat soils moves laterally with little change in gradients and any physical obstruction either from beneath the peat (such as subterrainian clay deposits or impermeable subsoils) or at the land surface (roads, dikes, culverts, dams, and beaver dams) can change direction of water flow. Pumping of large volumes of water can also seasonally effect these gradients. The 1980 study concluded in general that the horizontal gradient or the general movement of water in the bog ecosystem that surroundsThunder Lake was from south to north.

FIGURE 1. BOUNDARIES OF THUNDER LAKE WATERSHED.



Soils and Land Use

The soils that developed over the glacial outwash described above determined the vegetation and eventually the land uses found today around Thunder Lake. In most instances man induced changes on the landscape today replaced the many natural effects of fire, rain, wind, and drought of the last 9,000 years.

The soils of the uplands south and east of the lake varies from loam to sandy loam to loamy sand. Stoney areas dot the upland soil surfaces of moderate to steep slopes. Low flat areas often pond water seasonally. Tree and other vegetation growth and specie composition is bound by the richness, slope, and drainage of the soil as well as the length of growing season. See Table 1 & Figure 2.

The soils of the northwest, south, southwest, and southeast, shorelines have substratums of sand and gravel; Many of these areas are avenues for spring seepage from upland soil substratums which are also primarily sand and gravel. Spring seepage in these shoreline edge areas are important for fish and aquatic insect egg incubation areas. These areas are also important in providing minerals to the very acid environment of the bog complex. Islands of mineral soil are also scattered throughout Thunder Lake and the adjacent muck wetland complexes to the west and north which help buffer the acid conditions of the peat bogs to the east. Most soils in the upland are very porous which also makes them suseptible to any groundwater pollution from septic to fuel & oil contamination. See Table 1 & Figure 2.

The wetland soils adjacent to Thunder Lake are peat and muck. The muck soils are mainly northwest and west of the lake and the peat soils are north, east and southeast. Peat is at least 18 feet thick in many areas adjacent to Thunder Lake (1980 Study and Goldsworthy Reports) with some areas up to 25 feet thick. These peat soils and associated water now provide resources for commercial cranberry culture and for recreational activities that support the tourism industry of the north. Water levels changes have serious eroded these peat bog soils which in return have decreased the depth of the lake and effected water quality. Water level changes in these saturated soils have also effected the fish and waterfowl populations by changing and destroying an aquatic plant and invertebrate community that supported them. The muck soils to the west and northwest are exposed to mineral seepage and oxygen that allows decomposition and nutrient releases that do not occur in the acid environment of the peat bog soils adjacent to other areas of the lake.

WATER RESOURCE HISTORY OF THUNDER LAKE

Early History & Lake Use

Presettlement history data on the Thunder Lake Marsh was documented by Walt Goldsworthy in his analysis and interpretation of 18 feet of peat material on the Thunder Lake Cranberry Marsh in 1949 during the construction of a centrifical lift pump foundation. He utilized the rule of thumb that it requires approximately 500 years to form 1 foot of peat.

~8000 BC As the last glacial advance retreated Thunder Lake was part of a large open water lake that extended from Monico to Three Lakes. Cool weather and short growing season created conditions for peat bog formation

~7,000 BC Weather continued to warm. Peat in a 1000 years filled in shallow areas around the lake. Bog and wetland succession continued to shrink open water and peat accumulation attached floating bogs to bottom areas of even deeper water.

3500 BC Tamarack-Black Spruce forest (10" on stump) grew in shallow bog areas where peat attached to bottom areas became firm enough to support there sprawling roots. A fire swept through this areas at this time and for years of sedge grass growth florished. Thunder Lake was much smaller as marsh and peat encroachment cover most of the lake bed we now see. Open water was mainly north of islands with a deep water area with a maximum depth of 30 feet located north of the island.

3500 BC to 0 BC Plant succession changed the sedge grass community to a young spruce-tamarack forest again, another fire and the forested community again returned to sedge. Advanced to bog plant and forested wetland again. Thunder Lake was a small bog lake of several hundred acres with two large islands separating south wetland areas from open water.

1600AD Heavy rains, high water, and winds changed Thunder Lake as wetland and bog materials broke loose from shallows as cattails were found in bog area profile. More open water area appeared.

Water level & Lake Changes

Early documented records have brought more detail as to what happened to the Thunder Lake area after settlement. Below is a brief account.

1850 to 1900 Few Islands of Pine on Thunder Lake were cut during the White Pine Logging Boom. Cranberry bog area was a heavy spruce forest.

1900-10 Cranberry area of spruce forest burned.

1915-25 Drainage of bog area north,northeast, and east of Thunder Lake by land developers to sell as fertile farmland. Log dam- peat plug was left in to prevent Thunder Lake from draining. State lay claim to all islands of the state which separated islands from pennisulas by the ability to walk on dry land to the area during one period of the year. Peat dam was blown to prove "island" status. Lake supported large beds of rice and high populations of waterfowl.

1930-37 Drought combined with former ditching and subsequent fires created sedge grass communities on higher ground areas and on wetter areas spruce began to grow. More fires killed the spruce and blueberries began to dominate the area. During the drought sharptail grouse habitat and a hay marsh flourished and were used by area hunters and farmers. In 1934 fish stocking began with walleye,yellow perch, largemouth bass, bluegill, muskellunge, rock bass, white sucker stocked over the next few years. Conservation department began bringing problem live-trapped beaver into Thunder Lake wetland complex.

1938-46 In 1938 & 39 with WPA money concrete dams were built at the outlet of Thunder Lake and near the entrance of Rice Lake to flood areas north of Thunder Lake drained by ditching in the 1920's. The new dam on Thunder was constructed with capability of holding water levels 1 foot higher than former log- peat plug dam which held an elevation suitable for wild rice production. Both dams were in unstable peat areas and were subject to washout. Rice Lake entrance dam was abandoned and Thunder Lake dam difficult to maintain. Lake level conflict s between duck hunting sportmen and resort owners began. Thunder Lake Marsh construction began in 1946.

1948 Dam on Thunder Lake washed out lowering the water level and "damaging" the fish population". State water regulatory Board helped town government and local citizens rebuild the dam.

1949 Thunder Lake Cranberry Bog centrifical lift pump completed. Three Lakes Sportsman Club founded.

1950-67 - Dissolved Oxygen Levels of Thunder Lake were taken in 1951,1955, 1956, and 1959.
- In 1955 there were nuisance levels of aquatic plants in front of Sky Lodge.
- In 1961 floating bogs were a concern on Thunder Lake.
- In 1965 wild rice was abundant on south shore in front of the Alvin Schimke property at 2500 Anders Road.
- Prescibed burns began on wildlife area to maintain open areas in marsh. Local concern for reduction of deer habitat caused by the burning stopped this practice in 1967.
- Three Lakes wastewater treatment plant began discharging to the marsh in 1967.

1968-80 - There was little management of the Thunder Lake Wildlife Area. Spruce, tamarack, over grew the open grassy areas. Aspen, birch, and alder were abundant along ditches and ditch bank roads were closed.

1975 - Proposed muskellunge stocking in Thunder Lake stopped after a petition was presented in opposition. Last prior stocking of muskellunge was 1953.

1976-77 - Winter fish kill when summer and winter water levels were low.
- Water chemistry sampling of cranberry bog supply ditches.
- Fish shocker survey of fishery completed on lake
- request to Water Regulation Bureau of the DNR that a public interest water level be set on Thunder Lake.

1977-78 -Dissolved oxygen profile on 1-31-78

1979 - Dissolved oxygen profiles on Jan 20,29 and Feb 12. Fish kill of Bullheads on June 24 with photos by George Rydzewski.
- Fisheries report on public rights stage stated that no fish kills occurred when water levels were kept higher.

1980 - Dissolved oxygen profiles on Jan 15.
- Water diversion case regarding cranberry bogs settled. Water chemistry study of lake begins.
- Thunder Lake Wildlife Area master planning begins.

1981 - Water budget, nutrient analyses, plant community survey and cranberry bogs monitored.
- Fish kill occurs
- Algae a problem on south shore
- Depth profile of Thunder Lake completed.

1982 - Dissolved oxygen profiles taken on February 26 to March 15. Lake Management District considered to develope aeration system for Thunder Lake.

1983 - Dissolved oxygen at dam on Dec 17- 3 ppm, 150yds from dam at 3'-5.2ppm, 4' 2.5ppm, 5' bottom, Sound end, 3' 2.5ppm, 4' Bottom. Ice depth 18"w slush

1984 - Dissolved Oxygen good on January 26 & March 1. Lake district formed and aeration system installed.
- Stocking of fish resumes after 3 year break.
- Submerged aquatic plants begin to disappear

1985- - Submerged aquatic plants completely disappear
1986 - Ambient Lake Water Quality Program begins
- Fish shocking survey on Oct 21
- Bullhead population explodes
- Walleye fingerlings stocked

1987 - 50 tons of Bullheads removed by Thunder Lake District
- Walleye fingerlings stocked
- Canada goose goslings released in wildlife area
- Erosion heavy on north and east shores

1988 - voluntary secchi disc water clarity monitoring begins
- last year walleye fingerlings stocked
- pair ponds construction for waterfowl in wildlife area begins
- chemical eradication of bullheads considered but too costly
- Aquatic plant survey conducted as part of the Ambient Lakes Program

1989 -Water clarity poor, heavy algae blooms as suspended solids on contribute.
- Fish shocking survey finds few walleyes

1991- -Water clarity begins to improve and aquatic plants begin appear again.

1992 - Aquatic plant survey conducted; plants missing in north end of lake
- Fish stocking by lake district begins

1993 - Fish stocking by lake district
- Lake grant received in October

WATER RESOURCE APPRAISAL & ANALYSIS

WATER QUALITY

Introduction

Early water quality data of theThunder Lake ecosystem was limited to early dissolved oxygen sampling. The first recorded oxygen readings of Thunder, Rice, and Columbus Lakes were from January to April, 1940. This was a year after the concrete dam was built that added an approximately a two foot head to Thunder Lake. A dam was also in place at the entrance to Rice Lake at that time.

Date	Thunder Lake	Rice Lake	Columbus Lake
1-12-40	9.7 ppm (1 meter) 9.9 ppm (2 meters)	7.1 ppm (1 meter)	10.8 ppm (1 meter) 8.6 ppm (3 meters)
2-26-40	10.1 ppm (1 meter)	snow too deep	0.6 ppm (1 meter) 0.5 ppm (3 meters)
4-15-40	11.5 ppm (1 meter) 11.6 ppm (1 meter)	5.5 ppm (1 meter) 4.8 ppm (2 meters)	4.9 ppm (1 meter) 5.2 ppm (2 meters)

It appears at this time, with the recently raised water elevation, that Thunder Lake was maintaining oxygen with snow cover. The dams may also played a role in slowing water flow to Columbus Lake and created low oxygen problems there.

The next recorded Thunder Lake oxygen levels were in 1951, Feb 21,1955.1956, and 1959.

Over the next 15-20 years several changes were occuring in Thunder Lake without any water quality evaluation until a fish kill occurred during the winter of 76-77 under low water level conditions. A second and third winter fish kill occurred during the 1978-79 and 1980-81. Even water quality conditions in summer worsened as in June 1979 a large bullhead die-off occurred. Dissolved oxygens were taken on Thunder Lake during these years can be found in TABLE 2.

In 1980 a public rights water level was established to protect the resouces of Thunder Lake and a two year study of the water quality conditions of Thunder Lake was begun. Results of the water sampling can be found in TABLE 3.

TABLE 2. Dissolve Oxygen Levels of Thunder Lake From 1977 to 1983

Date	Depth (feet)	Temp. (oF)	Dissolved Oxygen (mg/l or ppm)	Oxygen Sat (%)
2-21-77		FISH MANAGEMENT FILES WOODRUFF		
1-31-78				
1-18-79				
1-26-79				
2-12-79				
3-9-79				
1-15-80				
2-5-80				
		North Basin		
3-2-81	2.0	33.8	7.6	54
1" snow	3.0	36.9	5.4	40
20" Ice	4.0	37.4	5.0	37
	5.0	37.4	5.1	38
	6.0	37.4	4.2	31
		South Basin		
	2.0	32.1	2.6	18
	3.0	33.8	1.0	7
	4.0	37.4	0.8	11
	6.0	37.4	0.7	9.5
2-26-82		FISH MANAGEMENT FILES WOODRUFF		
3-2-82				
3-5-82				
3-15-82				
2-12-82				
2-19-82				
12-17-83	Ice depth 18"w slush			
-At Dam			3.0	
-150yds from dam	3.0		5.2	
	4.0		2.5	
	5.0 bottom			
- South end	3.0		2.5	
	4.0 bottom			

TABLE 3. Thunder Lake Water Quality Data from 1980- 81 Study.

Date - Location	pH (su)	Alkal.(mg/l)	NH3-N(mg/l)	NO2+NO3-N	T.Kjedahl-N	Chlora(ug/l)S'	T. Phos.(mg/l)	Temp(oF) S'	O2(ppm)Sat(%)	Temp(oF) 3'	O2(ppm)Sat(%)	Temp(oF)6'orB'	O2(ppm)Sat(%)
4-30-80 N	7.8	24	0.1	0	1.01	19.7- 4.6'	0.044						
5-12-80 N	7.7	26	0.11	0	1.26	4.3	0.071	50.9	10.6(95)	50.9	10.6(95)	50.9	10.6(95)
5-29-80 N	7.7	28	0.1	0.01	1.12		0.029	69.8	8.0(90)	69.8	8.0(90)	69.8	8.0(90)
6-16-80 N	8.1	24	0	0.01	1.54		0.046	68	9.2 (101)	64.4	9.5 (100)	61.7	10 (102)
6-30-80 N	7.85	24	0.1	0.07	0.67	7- 3.5'	0.46	66.2	8.4 (90)	66.2	8.4 (90)	63.3	8.9 (93)
7-15-80 N	9.44	22	0	0	0.78	4.2- >4.6'	0.033	77	8.2 (100)	77	8.4 (102)		
8-4-80 N	9.5	26	0.11	0	0.76	4.7	0.029	69.8	8.4 (94)	69.8	8.4 (94)	69.8	8.3 (94)
8-12-80 N*	8.7	26	0.14	0.01	1.01	15.1	0.076	73.4	8.4 (98)	71.6	8.8 (101)	69.8	9.6 (108)
8-25-80 N	7.6	26	0	0	0.45	3.2- 4.8'	0.024	66.9	8.5 (92)	66.9	8.5 (92)	66.9	8.5 (92)
9-16-80 N	7.6	24	0.06	0.07	0.67	10	0.3						
9-29-80 N	7.4	20	0.01	0	0.62	10.3	0.41	51.8	10.7 (97)	51.8	10.7 (97)	51.8	10.7 (97)
10-16-80 N	7.58	24	0.1	0.08	0.84	9.2	0.013	41	12(94)	41	12(94)		
11-5-80 N	7.3	18	0	0.13	0.64	6.5	0.037	33.4	12.8 (91)	33.4	12.8 (91)		
11-19-80 N								THIN ICE					
12-17&18N	8.6	28	0.07	0.04	0.84		0.025						
12-23-80 N								39.2	11.6 (89)	39.2	11.6 (89)	39.2	11.6 (89)
14"I,3"S													
1-12&13-81 N	7.15	28	0.04	0.08	0.45		0.016	32	11.2 (77)	37.4	7.2 (54)	38.6	6.5 (49)
18"I,8"S													
1-28-81 N								32	10.4 (71)	34.8	8.0 (58)	37.4	1.4 (10)
18"I,3"S													
2-17-81 N	6.8	30	0.15	0.02	0.78		0.009	32	10.5 (72)	34.8	5.0 (36)	37.4	2.1 (16)
18"icew/sl@H2O													
3-2-81 N								32	7.6 (52)	34.8	5.3 (38)	37.4	4.2 (31)
20" I, 1" S													
3-16&17-81N	6.83	26	0.11	0.56	0.59		0.006	35	7.6 (55)	37.4	7.6 (56)	39.2	7.6 (58)
18" I, 1" S													
4-14-81 N	7.6	26	0.06	0.11	0.62	7- . 4.6'	0.03	46.4	11.2 (94)	46.4	11.2 (94)	46.4	11.2 (94)

Secchi Disc >5.5'

S'=Seechi (ft)

In 1984 the poor condition of Thunder Lake led the community to form the Thunder Lake Protection & Rehabilitation District . The new lake district installed a winter aeration system that year and began an intense stocking program to rehabilitate the fishery. The oxygen -temperature conditions during the first winter are recorded in TABLE 4 below.

TABLE 4.

Date	**Depth** (feet)	**Temp.** (oF)	**Dissolved Oxygen** (mg/l or ppm)	**Oxygen Saturation** (%)
		North Basin		
1-26-84	3.0	39.2	5.3	41
	6.0 bottom			
		South Basin		
	3.0	34.8	5.9	43
		North Basin		
3-1-84	2.0	33.8	8.0	58
Snow	3.0	38.3	3.5	26
& Ice ?	4.0	40.1	2.2	17
	5.0	40.1	2.1	16
		South Basin		
	2.0	34.3	6.4	46
	3.0	36.1	3.8	28
	4.0	39.2	0.3	3.9
	6.0	41.0	0.0	0

By 1985, Thunder Lake's large ecosystem complex combined with it's severe problems brought it to the attention of the new Ambient Lakes Program of the DNR. Long term monitoring of it's water quality had begun.

Long term water testing began in August of 1985 as chemical, physical, and biological sampling occurred periodically each year since that time. This allowed excellent documentation of the severe conditions on Thunder Lake the next 5 years and the recoveries that have occurred in the system the last 5 years. The water quality characteristics of these time periods are documented in Table 5 below.

TABLE 5. WATER QUALITY CHARACTERISTICS OF THUNDER LAKE 1985- 1994

pH (su)	Alkal.(mg/l)	NH3-N(mg/l)	NO2+NO3-N	T.Kjedahl-N	Phos-Dis Orth	Phos-Tot	Date	Temp (oF)	O2 (ppm)	O2 Sat. (%)	Chlor A (ug/l)	Turbidity(FTU)	COLOR(PT-CO)
						0.43	2/3/87	35.6	2.1	15.2			
						0.036	3/10/88	32	1.9	13			
						0.024	3/27/89	36.5	3	21.7			
						0.039	3/14/91	35.6					
						0.031	3/4/93	37.4	1.8	13.3			
						0.032	3/16/94	39.2	3.1	23.7			
6.8	16	-	0.05	1.3	0.004	0.13	4/23/86				140	12	80
6.8	20		0.1	2.7	0.004	0.15	4/21/87				140	14	60
7.2	22	0.0003	0.1	1.4	0.005	0.057	4/21/88	39.2	11.3	86.3	26	7.4	60
7.3	22	0.0002	0.2	0.8	0.007	0.04	4/27/89	51.8	10.6	95.5	18	4.2	35
-	-		0.02		0.01	0.113	4/26/90	66.2	9	95.7	76		
7.5	22	0.0001	0.02	1.2	0.005	0.048	5/14/91	68	10.1	109.8	30	5.1	60
7.3	20	0.00007	0.007	0.8	0.002	0.07	5/12/92	64.4	8.4	88.4	45	6.6	50
7.3	18	0.00006	0.03	1	0.002	0.065	5/13/93	60.8	8.6	86	29	7.9	50
7	14	0.00001	0.007	0.7		0.038	5/5/94	48.2	10.2	87.9	11.8	2.6	40
						0.155	6/30/86				200		
8.8F						0.09	6/17/87	75.2	10.6	124.7	180		
						0.125	6/23/88	73.4	8	92	110		
						0.075	6/21/89	72.5	9.4	106.8	44		
						0.127	6/20/90	64.4	8.5	89.5	81		
						0.058	6/18/91	73.4	8.3	95.4	23		
						0.055	6/30/92	66.2	10.2	108.5	21		
						0.042	6/30/93	64.4	8.8	92.6	16.9		
						0.032	6/21/94	74.3	7.3	83.9	14.1		
8.5F(7.3L)						0.135	7/28/86	75.2	8.7	102.4	380		
						0.2	7/23/87	78.8	5.9	72	80		
						0.234	7/28/88	77	9.2	109.5	120		
						0.091	7/12/89	72.5	7.3	83	53		
						0.1	7/12/90	66.2	9.5	101.1	70		
						0.075	7/16/92	71.6	8.8	100	37.3		
						0.069	7/27/93	71.6	7.2	81.8	44.5		
						0.046	7/21/94				19.8		
7	12	0.00008	0.02	1.8	0.004	0.13	8/5/85	71.6	8.3	94.3	120		
7.5F(7.0L)						0.146	8/21/86				80		
8						0.175	8/11/87	71.6	8.9	101.1	110		
						0.131	8/30/88	60.8	9.2	92	64		
						0.07	8/24/89	69.8	9.2	102.2	38		
						0.101	8/30/90						
						0.089	8/27/91	71.6	7.5	85.2	58		
						0.114	8/12/92	70.7	8.4	93.3	6.46		
						0.052	8/31/93	66.2	6.6	70.2	22.3		
						0.048	8/18/94				7.93		
7.1	25	0.00003	0.04	2.5	0.011		10/25/89	45.5	12.3	100.8	75	16	40
7.2	24	0.0007	0.05	1.9	0.007	0.085	10/31/90	42.8	10.8	86.4	17	7.6	50
6.9	18	-	0.2	2	0.005	0.07	11/4/86				-	6.4	50
7.3	20	0.0003	0.3	2.2		0.1	11/6/87	37.4	11.6	85.9	-	11.5	55
7.2	17	0.00005	0.1	1.4	0.007	0.104	11/7/88	33.8	12.2	85.9	-	9.3	60
7.1	12	0.00004	0.2	0.8		0.033	11/3/93	34.7	9.8	69	4.72	2.1	40
7	14	-	0.04	0.8		0.043	11/3/94				11.1		

Procedure

A focus of the planning grant was to review this water quality data and add additional information to understand water quality as it pertains to the fisheries resource. During the winter of 1993-94 water oxygen- temperature monitoring sampling occurred in the north basin location -where DNR monitors winter conditions in March - and at 10 other marked locations under the ice throughhout the lake. Locations for this sampling can be found on FIGURE 2. Conditions at these locations are documented below in TABLES 6 thru 9.

Results

December 21, 1993 The first winter oxygen-temperature profiling occurred on this dates at 11 locations throughout the lake. Ice was already 8" thick with 3" of snow covering the ten sample locations. When snow covers a lake sunlight does not reach the water below, photosythesis by aquatic plants including algae stops, and winter oxygen depletion begins.

Temperatures on this date just below the ice were from 33.2 oF to 35.6 oF and bottom temperatures ranged from 37.9 oF to 40.1 oF (See TABLE 6). Water density is greatest at about 40 oF, therefore it sinks to the bottom and accounts for the differences in temperature under the ice from top to bottom.

The colder the water the more oxygen it can hold. This is also evident during under the ice conditions. The oxygen goes out from the warmer bottom water first and just below the ice near the top of the water column last. The rate at which the oxygen disappears- once snow cover stops photosynthesis that produces oxygen- is relative t the amount of of dead and decaying oxygen consuming organic matter is on the bottom. In deeper lakes the water the distance between the oxygen consuming matter on the bottom and the more oxygeneated water below the ice is greater so winterkill from oxygen depletion is less likely to occur .

Thunder Lakes's shallow depth and large amounts of bottom organic matter were already dropping oxygen levels. Oxygen levels above 5.0 mg/l or ppm are needed to maintain a healthy fish and aquatic organism population to support them. Only three locations had oxygen levels above 5.0 mg/l on this date. They include location # 1, 2, and 6. Locations #2 & 6 are the at the centers of the North and South bay, the greatest distances from any island or shorelines that provide structure that would settle out suspended organic matter in a wind swept lake. Location #1 is in the South Southeast bay of Thunder where a northwest wind had blown the ice clear of snow. These oxygen levels were all just beneath the ice and quickly fell below 5 mg/l two feet below the ice. Location #9 was 75 yards north of the aeration field and oxygen levels were already low at this location.

Figure 3. Map of Oxygen-Temperature Sampling locations December 1993 through March 1994.

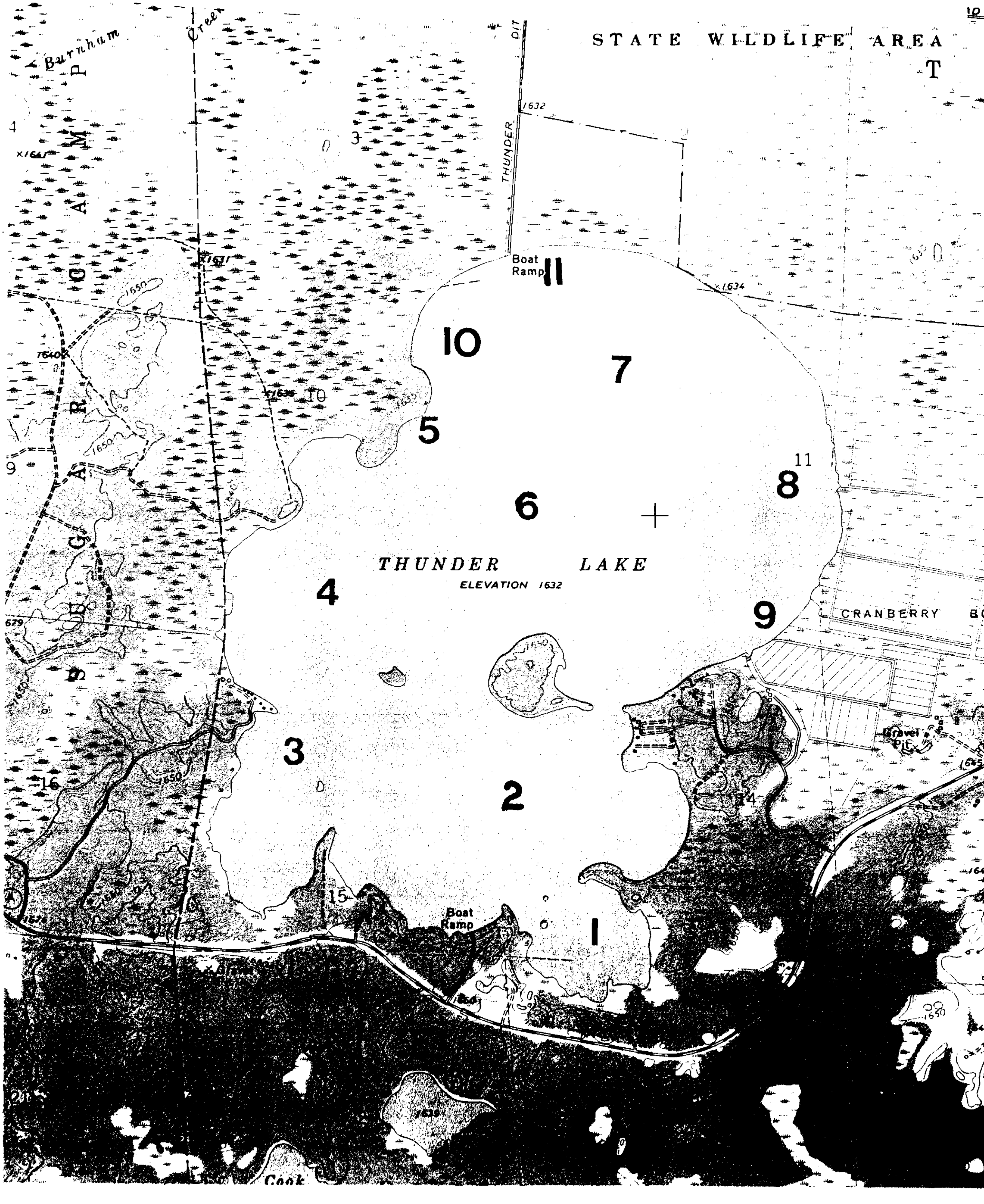


Table 6 . Oxygen- Temperature Profiles of Thunder Lake on December 21, 1993.

Location	Depth (feet)	Oxygen (mg/l)	Temp. (oF)	Oxygen Sat.(%)	er Data on 12-21-93
# 1	1'	5.6	33.4	39	Ice: 8"
S of SE Bays	2'	2.3	36.9	17	Snow: 3"
	3'B*	0	37.9	0	Weather: Cloudy
					Cloudy Day Prior
# 2	1'	6.2	34.2	44	
S. Basin	2'	3.5	36.9	26	
	3'	1.5	38.8	11	* Bottom
	4'	1.5	40.1	12	
	5' (6'B)	0.8	40.1	6	
# 3	1'	4.5	34.1	31	
SW	2'	2.4	34.2	18	
	3'	0.2	38.4	1.5	
	4' (4'3"B)	0	39.7	0	
# 4	1'	4.3	34.1	30	
W	2'	1.5	37.4	11	
	3'	0.5	39.2	8	
	4'B	0	39.7	0	
# 5	1'	1.8	35.6	7	
N.Basin W	2'	0	35.7	0	
	3'	0	39	0	
	4'	0	39.3	0	
	5' (5'3"B)	0	39.3	0	
# 6	1'	6.2	33.8	44	
N.Basin Cent	2'	4.8	37.6	36	
	3'	4	39.3	31	
	4'	3.6	39.3	29	
	5' (5'6"B)	3	39.2	23	
# 7	1'	3	35.1	22	
N.Basin NE	2'	2.8	35.2	20	
	3'	1.8	35.2	14	
	4'	1.2	37.6	9	
	5' (5'6"*)	1.2 (0)	37.8 (38.3)	9 (0)	
# 8	1'	2.2	33.4	17	
N.Basin E	2'	2.1	35.3	15	
	3'	1.7	35.9	12	
	4'	1.1	37.6	3	
	5' (5'5"B)	0.7	38.3	5	
# 9	1'	2.3	34.5	18	
N.Basin SE	2'	1.8	35.9	13	
200' from	3'	1.5	36.4	11	
AerationHole	4' (5'B)	1.7 (0.5)	38.3 (39)	13 (4)	
# 10	1'	2.8	34.6	21	
N.Basin NW	2'	0.5	38.8	4	
	3'	0	39.2	0	
	4'B	0	39.2	0	
# 11	1'	4.2	34.2	30	
N. Basin	2'	3.2	38.3	24	
200'E of Dam	3'	3	39	23	
	4' (4'3"B)	2.3	39.3	18	

TABLE 6

January20, 1994 By the third week in January the ice depth had increased from 8" to 17" and snow depth was from 2 to 12" as wind drifted and moved snow freely over the lake. In most of the lake oxygen levels dropped to 0 below the 3' depth and below 5 mg/l throughout the entire lake. See TABLE 7.

The maximum oxygen condition just below the ice was 2.1 mg/l at the center of the north basin. The southern SE bay(#1) and SE north basin locations (#9, 75 yards north of aeration field) were completely void of oxygen. In general, all the sampling locations on the west side of the lake had more oxygen than the locations on the east side of the lake- where submerged peat beds and eroded peat material had settled. Muck soils which develop under aerobic(oxygen) conditions are also found on the west side of Thunder Lake as opposed to the peat soils found on the east side that develop because of anaerobic(without oxygen) conditions.

Table 7. Thunder Lake Oxygen-Temperature Profiles at 10 locations on Jan 20,1994

Location	Depth (feet)	Oxygen (mg/l)	Temp. (oF)	Oxygen Sat.(%)	er Data on 1-20-94	
# 1	2'	0	33.9	0	Ice: 17"	
S of SE Bays	3'	0	34.9	0	Snow: 2-12"	
	4'B*	0	36	0	* Bottom	
# 2	2'	1.2	33.8	9	Weather: Sunny	
S. Basin	3'	0	35.8	0		
	4'	0	38.3	0		
	5'	0	38.5	0		
	6'	0	38.8	0		
	7'B	0	39.6	0		TABLE 7
# 3	2'	1.8	34.6	13		
SW	3'	0.9	37.5	7		
	4'	0	37.8	0		
# 4	2'	1.8	35.3	13		
W	3'	0.9	35.8	7		
	4' (4'6"B)	0.4 (0)	38.7 (38.7)	3 (0)		
# 5	2'	1.2	33.9	9		
N.Basin W	3'	0.3	35.8	2		
	4'	0	38.8	0		
	5'B	0	39.2	0		
# 6	2'	2.1	35.1	15		
N.Basin Cent	3'	1	35.9	7		
	4'B	0	37.8	0		
# 7	2'	0.2	33.6	1		
N.Basin NE	3'	0	34.7	0		
	4'	0	35.3	0		
	5"6"B	0	37.5	0		
# 8	2'	-	-	-		
N.Basin E	3'	-	-	-		
	4'	-	-	-		
	5'	-	-	-		
	5'5"B	-	-	-		
# 9	2'	0	33.9	0		
N.Basin SE	3'	0	34.8	0		
200 ' From	4'	0	35.6	0		
AerationHole	5'	0	36.9	0		
	5.5'B	0	36.9	0		
#10	2'	-	-	-		
N.Basin NW	3'	-	-	-		
	4'B	-	-	-		
#11	2'	1.8	32.9	13		
N. Basin	3'	0	36.9	0		
200'E of Dan	4'	0	37.8	0		
	4'3"B	0	38.5	0		

February 21, 1994 By February, winds and a warm period cleared the ice of snow and clear ice was found over the entire lake varying in depth from 12" to 24". See TABLE 8. The sunny sampling date was preceeded by several sunny days which apparently triggered photosynthesis activity and oxygen production in several areas of the lake.

At location # 1 with 18" of clear ice oxygen levels remained at zero. Locations #2, 3, 4, and 10 oxygen levels continued to decline. At locations #5, 6, 7, & 9 oxygen levels rebounded slightly. At the center of the north basin (#6) and at the north basin location just east of the dam (#11) there were significant increases in oxygen. A large living weed bed was located just north of location # 6 and increased flows at the outlet (near location #11) from the winter thaw would account for oxygen increases at these locations.

Water temperatures on the bottom of Thunder Lake cooled to 35-36 oF in the north central and NE areas of the north basin (locations # 6 & 7) and the southern southeast bay(Location # 1). The rest of the lake's bottom cooled to near 37 oF in during February.

Table 8. Oxygen- Temperature Profiles of Thunder Lake on February 21, 1994.

TABLE 8

Location	Depth (feet)	Oxygen (mg/l)	Temp. (oF)	Oxygen Sat.(%)	ıer Data on 2-21-94
# 1	2'	0	33.3	0	ıather: Sunny 30oF
S of SE Bays	3'	0	34	0	ıunny Days Prior
	4'B*	0	35.1	0	<18" Clear Ice
# 2	2'	0.2	32.9	1	<24" Clear Ice
S. Basin	3'	0	34.3	0	
	4'	0	34.8	0	* B = Bottom
	5'	0	35.7	0	
	6' (6'3"B)	0	37.4	0	
# 3	2'	0.3	33.8	2	<12" Clear Ice
SW	3'	0	34.3	0	
# 4	2'	0.5	34.3	4	<17" Clear Ice
W	3'	0	34.8	0	
	4' (4'6"B)	0 (0)	35.7 (37.1)	0 (0)	
# 5	2'	2.3	34.3	16	16" Clear Ice
N.Basin W	3'	1	34.6	7	
	4'	0.2	34.8	2	
	5'3"B	0	37.8	0	
# 6	2'	5	33.3	35	<18" Clear Ice
N.Basin Cent	3'	0	34.6	0	ed Bed to the North
	4'	0	34.8	0	
	5'B	0	35.1	0	
# 7	2'	2.2	34.6	16	<17" Clear Ice
N.Basin NE	3'	1	35.3	7	
	4'	0	35.8	0	
	5'4"B	0	35.9	0	
# 8	2'	1.8	34.3	13	<18" Clear Ice
N.Basin E	3'	2.2	34.3	16	
	4'	1.2	34.8	9	
	5'	0.5	35.1	4	
	5'6"B	0	36.4	0	
# 9	2'	1.2	34.4	9	<16" Clear Ice
N.Basin SE	3'	0.3	34.4	2	
AerationHole	4'	0.1	34.8	1	
	5' (5'6"B)	0	37.4	0	
# 1 0	2'	0.5	34.2	4	17" Clear Ice
N.Basin NW	3'	0.2	34.4	1	SE of Weed Bed
	4'	0	34.8	0	
	4'11"B	0	37.4	0	
# 1 1	2'	5.3	33.6	37	13" Clear Ice
N. Basin	3'	1.4	34.3	10	; out from beaver lodge
200'E ofDam	4'B	0.2	37.9	2	

March 16, 1994 By mid March the ice was still clear and ice depth varied little from February 21. Again, the sunny sampling date was preceded by mostly sunny days prior to sampling. Several weep holes through the ice were observed indicating that pools of water that had collected on the surface of the ice were beginning to drain through holes in the ice.

There was a dramatic increase in dissolved oxygen levels at location #1 just beneath the ice in the southern south east bay of the lake. See TABLE 9. Phytoplankton was abundant in drill hole and through photosynthesis was producing an oxygen rebound at this location.

At locations #2 & 3 oxygen levels continued to decline though some oxygen was detected at the bottom of location #3. Oxygen levels increased slightly at locations #4 & 10. At locations #5, 6, & 7 - through the center of the north basin -oxygen levels again declined. At locations 8, 9, 10. & 11 there were oxygen increases. Increased water runoff from cranberry bogs and oxygen being added at the large aeration hole would account for increased oxygen at locations # 8 & 9; while increased flows from late winter thawing would increase oxygen's near the outlet.

The water temperatures found during the March sampling were warming with density stratification being replaced by uniform temperatures from top to bottom. The warmest water below the ice was found in shallow bays where spring seepage from upland soils occurred and where water movement was occurring near the outlet dam.

Table 9. Oxygen- Temperature Profiles of Thunder Lake on March 16, 1994.

Location	Depth (feet)	Oxygen (mg/l)	Temp. (oF)	Oxygen Sat.(%)	ıer Data on 3-16-94
# 1	2'	5.5	36.9	40	ather: Sunny, 10oF
S of SE Bays	3'	1.2	35.7	9	y Sunny Days Prior
	4'B*	0	35.7	0	Clear Ice,Phytoplankton
# 2	2'	0	38.8	0	
S. Basin	3'	0	38.8	0	<14" Clear Ice
	4'	0	38.8	0	
	4'8"B	0	38.8	0	
# 3	2'	0	37.4	0	<15" Clear Ice
SW	3'	0	39.2	0	TABLE 9
# 4	2'	1.8	37.4	13	<16" Clear Ice
W	3'	1.2	37.8	9	
	4'	1.2	37.8	9	
	5'B	0	39.2	0	
# 5	2'	0.5	38.8	4	<14" Clear Ice
N.Basin W	3'	0	38.8	0	
	4'B	0	39.2	0	
# 6	2'	0.8	38.3	6	<14" Clear Ice
N.BasinCntrl	3'				Heavy Cracking of Ice
	4'	0.5	39.2	4	
	5'	0.5	38.8	4	
	5'6"B	0	38.8	0	
# 7	2'	2.3	37.4	17	<17" Clear Ice
N.Basin NE	3'	2	37.9	15	
	4'	1.8	37.9	13	
	5'B	1.5	39.2	12	
# 8	2'	2.2	37.4	16	<13" Clear Ice
N.Basin E	3'	2	37.4	15	vater at Aeration Field
	4'	1.8	37.8	13	Trailer On Shore
	5'B	1.5	38.3	11	
# 9	2'	3.5	37.4	26	<16" Clear Ice
N.Basin SE	3'	3	36.9	22	
200 ' From	4'	1.2	37.4	9	
AerationHole	5'	1	37	7	
# 10	2'	1	39.2	8	<13" Clear Ice
N.Basin NW	3'	0.3	39.2	2	
	4'	0	39.2	2	
	5'B	0	39.2	2	
# 11	2'	3	39.2	23	<13" Clear Ice
N. Basin	3'	2.7	39.2	21	
200'E ofDam	4'B	1.8	39.2	14	
# 12					
N of SE Bays	2'	0.8	37.8	6	<14" Clear Ice
	3'	0.8	39.2	11	
	4'	0.8	39.2	11	
	4'4"B	0	39.2	0	

Discussion

The first extensive water quality evaluation of Thunder Lake occurred 1980-81. During the 1980-81 evaluation of the lake a healthy aquatic plant community was described; but even this aquatic plant community was different from the early plant communities of the 1940's and 50's. Even with this healthy aquatic plant community water quality problems were occuring as indicated by both summer and winter fish kills that occurred during that time.

The water quality of Thunder Lake- as well as the fishery and aquatic plant community- has changed drastically during the last 16 years since this survey. These changes are documented from 1985 to the present . From 1985 to 1996 water quality has improved as nutrient represented by various forms of phosphorus and nitrogen dissolved or suspended in the the water have been incorporated in aquatic plants and animals including fish and the organisms they feed on. See TABLE 5.

The attached aquatic plants that currently have grown to nuisance levels are the major nutrient sinks for the dissolved phorphorus and nitrogen that was causing the massive algae blooms in the mid 80's. This plant community change from the mid 1980's also has changed the lake physically. Suspended organic matter that at one time was swept off the bottom by wind induced wave action has been reduced by the massive weed beds that have formed; but the majority of plants that have returned thus far are plants that are fine-leaved and without much of a root system. They have the ability to remove nutrients from the water column and therefore can get an earlier start in the growing season than those aqautic plants with wider leaves and more extensive roots which must wait for the sediment to warm. It is these wide- leaved plants that dominated the lake in 1980 and before. These fine- leaved plants also decompose more quickly that add to the quicker oxygen depletion under the ice.

The fishery is also recovering despite low winter dissolved oxygen levels over most of the lake as oxygenated refuges exist in the aeration fields, seepage areas and other areas where photosynethesis periodically occur under the ice. A diverse fishery exist at this time, but will change further as the aquatic plant community changes.

The keys to the further recovery of Thunder Lake and prevention of the reoccurance of water quality problems in the past are to maintain a steady water level and continue to stabilize the bottom sediments. Improvement in winter oxygen levels will only occur if the sediments are stabolized on the shallow fringes of the lake increasing the depth of deep water areas and/ or a shift in the submerged aquatic plant community to wider-leaved and larger- rooted plants.

AQUATIC PLANT COMMUNITY

Introduction

Aquatic plant surveys were completed on Thunder Lake in 1980, 1988, 1992, and 1995. These surveys varied in methods and corresponded in time to recognize a full cycle of aquatic plant community changes from abundant submerged aquatic, to no submerged aquatic vegetation, and back to abundant but different submergent vegetation.

The 1980 survey was a part of a review of the lake's nutrients and water quality when submerged aquatic plants were abundant but when other water quality problems were evident. The 1988 plant survey was after several years of suspended solids suspension and algae blooms that limited light penetration and eliminated all submerged plants. In 1992 the submerged aquatic plant community was rebounding and by 1996 the aquatic plant community rebounded to nuisance levels of fine- leaved plants. From 1992 to 1995 their was a decrease in emergent and floating aquatic plants and an increase in the submergent plants.

An aquatic plant survey was scheduled as a part of the planning grant to assess the plant community and how changes in it effected the fishery. The Ambient Lake Monitoring Program completed the plant survey in 1995 and provided the results to the consultant. An analysis of this plant survey was made with emphasis on how it changed from and compared to past plant surveys in regards to the effects these changes had on the fish and waterfowl that depend on them. The results of this analysis follows.

Results & Discussion

Thunder Lake's shallow (but increased depth since the early 1900's) and large surface acreage are two factors that when combined have effected the aquatic plant community. It's current average depth is less than 5 feet. Thunder Lake's 1800 acres with flat terrain adjacent in nearly every direction, creates an aquatic environment greatly effected by the wind. Water level increases the last 80 years caused by the current 2 to 3 foot head concrete dam and the lower head peat and log dams it replaced has changed the original plant community significantly.

Little information on the earliest aquatic plant community of Thunder Lake is available but it was known that massive beds of wild rice were found throughout Thunder Lake when the low head log peat plug dam was in place from earlier in the century to the early 1940's. At that time the WPA built a concrete replacement dam with a head 1 foot higher than the peat log dams. This dam was washed out a few years later and was replaced by another town dam in 1948. Stable water levels are important in the development and maintaining any stable population of aquatic plants.

From 1948 to 1965 the wild rice beds dwindled until they were only found in areas along the south shore. Only a few small patches can be found periodically on the lake today. Ideal conditions for wild rice are: 1.) shallow water that is from a few inches deep to 2.5 feet, 2.) a muck bottom, 3.) sufficient water movement to prevent substrate stagnation, 4.)no appreciable amount of alkali in the water, and 5.) little changes in water level at critical times in plant development. The creation of a new dam with a greater head that altered storage and drainage patterns as well as effected shoreline and other littoral areas hydrology has created a situation where many of the factors that supported wild rice production in most of Thunder Lake have now been disrupted or changed.

Just as wild rice has certain requirements for growth and reproduction, other aquatic plants vary in the habitats and conditions in which they survive and thrive under. They all need light for photosynthesis but factors such as the depth of water they can grow in and the type of sediment they need for survival are quite specific. Aquatic plants are identified in the general categories of submergent, floating, or emergent.

It is these categories that the aquatic plants identified in the 1980, 1986,1988, 1992, and 1995 surveys were placed in for comparing the effects of water quality changes over time. Also, these categories are important in understanding aquatic plant values to fish and waterfowl.

Plant surveys categorize these plants into ratings of how often they occur, how dense they are, and how they compare in abundance to other aquatic plants. Early surveys- as the 1980 survey- used only a descriptions of scarce, present, or abundant under categories of Lake Wide, Where Present, and gave a rank for comparison to other plants. In the 1986 and 1988 survey, when free floating algae (phytoplankton) and suspended organic matter stopped light penetration there was little or no submergent vegetation found- and floating and emergent vegetation was only identified in the category- present. In 1992 and 1995 the more detailed numerical rating systems was used. The 1995 survey is by far the most detailed and comprehensive. These surveys are compared and analyzed below.

TABLE 10 list all the aquatic and semi-aquatic plants that have been identified in the Thunder Lake plant surveys by scientific name, common name, and plant characteristics as being the sumergent, emergent, or floating plants.

The 1992 and 1995 surveys are recent views that include the recovering submergent aquatic plant community after it's complete dissappearance in 1986. An interpretation and comparison of these two recent surveys indicates a further shift from an emergent/floating plant community to a submergent dominated community. The most alarming factor from the above shifting is that there was a 19% reduction in the 3 year period in the percentage of littoral(along the shore) area vegetated. The percentage of littoral area vegetated is calculated by dividing the number of vegetated plots by the total number of plots sampled.

In 1992 the twenty five plant species were identified of which 9 species had relative frequencies (RFRQ)*** of 5% or greater. See TABLE 11. The emergent plants include pickerelweed (12%), broadleaf cattail (9%), needle spikerush (5%) and pond sedge (5%). The floating plants included the bull-head pond lily (7%) and the white water lily (7%). The submergent plants were dominated by the common waterweed (11%) and the bushy pondweed (5%), and pipewort (5%).

In 1995 thirty seven plant species were identified and again 9 species were found with relatives frequencies (RFRQ)* ** of 5% or greater. See TABLE 12. The emergent plants were broadleaf cattail(8%), softstem bullrush (7%), and pickerelweed(5%). The floating plants included the bull-head pond lily (6%) and the burreed-S.chlorcarpum (5%). Submergent plants were dominated by small pondweed (10%), slender waterweed (8%,Elodea sp.), bladderwort (6%), and bushy pondweed (5%). Common waterweed and slender waterweed may have both been present in 1992 but because of their similarities they may both have been identified as common waterweed in 1992 where in 1995 they both were identified wih the more abundant slender waterweed.

Looking back to 1988(TABLE 11) the common or slender waterweed (Elodea sp.) was the first submergent aquatic plant to emerge from the 1986 poor water clarity times when no submergents were identified on Thunder Lake. These plants ability to tolerate cool water and low light conditions allows the entire plant to overwinter, continuing photsythesis at a reduced rate under the ice. They also can grow in water ranging from less than a foot to over 30 feet deep. Elodea sp. are most abundant over fine sediments enriched with organic matter but can tolerate almost any change in sediment conditions. These conditions of alkaline nutrient-rich water have been created in Thunder Lake by the erosion of the littoral bog areas.

*** **RFRQ** is the relative frequency that describes the occurrence of individual species in relation to other plant species found within the Thunder Lake population on a scale of 0-100.

FQR is the frequency(number)of occurrences for each plant specie divided by the number of plots the plant were found at minus the maximum rooting depth.

MDR 1 is an average species density calculated by adding the density rating for each specie and dividing the number of sampling plots where the species occurred.

Looking back even further to the extensive 1980 plant survey and the early more simple system of ranking species by abundance from one to ten waterweed (Elodea sp.) were ranked #1 on the lake that year (TABLE 13). It was the first plant to reappear in 1988 after a complete loss of submergent vegetation in 1986. It has held this ranking through 1992 and even into1995 if the two species of Elodea from this survey are combined. The rest of the plants that were found in Thunder Lake in 1980 are as follows:

#1 Waterweed (Elodea sp.)
#2 Richardson's pondweed*
#3 Bushy pondweed
#4 Wild celery or eel grass*
#5 Hill pondweed*
#6 Ribbonleaf pondweed* — *Wide-leaved & Firmly-rooted

#7 Small pondweed** — ** Fine-leaved & Firmly-rooted
#8 Spiked watermilfoil
#9 Variableleaf pondweed*
#10 Largeleaf pondweed*

The most significant fact when comparing the1980 and 1995 surveys is the complete loss of submerged aquatic plants with wide or long leaves or larger and more extensive root systems. Looking at the above list of submergent plants found in 1980- six species of wide leaf, firmly-rooted submergent plants have completely dissappeared from the lake. One firmly-rooted, but fine-leaved plant has also disappeared.

Two firmly-rooted wide-leaved plants identified in 1992, the whitestem pondweed and the flatstem pondweed, had disappeared by 1995. Also, wild celery identified in 1994 in the north dam area has also disappeared or were not identified in the 1995 survey. The presence of these plants in 1992 and during the 1994 field observations was an indicator that Thunder Lake's healthy plant population of wide-leaved and firmly-rooted vegetation could be returning.

The more recent 1995 survey indicates this healthy aquatic plant population is not returning but at the present the Thunder Lake submerged aquatic plant community is now dominated by fine-leaved species. These plants have special adaptions that allows them to live in cold water under the ice under low light conditions and store carbohydrates and nutrients over winter to support rapid growth in the spring. Another plant that is doing well in Thunder Lake, bushy pondweed, completely dies back by winter but produces a large number of seeds with heavy coats that withstand the rigors of winter and are genetically enhanced for survival the next season. The severe winter of 1995-1996 with ice depths to 3 feet and a heavy snow cover favor these plants fine- leaved plants even further.

Conclusions

The importance of a plant community to the fishery and waterfowl populations of Thunder Lake is documented in Tables 14 and 15. The latest plant survey indicates that the floating and emergent vegetation- so important for fish and waterfowl nesting, food, and cover- is being replaced by submergent vegetation that do not produce these qualities. Worse yet, the submergent vegetation is now dominated by fine-leaved and poorly- rooted plants that store most of the lake's nutrients they absorb in the stem and leaf structure not in their roots. The wide-leaved submergent plants - such as the Richardson Pondweed- that dominated the lake in 1980- had broad leaves and stored nutrients in their firm roots. When comparing a narrow-leaved plant population to a wide leaf plant population the narrow leaf population is more dense and easily reaches nuisance levels.

These dense, fine- leaved submergent plants can restrict fish movement that keeps the largemouth bass, walleye, or other game fish (especially larger individuals) from reaching prey species such as the pumpkinseed sunfish and yellow perch in Thunder Lake. If these plants persist, stunting of the prey species can occur. But at present these same fine-leaved plants are excellent habitat for small clams that yellow perch of all sizes are utilizing. The corresponding loss in floating and emergent aquatic plants decreases cover needed by fish for shade and spawning and protection from bird predation. Cormorants,osprey, and eagles are fish predators that have taken advantage of these changes in the aquatic plant population.

These dense fine-leaved plants also effect the movement and feeding of certain dabbling and diving waterfowl. The large coot population that dominated the fall flight in 1996 feeds predominately on the small mollusks(clams) that thrives in the fine-leaved plants that now dominate the lake. The loss of emergent and floating aquatic vegetation has removed specific food items required for both resident and migrating ducks. Loss of this type of vegetation cover has also effected the nest and brood survival of resident ducks through increase predation by eagles.

The effects that these changes in the aquatic plant community have gone beyond their effects on the fish and waterfowl. They also have severely effected water quality and recreational use of the lake. Erosion of the bog areas and settling of the detritus over much of the lake has made the lake shallower in the deeper areas, and tapered shallow shoreline areas have became deeper overrall. Loss of emergent, floating, and submergent plants with extensive root development that stabolizes shoreline and shallow areas has increased this erosion process even further. Water loss from Thunder Lake from evaporation is greater in the increased open water than when a smaller surface area was bordered by bog and other emergent/floating wetland communities. Motor trolling in the spring that only a few years ago was possible is now impossible due to the early growth of fine-leaved submergent. Navigation is restricted by these aquatic plants and increased shallowness especially in the south bay where most of the development and access occurs.

FISHERIES OF THUNDER LAKE

Introduction & History

Thunder Lake's first recorded fishery history began with fish stocking in 1934 or about 10-15 years after the bog to the north and east of the lake was drained and a peat dam was left to maintain water levels in the open water areas. See Fish Stocking History in TABLE 16. From 1934 to 1945 walleye,northern pike, largemouth bass, yellow perch, bluegill, rock bass, and suckers were stocked and from that time on stocking centered around walleye and largemouth bass stocking. Good winter oxygen levels were recorded in the winter of 1939-40 which was followed by extensive walleye fry stocking for the next 5 years.

A conflict between duck hunting sportsmen and resort owners over a lower water level condusive for wild rice production and a higher one for navigation and a fishery dominated the in the early 1940's. A permanent concrete dam capable of holding the lake 1' higher than the present log/peat dam was built with WPA money as was a second dam at the entrance to Rice Lake to restore the present Thunder Lake wildlife area drained in the 1920's. At the same time cranberry bog contruction began in the adjacent marshes. Both dams were in unstable peat areas and were subject to washout. The Rice Lake dam was soon abandoned and Thunder Lake dam hard to maintain.

Probably because of this conflict , the first recorded fish survey was conducted September 24-27, 1947. Survey results are documented below in TABLE 17. The intensive fry stocking in the early years appeared to have created a healthy walleye fishery with a main forage-panfish base of yellow perch and suckers. According to the stocking records the last walleye fry were stocked in 1945 or nearly two and one hal f years before the survey. The six & seven inch walleye identified in this survey appear to be from natural spawning. With three growing seasons since the last stocking the walleye fry from this planting should be much larger. Very large bullheads were also found- it appears these opportunistic feeders were also utilizing the forage base and nutrients available in this impoundment.

A year after the survey the concrete dam at the outlet of Thunder Lake washed out "damaging the fish population". The dam was rebuilt in 1948 by the township with help from the Wisconsin Waters Regulatory Board.

Stocking of walleye and muskellunge began again in 1950 and continued until 1958. Dissolved oxygen were watched closely in the lake as profiles were taken in 1951, 1955, 1956, and 1959. By 1955 nuisance levels of aquatic plants were noted on the south end of the lake in front of Sky View Lodge (now Cedar Crest Resort) and by 1961 floating bogs were a problem in the lake- approximately 10 to 15 years after the lake was raised at least 1 foot. Wild rice became abundant on the south shore property of Alvin Schimke at 2500 Ander Road in 1965, probably due to the increased organic sediment load from the erosion and blowing of bogs around the lake.

From 1958 to 1977 no stocking by the conservation department occurred though a proposal to stock muskellunge in 1975 was stifled by a petition against it. During the winter of 1976-77 a winter fish kill occurred and was documented as being caused by low summer and winter water levels but was also caused by the increased organic load noted above. A spring shocker survey was conducted on April 20, 1977 and the results are also included with the 1947 results below in TABLE 17.

TABLE 17. Early Fisheries Surveys of Thunder Lake.

	1947 Survey Results							
	N.Pike	**LMB**	**WE**	**Y.Perch**	**Sunfish**	**RockBass**	**Sucker**	**Bullhead**
2-2.9"				4				
3-3.9"								
4-4.9"		1		10				
5-5.9"				8	3	2		
6-6.9"			10	37		1		
7-7.9"			7	22	1			
8-8.9"				8	7			
9-9.9"				13				
10-10.9"				10				1
11-11.9"			1	2				2
12-12.9"	1		23					11
13-13.9"			75					10
14-14.9"			76					1
15-15.9"			18					
16-16.9"	1		6					
17-17.9"			2					
18-18.9"	2							
19-19.9"	2							
20-20.9"								
21-21.9			1					
Totals	**6**	**1**	**219**	**114**	**11**	**3**	**204**	**25**

1977 Survey Results After Winterkill

N.Pike: 17.0", 22.5", 22.5",21.8"
Y.Perch: 3.8", 4.3", 5.5", 5.7", 6.0", 6.5", 6.5", 6.6", 7.4", 7.8"
Sunfish(Pumpkinseed): 3.4"
Bl.Bullhead: 7.8", 7.9", 8.4", 8.6", 9.3"

Other Yellow Perch, Sunfish, Bullheads, White Suckers, and Golden Shiners observed. No walleyes or Muskellunge observed or captured.

After the 1977 fish kill and shocker survey 2 million walleye fry were stocked in early May and 90,000 fingerlings in August of 1978. Two million walleye fry were again stocked in May 79 followed by stocking of 11,700 largemouth bass fingerling in July. Fifty thousand 1" LMB were again stocked in June 1981.

From 1980 to1987 757,230 walleye fingerlings were stocked in Thunder Lake during July and August. These were the poorest water quality times for Thunder Lake. Winter- spring fish kills occurred in 1979 and 1981 and low winter oxygen levels were documented from this time forward. A lake district was formed in 1982 to address the low winter oxygen problems and by 1984 an aeration system was installed by the district. Water quality problems from suspended organic matter in the water and algae blooms completely destroyed all submergent plant life and fish cover by 1985. The lake was soon overrun with bullheads. An electrical boom shocker survey of the east side of the lake to assess the survival of walleye stocked was made on October 21, 1986. The results were as follows:

Yellow Perch	1- 5.1"
Black Bullhead	19- 4.5 to 6.8"
Golden Shiners	3- 2.9 to 4.8"
Redear Sunfish	1- 5.9"

In 1987 50 tons of bullheads were removed by the Thunder Lake P & R Disrict. In 1988, chemical eradication of the bullheads was considered by the DNR but was found to be too costly. In 1987 erosion on the north and east shores increased and was documented by water clarity monitoring in 1988. Heavy algae blooms- that further affected water clarity- were then documented in 1989 & 90. A shocker survey in 1989 found very few fish.

In the fall of 1990 the Thunder Lake Protection & Rehabilitation District began an intensive stocking effort to restore the gamefish population of Thunder Lake. From 1990 to 1993 over 7,000 large fingerling walleyes from 8-10" and 5,000 largemouth bass fron 4-10" were stocked in the lake. This effort coincided with an improvement in water quality as rains and cool weather relieved the drought conditions of the late 1980's. Corresponding with this cool weather and stocking effort the bullhead population began to decline. Cooler summer water temperatures hampered bullhead spawning success and growth. By 1994 fewer schools of black bullheads young were observed and the overall size began to increase. At the same time by 1992 the fine-leaved aquatic plant population was returning and summer water clarity conditions were improving.

The dramatic changes in water quality and the collapse of the fishery in the 1980's prompted the Thunder Lake District to develope a long term planning strategy: therefore the district applied for a planning grant to recognize what could be done to avoid the reoccurrence of these conditions in the future.

ANALYSIS OF FISHERY

Procedure

The intent of this part of the first phase of the planning grant was to inventory the current fishery resources in regard to age,growth, and population. This inventory was then to be combined with current resource information and observations of water quality and habitat for ecological interpretation. From this information, fishery recommendations in regard to stocking, habitat development, and regulations were presented at the bi-annual meetings and are documented in this report.

The inventory of the current fishery resource was completed by:

1.) Spring and summer field observations of habitat and spawning areas in 1994 & 1995,

2.) An extensive panfish survey in partnership with DNR Fisheries personnel in June 1994, with age/ growth analysis 1995.

3.) A collection of scales of gamefish during the panfish survey for age/ growth analysis,

4.) Fall of 1994 shoreline seining for young-of-the year production and boom shocker sampling in the fall of1994 & 1995 for walleye recruitment, and fall 1996 for gamefish winterkill assessement.

5.) interviews with residents regarding their personnel observation on fishing success and pressures.

Results and Discussion

As lake evaluation preparations began in November 1993 the results of an improved fisheries of Thunder Lake were already appearing. Ice cover brought fishing pressure to Thunder Lake during the winter of 1992-93. Limits of 5 , 17 to 20" wallleye were being caught on a regular basis. The lake district was concerned with this sudden pressure on this predator fish and moved for emergency closure of the ice fishery in December 1994 through a recently approved state regulations for emergency closure. Though the situation of a rehabilitating fishery on Thunder Lake met the requirements of the new emergency closure law the Department of Natural Resources interpreted it did not apply to the "partial" closure proposed and yet could not justify the any closure without an up to date survey.

A meeting was held on November 10, 1993 with Department personnel to arrange a cooperative fishery survey of Thunder Lake and discuss a bag limit reduction for walleye to 2 to coincide with other area lake bag limits and to reduce fishing pressure on the recovering walleye fishery. A creel survey of ice fisherman was proposed as apart of the fisheries survey but the volunteer time and planning grant proposal objectives could not accommodate the DNR requirements for the creel survey. A cooperative effort for summer and fall analysis of the fishery was arranged. An 18 month process to reduce the bag limit was began by the department and the district also went forward to present it at the spring Conservation Congress hearing.

Winter under the ice oxygen/ temperature evaluations found low oxygen conditions at most of the eleven sites selected from December to March though clear ice and the aeration system provided oxygen through attached plant and phytoplankton photosynthesis as well as open water air contact. See Water Quality Section for these results.

A winter review of the historic fishery data of Thunder Lake revealed a exceptional walleye-perch fishery with an additional excellent sucker forage base during the early years of the documented fishery history. The key to the successful restoration of the fishery - besides maintaining a predator population- was to maintain and restore a yellow perch fishery. Yellow perch has the ability to 1.) sustain low dissolved oxygen, 2.) build a large population quickly under the present conditions, 3.) compete with the bullheads, and 4.) provide excellent forage for the walleye and northern, and crappies.

Ice out occurred on April 16 and temperature of the lake reached 43 oF on April 20, 1994. Yellow perch spawn shortly after ice out and the temperature observed above would correspond to peak walleye spawning.

On May 7 1994, the entire lake shoreline, including the shoreline of the large island, was surveyed for yellow perch spawning areas. The water temperature was 53 oF at 10:00 am. Yellow perch egg strands were found in the protected bays of Thunder Lake at the locations marked in FIGURE 4. The eggs were found in sandy bottom areas drapped over the previous season still-standing bullrush beds or on old cattail beds over soft sediment but still near sandy shoreline areas. At most locations the eggs had eyed up and body development was also observed. One area where the egg ribbon was tangled in cattails and soft sediment the eggs had turned white and died. Protected bays, emergent vegetation that is standing at ice out, and a sand bottom free of organic accumulations are all important to the survival of yellow perch spawn.

Also on this date the south-southeast shoreline of the north bay of Thunder Lake was sampled for walleye eggs and/or emerging walleye fry. Area residents had observed that walleye had been active at ice out in this area in the past. This is the only area of the lake with large areas of wind- swept rock rubble which would be a primary spawning habitat for walleyes. Five bottom areas were swept with D-frame dip net and no walleye eggs or fry were found.

On June 2 the entire shoreline described above was surveyed to identify largemouth bass and other nest building fish spawning areas. The water temperature in shallows at the dam and at the Cedar Crest Resort on the south shore was 64 oF at mid day and rose to 68 oF at the dam by 4:00 pm. These temperatures correspond to largemouth bass nest construction and spawning activity. Lake oxygen levels were 8.0 mg/l on the south shore and 8.5 mg/l at the dam.