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

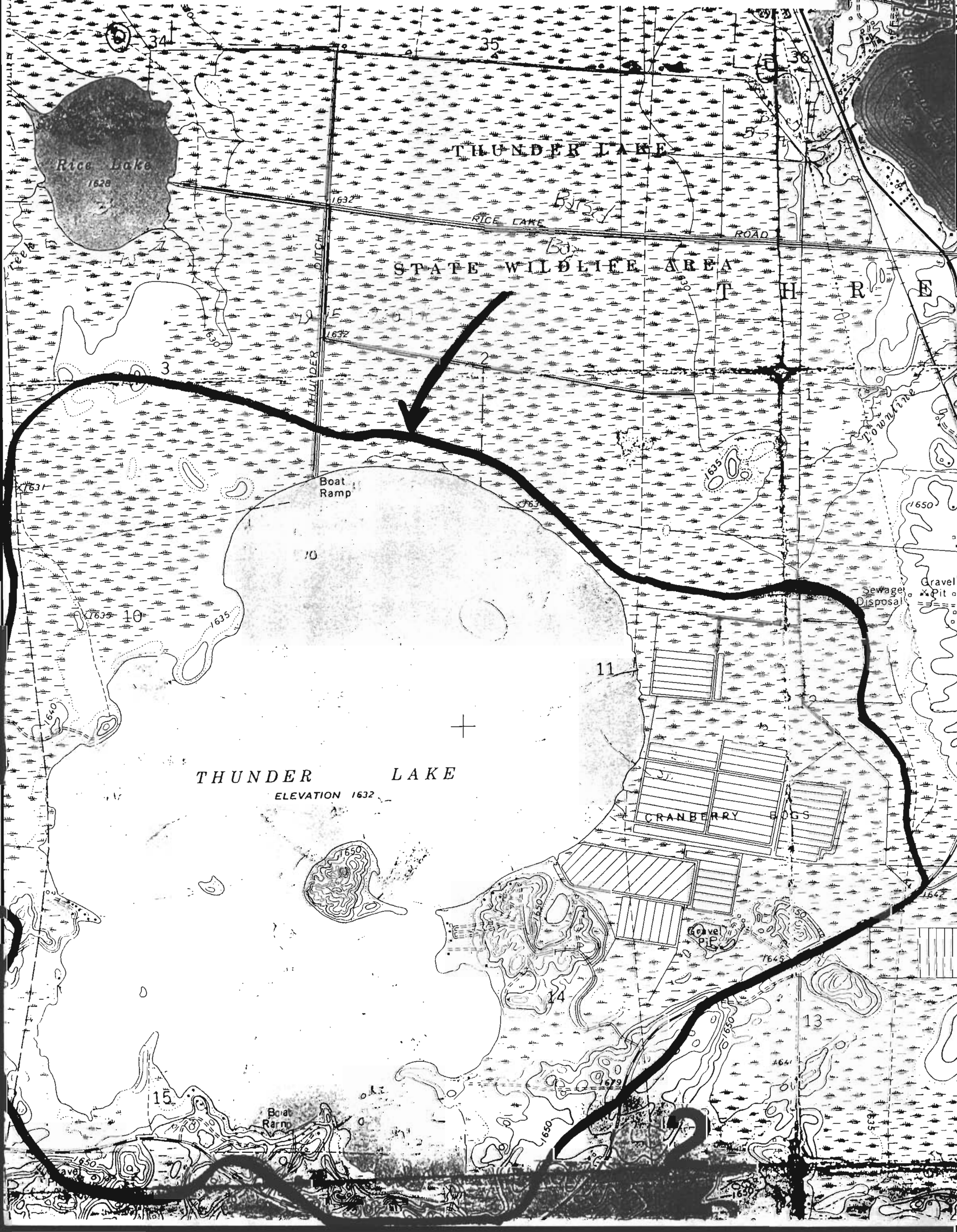
Thunder Lake is an 1800 acre impoundment whose shoreline is bordered by an upland watershed to the south, southwest and southeast. Extensive marsh areas surround the rest of the lake to the east,west and north. The soils and the underlying glacial materials that makeup the upland and marsh areas of the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

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.

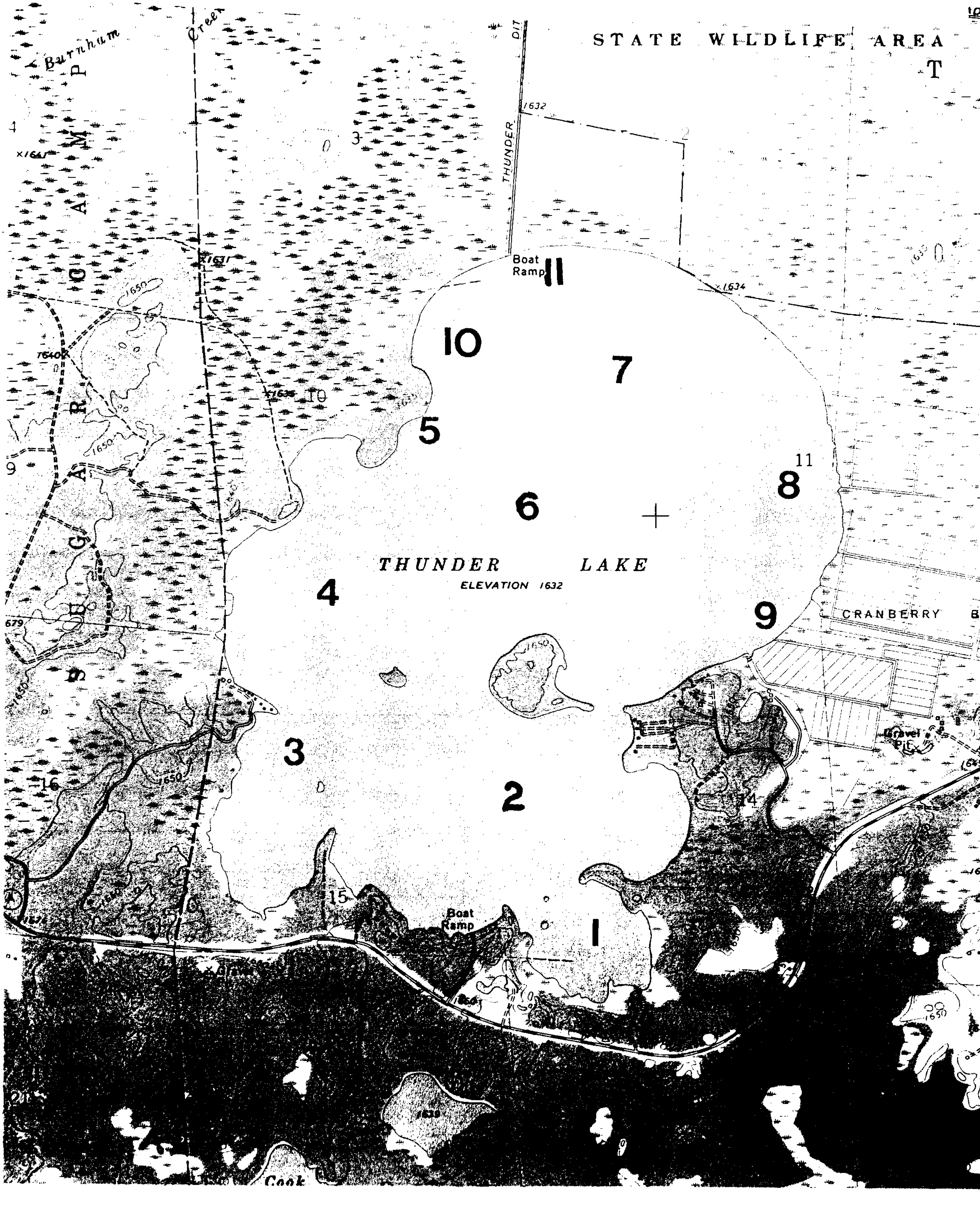


Table 6 . Oxygen- Temperature Profiles of Thunder Lake on December 21, 1993.

TABLE 6

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	

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 Dam	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.(%)	er Data on 2-21-94
# 1	2'	0	33.3	0	ather: Sunny 30oF
S of SE Bays	3'	0	34	0	unny 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.

TABLE 9

Location	Depth (feet)	Oxygen (mg/l)	Temp. (oF)	Oxygen Sat.(%)	ier 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	lear 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	
# 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%,<u>Elodea</u> 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 (<u>Elodea sp</u>.) 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. <u>Elodea sp</u>. 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.

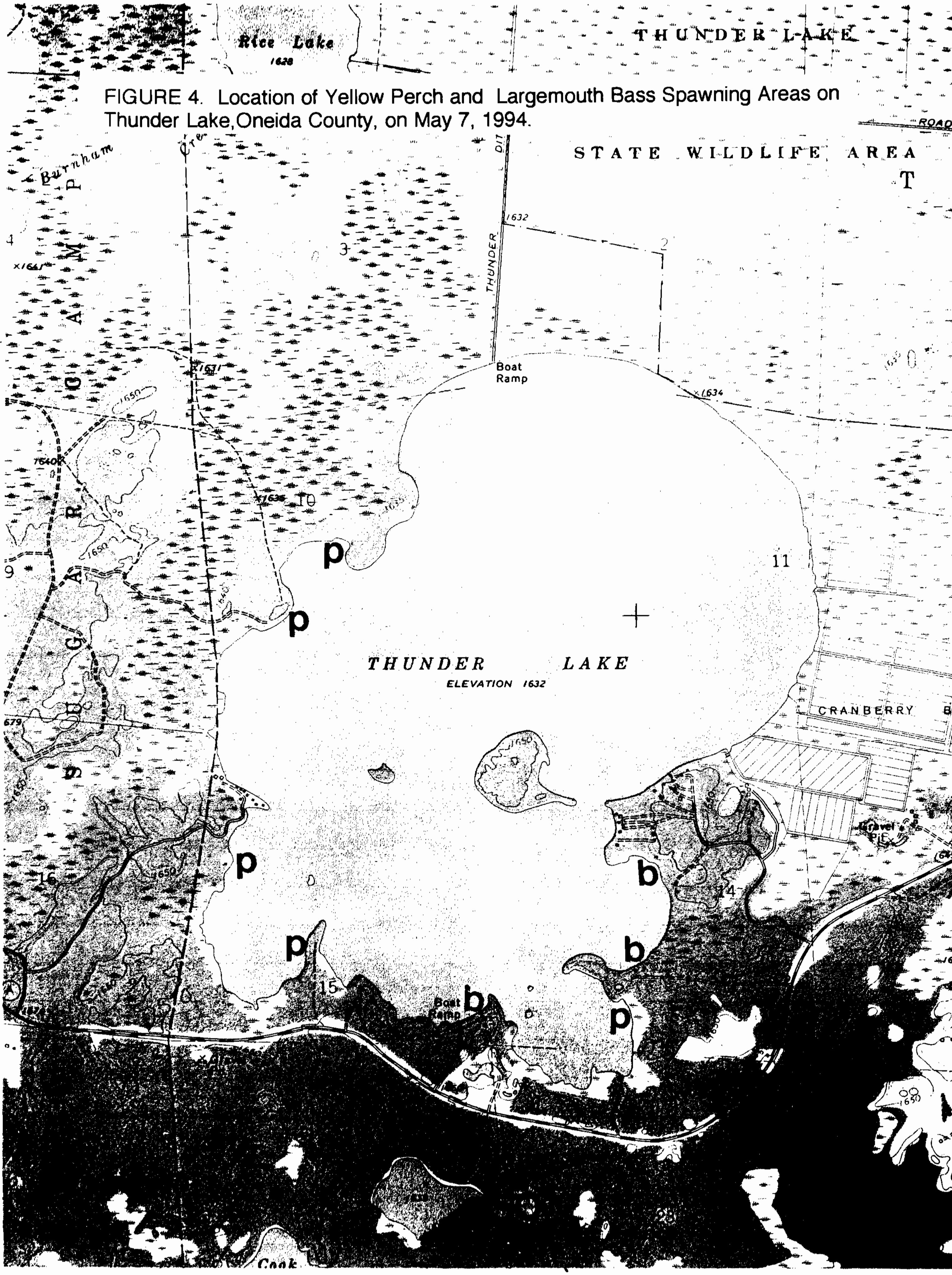


FIGURE 4. Location of Yellow Perch and Largemouth Bass Spawning Areas on Thunder Lake,Oneida County, on May 7, 1994.

Three largemouth bass nesting areas were identified but no panfish nest were observed. There locations are identified in FIGURE 4. These bed were located in protected bay areas of sand and gravel with newly emerging vegetation adjacent to the beds. These plants protected the nesting bass from the eagles that were perched on the small island in this area. As the season progresses and the emerging vegetation develops it will provide further protection for the fry and protective parent until yolk sac absorption occurs and they moved to open water areas to feed on zooplankton.

Windrowed large phytoplanktonic algae was present on areas adjacent to the spawning beds as the wind shifted from the northwest to northeast during the survey. What effect would the windrowed algae have on egg spawn if the nesting bass is not able to keep the nest clean of the algae? On other lakes many bass and panfish nest have been observed abandoned by their caretakers and the eggs were found dead with fungus growing on them. Could have dead and decaying algae contributed to this situation? Elodea plants in beds in the south southeast bay of the lake were also found covered with a thick layer of silt. It is obvious that protected areas for spawning fish are limited in Thunder Lake not only by suitable substrate but also by suitable substrate areas not exposed to settling of suspended matter.

From June 20 -24 an extensive fyke net survey targeted at panfish was conducted on Thunder Lake. Net locations are described in FIGURE 5. A net located at the east bay of the big island was moved after the first day to west of the dam. A total of 11,120 fish were captured during the survey. An overview of the survey can be found in TABLE 18 below. This overview was presented at the fall meeting of the Thunder Lake District. Walleye scales were removed during the survey and used to determine age and growth. The results of the walleye aging process was also presented at the meeting and the is documented below.

TABLE 18. Overview Panfish Survey of Thunder Lake, Oneida County conducted from June 20 to June 24, 1994.*

Species	# Captured	Size Range	Dominate Size
Black Bullhead	5,926	8.1- 10.4"	8.5- 9.5"
Pumpkinseed	3,345	3.5- 7.5"	5.1- 6.0"
Yellow Perch	1,407	4.7- 10.6"	6.1- 7.0"
Black Crappie	263	5.2- 12.6	7.8-8.7"
Bluegill	70	5.5- 8.8"	6.2-8.2"
Yellow Bullhead	13	7.6- 11.0"	
Bluegill x Pumpkinseed	4	-	6.8 " (1)
Green Sunfish	1	-	
White Sucker	5	10.5- 11.4"	
Golden Shiner	50	5.8- 7.7"	
Walleye	24	8.5- 22.0"	
Northern Pike	10	11.5- 30.2"	
Largemouth Bass	2	4.7- 5.3"	

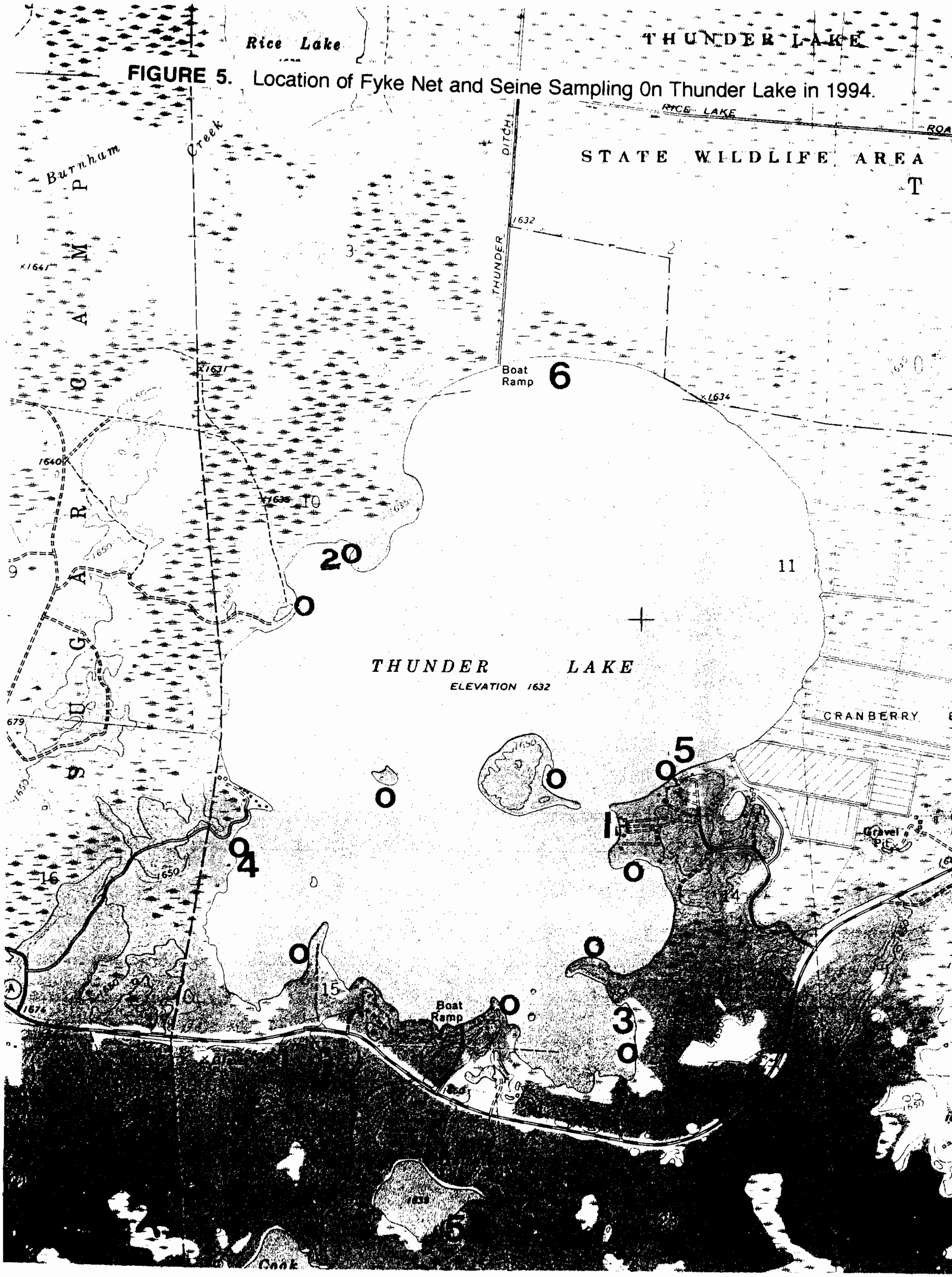


FIGURE 5. Location of Fyke Net and Seine Sampling 0n Thunder Lake in 1994.

A comparison of walleye ages and year classes indicates that all the walleye found in the summer survey could have originated from either extended growth fingerlings/ yearling stocked in the fall or summer stocked young-of-the-year. The question if natural reproduction is occurring and contributing to the fishery was not answered in this analysis.

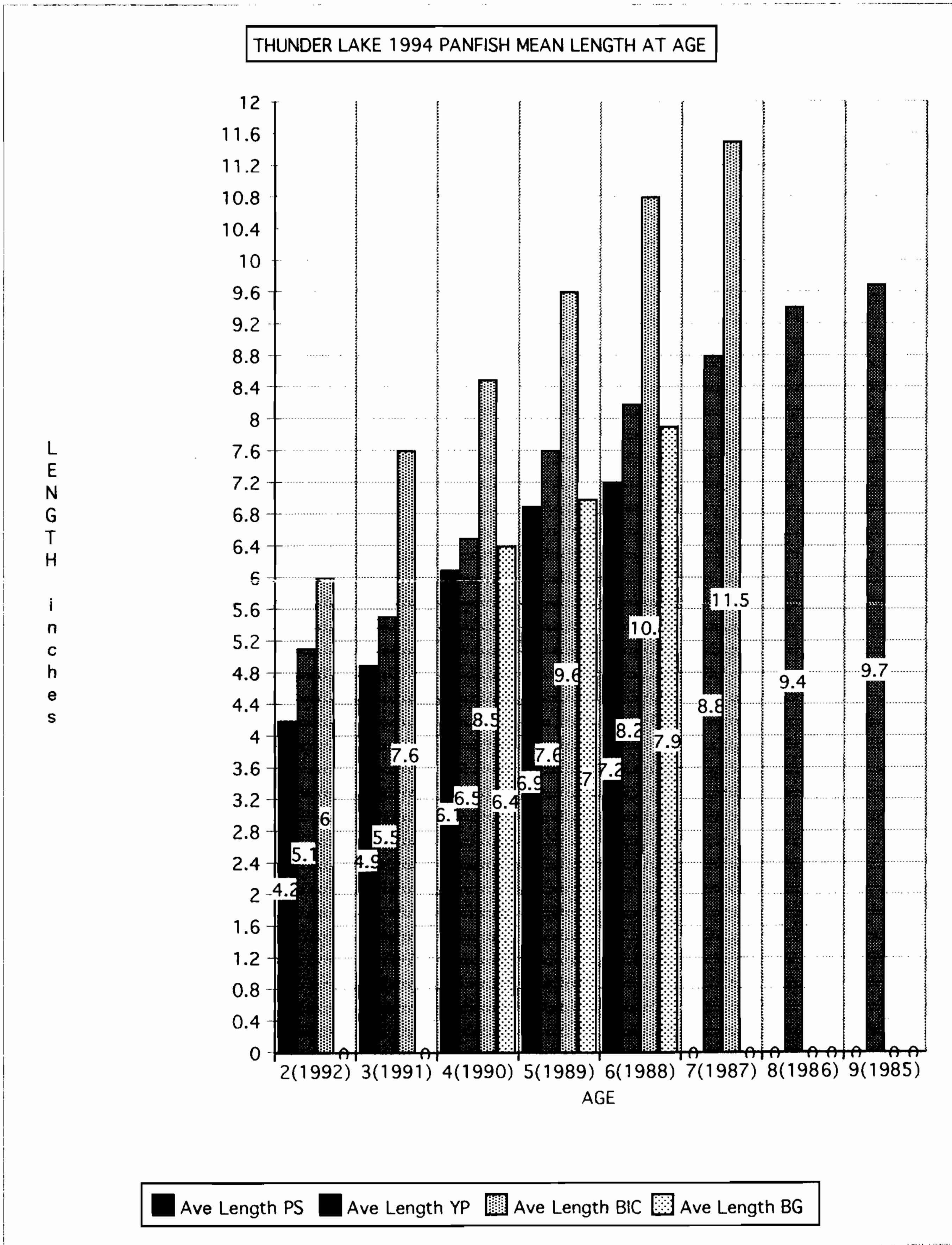
Walleye Length	# Captured	Age	Young of the Year
8.5- 8.9"	2	2+	1992
9.5- 9.9"	1	-	No scale taken
10.5- 10.9"	3	2+	1992
12.5- 12.9"	1	2+	1992
15.5- 15.9"	1	3+	1991
16.0- 16.4"	2	3+	1991
17.0- 17.4"	1	4+	1990
17.5- 17.9"	3	4+	1990
18.0- 18.4"	3	5+	1989
18.5- 18.9"	2	6+	1988
19.0 -19.4"	3	6+,8+	1988, 1986
19.5- 19.9"	2	7+,8+	1987,1986
20.0- 20.4"	1	7+	1987
22.0- 22.4"	1	10+	1984

In a September 22, 1995 DNR report stated that the "1994 panfish age growth in general were good and met or exceeded the averages for this portion of northern Wisconsin". This age growth data is documented below in FIGURE 6.

In reviewing the age/ growth data and corresponding capture numbers in each particular age group it appears that the strongest year classes for bluegill, punpkinseed, and black crappie were in 1990. The strongest year class for yellow perch was in 1989. When compared to seechi disc and water quality data, it is during these years that water quality was improving drastically. In 1990 the lake was low with an early ice out (April 9) and was 4-6" low throughout the growing season. Water clarity during this time was limited to less than 2 feet because of an intense planktonic algae bloom. Zooplankton -whose density is proportional to planktonic algae levels they feed on - is the food needed by post larval fish to establish a strong year class. It is apparent this food source was available in 1990 for the nesting species above.

In 1989 ice out occurred late (April 24) and planktonic algae was abundant and limiting seechi visibility to less than 1.5' from around June 1 to Mid July. Water levels were near normal. This would correspond to critical feeding times for post larval yellow perch but not for the later nesting species who faced turbid conditions.

FIGURE 6. Mean Length/ Age Thunder Lake Panfish in June 1994.



On September 28, 1994 a fall seining survey of shallow water areas was conducted to assess young of the year production. Five seinable locations were identified and seined. Their locations are marked in FIGURE 5 with the ten summer fyke netting locations. A summary of the fish captured is documented below:

Species	# Captured	Size Range	Average Size
Yellow Perch	150	2.1- 3.3"	2.5"
Yellow Perch	40	3.8- 4.8"	4.3"
Yellow Perch	13	5.6- 8.2"	-
Largemouth Bass	39	1.5- 4.0"	2.6"
Pumpkinseed	35	1.0 -2.6"	1.75"
Black Crappie	15	1.5- 3.5"	2.6"
Johnny Darter	1	1.8"	
Bullhead	1	1.8"	

The presence of large numbers of yellow perch young is a good indication of the recovery of the perch fishery. The number of young-of-the-year largemouth present is also a good sign of restablishment of a predator bass fishery so important in maintaining a healthy pan fishery- as well as supressing the bullhead population The extensive stocking of largemouth bass in 1992 & 1993 has established a mature population with high reproductive capacities that should be self- sustaining - if any further water quality problems are avoided.

The importance of the south and west sand and gravel shoreline areas as spawning and nursery habitat for young-of-the-year fish is evident from the seining effort. Seining locations #1 and #3 in the southeast corner of the lake produced the majority of the fish in this seining effort. The importance of floating and emergent vegetation, such as burreed and bullrush, growing on these sand areas of the lake for young of the year fish food and cover cannot be disputed.

This seining effort was combined with a fall boom shocking survey on October 11, 1994 to assess walleye recruitment. The department stocked 30,000 walleye fry in May and 15,000 fingerling in July that year. None of these stocked fish appeared in this survey. The results from this survey are documented below:

Species	# Captured	Size Range	Average Size
Northern Pike	5	19.9- 29.5"	22.4"
Largemouth Bass	4	3.2- 5.1"	4.4"
Largemouth Bass	3	13.5- 14.6"	13.9"
Smallmouth Bass	1	4.2"	
Walleye	2	7.0- 7.2"	7.1"
Walleye	18	10.2- 13.6"	11.8"
Walleye	14	14.0- 16.8"	15.5"
Walleye	8	17.1- 17.9"	17.5"
Walleye	6	18.2- 19.4"	18.9"
Walleye	3	20.1- 20.9"	20.4"
Walleye	1	25.1"	

A second fall boom shocking survey was completed on September 27, 1995 to again assess walleye recruitment. 46,004 walleye were stocked on September 5, 1995. An algae bloom was occurring during the sampling and plant growth thick so it was noted that the visibility and dipping efficiency was poor. Few Age 0 walleyes stocked were captured. The results of this fall of 1995 survey is noted below:

Species	# Captured	Size Range	Average Size
Northern Pike	17	17.5- 26.9"	
Largemouth Bass	23	2.6- 15.4"	
Walleye(Age 0+)	9	2.7- 6.8"	6.2"
Walleye(Age 1+)	32	7.3- 10.6"	8.8" & 10.6"
Walleye(other)	47	11.2- 25.9"	

Other Species Observed	Size Range	Abundance
Black Crappie	2.0- 12.0"	Abundant
Yellow Perch	2.0- 9.0"	Abundant
Golden Shiner	2.0- 4.0"	Abundant
Pumpkinseed	2.0- 7.0"	Common
Bluegill	2.0- 6.0"	Present
White Sucker	6.0- 14.0"	Present
Yellow Bullhead	5.0- 10.0"	Common
Black Bullhead	5.0- 10.0"	Common

The latest fishery assessment of the lake occurred on October 15, 1996 when a boom shocker survey was made to assess the effects of a gamefish winterkill after the severe winter 1995-96. The entire shoreline was covered as in 1995. No stocking occurred in 1995. Again , No Age O Walleye were captured. The results of this survey are modified from the DNR fisheries staff SUMMARY FISHING RECORD as Walleye(other) was reported as 0 and all the DATA COLLECTION SHEET walleye numbers were not forwarded to the front sheet. The results are as follows:

Species	# Captured	Size Range	Average Size
Northern Pike	4	19.0- 23.5"	
Largemouth Bass	7	12.4- 18.0"	
Walleye(Age 0+)	0		
Walleye(Age 1+)	3	8.3- 9.2"	8.6"*
Walleye(other)	28	11.0- 23.4"	

*** Lake District Stocking Week Prior**

Other Species Observed	Size Range	Abundance
Black Crappie		Abundant
Yellow Perch		Common
Golden Shiner		Common
Yellow Bullhead		Common
Pumpkinseed		Present
Bluegill		Present
Northern Pike		Common

The current fishery of Thunder Lake reflects other shallow lakes that face periodic low oxygen, abundant vegetation, abundant food, and often low transparency. The fish that do best under these conditions have recovered the fasted as water quality improved from the 1980's.

The black crappie that is always associated with an abundant growth of aquatic vegetation, likes clear to slightly turbid water, and has a low oxygen threshhold is in prime habitat under the present conditions of Thunder Lake. As a mid- water feeder, it feeds among aquatic vegetation in open water habitat that now abounds in Thunder Lake. It's numerous gill rakers gives it the ability to feed on the smallest crustacean zooplankton and and the same time it's largemouth allows it to feed on almost any fish of any size during some period of it's life- all of these food organisms are thriving in Thunder Lake. Also remember that it actively feeds during the winter and does not go into semihibernation as other fish in it's centrachid family do. The black crappie fishery of Thunder Lake should be watched closely as the removal of larger fish through selective fishing can cause crowded populations of stunted crappies. Also at the same time they can quickly dominate other panfish. Predator control is nearly impossible once this happens. In the observations of the last two fall boom shocker surveys in the fall of 1995 & 1996 yellow perch and golden shiner- that were listed as abundant along with the black crappie in 1995- have dropped to a only common abundance in 1996.

Also there is a possible shift in the bullhead population. Yellow bullheads maybe replacing the black bullhead. Black bullheads are more tolerant of siltation, turbidity, and warmer than the yellow bullhead. As conditions have improved and the water has cleared yellow bullheads do better. These are boom shocker observations and distinquishing the two apart in poor visibility could also account for this change.

The golden shiner population appears to be thriving under the current Thunder Lake conditions. It is a fractional spawner as it begins laying eggs when the water temperature reaches 68 oF and continues to spawn as long as temperatures stay above it. It spawns over very dense submerged vegetation which at this time is dominate in Thunder Lake. It also feeds on many of the fine-leaved plants that dominate the center of Thunder Lake; but it also feeds on burreed and emerging aquatic insects(especially emerging mosquitoes) with it's upturned mouth. It can survive the lowest oxygen's of winter with the larger reproducing individuals tolerating lower oxygen than their smaller young. These open water habits concide with it's principle predator in Thunder Lake- the black crappie. The expanding population of black crappies is probably directly related to the abundance of golden shiner. A decrease in shiner numbers in the future maybe an indicator of crowded crappies in the future. Largemouth bass, northern pike, and walleye predators will also be competing for this forage also.

Low winter oxygen's also favor the pumpkinseed, yellow perch, and northern pike that have tolerances for these common conditons on Thunder Lake. Yellow perch, white suckers, and northern pike spawn shortly after ice out and have long egg incubation and yolk sac absorption periods in the cold water of spring before a successful year class can emerge. Fluctuating water levels at this time can strand their eggs and sac fry; therefore stable water levels after ice out are important on Thunder Lake for continual good year classes of these three species.

Pumpkinseed are doing better in Thunder Lake than the bluegill for several reasons. One is there ability to tolerate low winter oxygen. Second, pumpkinseed's have a larger nesting territory than bluegills. Both prefer spawning on sand and gravel in shallow warm bays- a habitat that is limited in Thunder Lake in proportion to it's size. Sand areas are also important for juvenile habitat ; therefore again these limited areas on the lake puts them in competition with bluegills and bass. Pumpkinseed's diet includes plant food and snails; therefore, weedy and shallow impoundments like Thunder Lake has at this time provides an excellent environment. Adults can be found in deeper water over rocky or plant covered substrate in pairs or groups of three or four. This places them in competition with the black crappie that also favors these conditions.

Largemouth bass can do well in the shallow water of Thunder Lake with it's warm summer temperatures and abundance of food. Spawning areas, for such a large lake, are limited; therefore, a sustainable bass population of the future will dependent on maintaining these beds and a mature spawning population.

Maintaining a sustainable walleye population appears to be a problem. The survival of spring stocked walleye fry, summer stocked fingerling, or natural reproducing walleye young seems to be limited as indicated in the fall boom shocker surveys of 1994,95, and 96. Natural reproduction of walleyes on Thunder Lake appears to be limited to the amount of suitable spawning areas on the lake as wave-washed rock rubble-gravel areas are limited. Connecting ditches from the adjacent cranberry bogs also may be a problem in successful walleye reproduction. At the time of walleye spawning flow from from melting ice draws walleye into the ditches to spawn. When flow subsides incubating eggs could be left under adverse conditions that would lead to their mortality.

WATER LEVELS AND DRAINAGE

Introduction

Thunder Lake water levels have been the subject of controversy since the early 1900's. This early history is documented in the first part of this report. The water level at the dam does not just effect the open water area of the lake but the surrounding areas in every direction. The surface elevation of Thunder Lake effects seepage from the adjacent uplands, discharges to the Thunder Lake Wildlife Area and Rice Lake Natural Area & beyond, and water elevations in a network of ditches throughout the adjacent soils. A water level change of less than a foot can drastically effect water drainage and seasonal conditions on the lake and in the adjacent wetland areas. Man has altered the water levels and lateral movement of the water through contruction of ditches, building of roads and dams, and pumping of ground and surface water.

The economy of the area is also dependent upon the resources affected by this water level. Cranberry operations depend on the Thunder Lake reservoir's water for irrigation,floating fall cranberries, and winter protection of their cranberry beds. Recreational industry people depend on a healthy lake and wildlife area that supports both wildlife and a fishery. Adjacent land owner's are also concerned about the health of the lake not only for recreational assets but the water level effects on erosion of their shoreland or flooding of land adjacent to the lake.

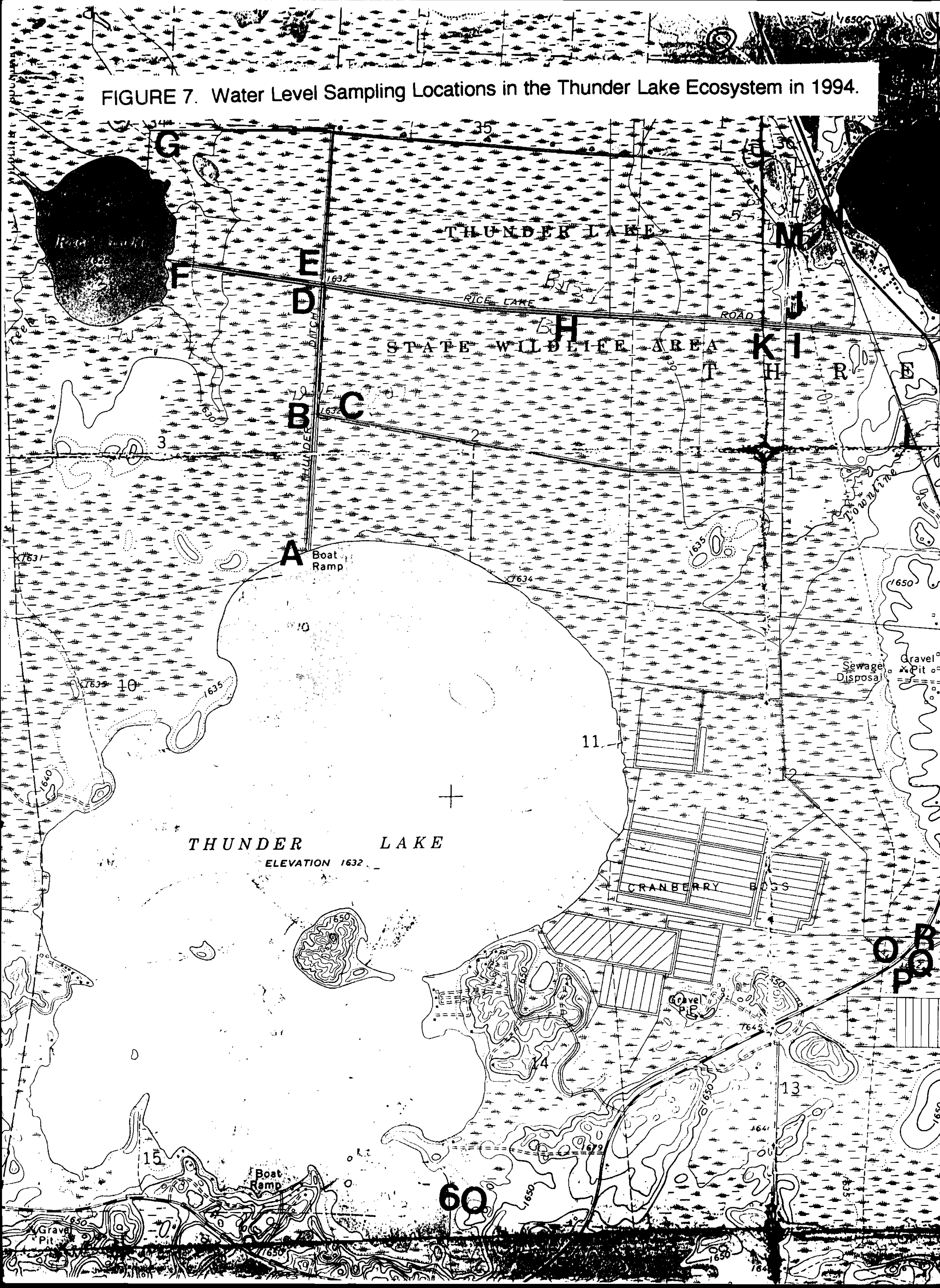
The intent of this part of the planning grant was to gather data on the water levels in the Thunder Lake ecosystem, analyze the effects of the water levels and flow patterns on the resources, and present management objectives that could be initiated to correct current problems.

Investigations in 1980 and 81 reported ground water movement as it relates to areas adjacent to the lake through the testing of wells and nested wells for water levels and phosphorus. In general, the horizontal gradient was from south to north. This gradient was effected by cranberry bog development & pumping as well as clay till deposits beneath the surface of the soil that acted as a barrier to horizontal flow. Vertical gradients appeared to fluctuated seasonally from the two wells sampled. This study calculated ground water flow into the lake from the adjacent wetlands from a depth of 18 feet.

Procedure

This investigation centered on the pattern of water levels and related flows in this low gradient system through a growing season. Water level sampling locations were chosen thoroughout the Thunder Lake system where roads,culverts, and dams had interrupted the natural lateral movement of water through this wetland system. These locations are marked in FIGURE 7.

FIGURE 7. Water Level Sampling Locations in the Thunder Lake Ecosystem in 1994.



Thunder Lake gets most of it's water from atmospheric precipitation and from overland runnoff from surrounding highlands discharging to the the adjacent wetlands. There are no flowing inlet streams but surface water outlet flows to the north. Thunder Lakes surface area was calculated to be 1,835 acres in size with a total watershed area of 2,230 acre; Therefore, besides the open water they are 395 acres of watershed most of which is wetland. Very little watershed area is located south of CTH A.

With these watershed facts in mind the water level sample locations concentrated on the outlet flow areas. All outflow sampling locations were in or adjacent to the Thunder Lake Wildlife Area where ditches channel water from Thunder Lake to Rice, Rangeline, and Townline Lakes. One location where a ditch and culvert under CTH A east of the lake connects a large wetland southeast of CTH A was also looked at to determine the direction of water flow between these two systems.

Water levels at each location were sampled from May through October. Two rain gauges were kept to monitor rainfall. One was located at the south end of Thunder Lake at Cedar Crest Resort where daily rain was recorded. The second was located on the NE edge of the ecosystem on the Top Notch Tree Service property, where rain amounts were recorded as a total amounts between visits. Observations in regard to flow and water quality were added to the water level data.

In most cases water levels were measured from an established benchmark. If a culvert intersected the waterway the top of the culvert was the bench mark, the diameter of the culvert recorded, and the invert was then used to calculate the water elevation in the culvert. On June 28, three survey crews including DNR wildlife and water regulation staff from Woodruff, Rhinelander, and Madison ran elevations from a known USGS sea level benchmark in Three Lakes to all the established benchmarks at the water level sample locations. With this described effort water levels at each site could be compared using USGS sea level datum. Also at this time, a new benchmark was established on Rice Lake.

Results & Discussion

Drainage waterways exit the Thunder Lake system at three locations: 1.) Through the Thunder Lake dam outfall and road ditch with water movement towards Rice Lake, 2.) Through Townline Creek via a railroad culvert to Townline Lake, and 3.) Through a private dam and drainageway to Rangeline Road under STH 45. These exit drainageways are connected to a vast complex of ditches in the Thunder Lake Wildlife area and land to the east of the Thunder Lake system.

The water elevations for each water level sample location can be found in TABLE 19. The location number corresponds to the description on the bottom of the table. All data is in feet above sea level (USGS Datum) except for the CTH A data which used an assumed elevation of 100.00. Rain data can be found in FIGURE 8. Elevations of culverts and dams in the Thunder Lake system can be found in FIGURE 9.

TABLE 19. Thunder Lake Water Levels 1994. PAGE 1

LOCATION/DAT	5/5	5/12	5/25	6/2	6/12	6/28
A	1633.41	1633.39	1633.29		1633.34	1633.29
B	1629.05	1629.05		1628.98	1629.15	1629.22
C	1629.55	1629.39		1629.36	1629.39	1629.22
D	1628.83	1628.65		1628.73	1628.9	1628.71
E	1626.52	1628.23		1628.38	1629.05	1627.4
F	1628.65	1628.4	1628.67	1628.78	1628.75	1628.5
G	1630.17	1629.07	1630.19			1631.15
H	1628.56	1628.51		1628.72	1628.81	1629.14
I	1627.58	1627.45		1627.02	1627.22	1626.87
J	1628.45	1628.11		1628.43	1628.22	1627.97
K	1628.97	1628.84		1628.99	1629.15	1629.28
L	1625.77	1625.69		1625.77	1625.96	1625.77
M	1628.06	1627.25	1627.44			1627.15
N	1625.52	1625.29	1625.5	1625.7	1625.89	1625.64
	5/5	5/12	5/25	6/2	6/12	6/28
O	97.5	97.46	97.46	97.96		97.9
P	96.06	95.93	95.81	96.87		96.38
Q	97.16	97.1	97.03	97.45		97.52
R	97.17	97.11	97	97.46		97.53

TABLE 19. Thunder Lake Water Levels 1994. PAGE 2

	7/14	7/29	8/11	8/25	9/8	9/22	11/1
A	1633.68	1633.73	1633.14	1633.05	1633.04	1633.34	1633.45
B	1629.15	1628.11	1629	1628.69	1628.55	1629.3	1629.73
C	1629.19	1629.26	1629.16	1629.09	1629.09	1629.09	1629.73
D	1678.73	1628.83	1628.67		1628.42	1629.57	1628.77
E	1627.35	1627.5	1627.36		1627.19	1628.23	1627.5
F	1628.22	1628.66	1628.35	1628.48	1628.65	1628.88	1628.7
G	1631.04	1631.04	1631.08	1630.79	1630.73	1631.45	1631.27
H	1629.14	1629.54	1629.62	1629.39	1629.39	1629.56	1629.32
I	1626.89		1628.31	1627.52	1828.08	1627.52	1628.08
J	1628.17		1627.88	1627.83	1627.76	1628.34	1628.3
K	1629.28	1629.82	1629.6	1629.38	1629.38	1629.55	1629.3
L	1626.21	1625.67	1625.63	1625.62	1625.61	1625.9	1625.63
M	1626.94		1626.79	1626.73	1626.69	1627.39	1627.19
N	1625.72		1625.66	1625.73	1625.62	1625.86	1625.58
	7/14	7/29	8/11	8/25	9/8	9/22	11/1
O	97.79	97.73	97.48	97.12	94.62	97.91	98.12
P	96.32	96.22	95.98	95.6	95.37	96.43	96.72
Q	97	97.39	97.05	96.99	96.78	97.6	97.87
R	97.49	97.38	97.06	96.75	96.52	97.61	97.97

A.Thunder L. Dam Water Level
B.N-S Thunder L. Dam Rd Ditch
C.E-W Thunder L. Dam Rd Ditch
D. E-W Intersection DitchW
E.N-S Intersection-W.Ditch N
F. Rice Lake Water Level
G.E-W Ditch- Rice Lake N
H.Rice Lake Rd. S DitchW
I. Wildlife Entrance S&E Ditch
J. Wildlife Entrance N Ditch
K. Wildlife Entrance W Ditch
L. Townline Exit RR Culvert
M. Rangeline Old Dam
N. Rangeline Lake STH 45 Culvert
O. CTH A Culvert NW
P. CTH A Culvert SE
Q. CTH A Side Road Culvert N
R. CTH A Side Road Culvert S

FIGURE 8. Rain Data in 1994 Through Water Level Sampling Period.

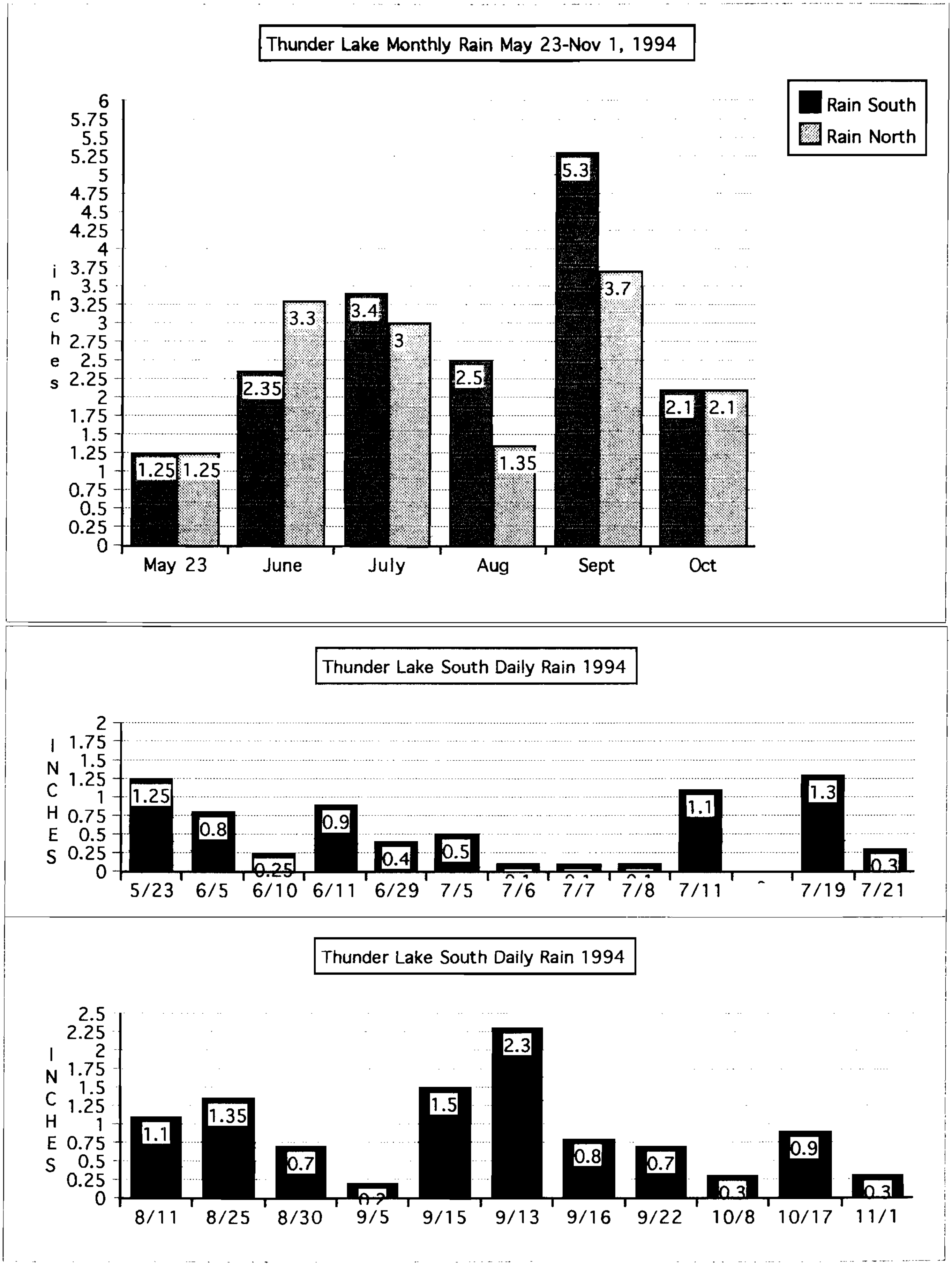
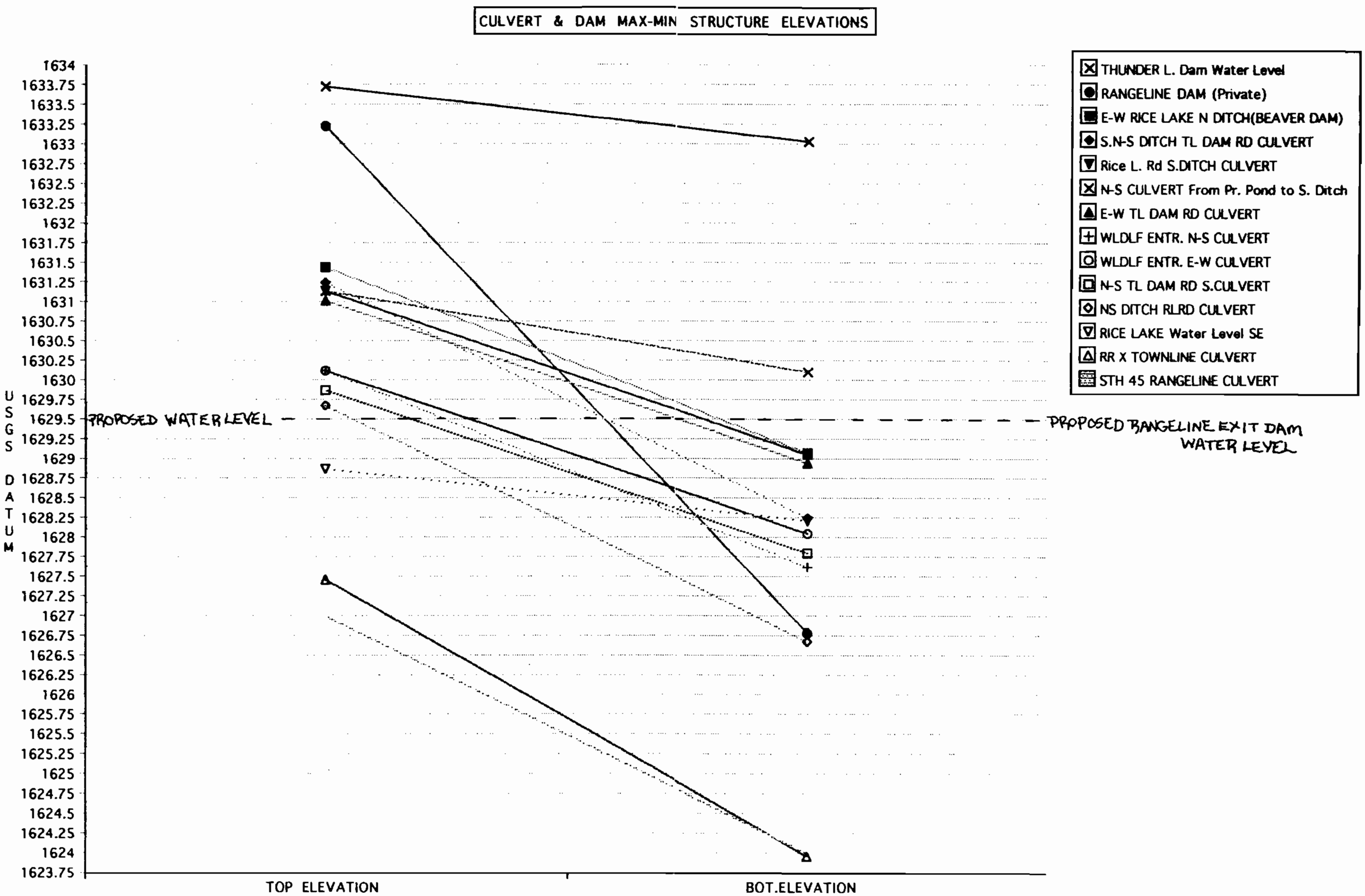


FIGURE 9. Thunder Lake Structure Elevations PAGE 1. FIGURE 9. Thunder Lake Structure Elevations PAGE 2.



Water level of Thunder Lake fluctuated from 1633.04 to 1633.73 feet or about 8 1/4" from May 5 to September 8 in 1994 during a period when two stop logs(7" in elevation) were removed from the dam's maximum elevation. See FIGURE 10. May and June water levels fluctuated very little with water levels decreasing slightly in May and rose slightly in early June when 2 inches of rain fell from June 5 through 10. During the last days of June and through the third week July nearly 4" of rain fell raising water levels to the maximum water level of 1633.73 on July 29. No rain fell from July 21 to August 11 dropping the water levels quickly the first 10 days in August. Despite 1.6" of rain on August 11 and 0.9" on August 25 the lake dropped slowly to the seasonal low of 1633.04 on August 25. More rain on August 30 (0.7") and September 5 (0.2") and water level remained the same.

Two stoplogs were added to the Thunder Lake dam on September 8. From September 8 to to September 22 5.3 inches of rain fell raising the water level to1633.34. It continued to rise through October when 2.1" of fell. By November 1 the water level was at 1633.45 when one board was removed to drop the water level.

Rice Lake water levels fluctuated in 1994 from 1628.22 to 1~~6~~628.88 or about 8" See FIGURE 10. Water levels of Rice Lake were definitely effected by the stoplog water levels of Thunder Lake(2 Stop logs removed or 7"). May and June lower stop log levels passed more water directly to Rice Lake, so while water levels remained steady on Thunder Lake, Rice Lake water levels climbed in Late May and early June. They were steady on Rice Lake through the rains of mid June and dropped drastically during the 4" drawn out rain periods from mid June to mid July when the water level on Thunder was increasing to it's yearly high. While the water level dropped in Thunder Lake to its lowest levels in late August and early September water levels were increasing in Rice Lake. After the two stop logs were placed in the dam on September 8 and the heavy rains that followed both lake's water levels increased through the rest of September. In October Thunder Lake's water levels continued to climb but Rice Lake dropped from 2" from it's highest level of 1628.88 on September 22.

Rangeline Lake water levels fluctuated with the timing of rainfall more closely than Thunder or Rice Lake. See FIGURE 10. During the study period Rangeline Lake fluctuated from 1625.29 to 1625.89 or 7.2 ". Operation of the Three Lakes Chain-Burnt Reservoir Dam effects the water level of Rangeline Lake. During October this reservoir is dropped from summer level of 1624.21 to a winter level of 1622.96 and in April/ May is returned to summer levels again.

How do the ditches and culverts in the Thunder Lake Wildlife Area effect the flows and water levels from Thunder Lake to the Rice, Rangeline, and Townline Lakes? See Figures 11,12, & 13. There is a nearly 4 foot drop from the Thunder Lake water levels to the first east-west ditch east of theThunder Lake Dam Road. This ditch varied in elevation from 1629.09-1629.59 over the study period. This E-W ditch water level was higher and drained to the north-south Thunder Lake Dam Road ditch through the entire season.

FIGURE 10. Rain and Water Level s of Thunder, Rice & Rangeline Lakes In 199FIGURE 10. Rain and Water Level s of Thunder, Rice & Rangeline Lakes In 1994.

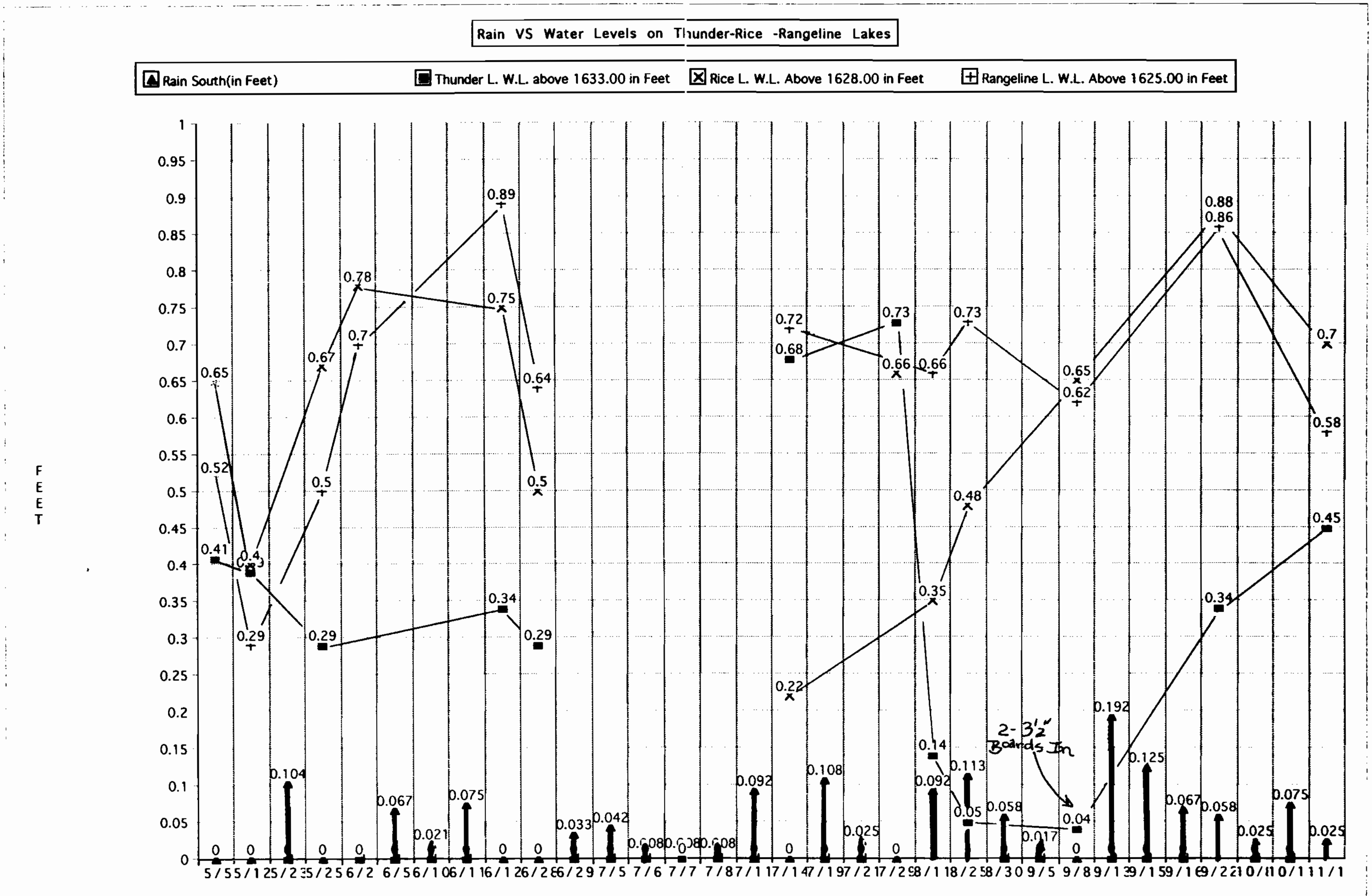


FIGURE 11. Water Level Elevations of the SE Thunder Lake Wildlife Area 1994FIGURE 11. Water Level Elevations of the SE Thunder Lake Wildlife Area 1994.

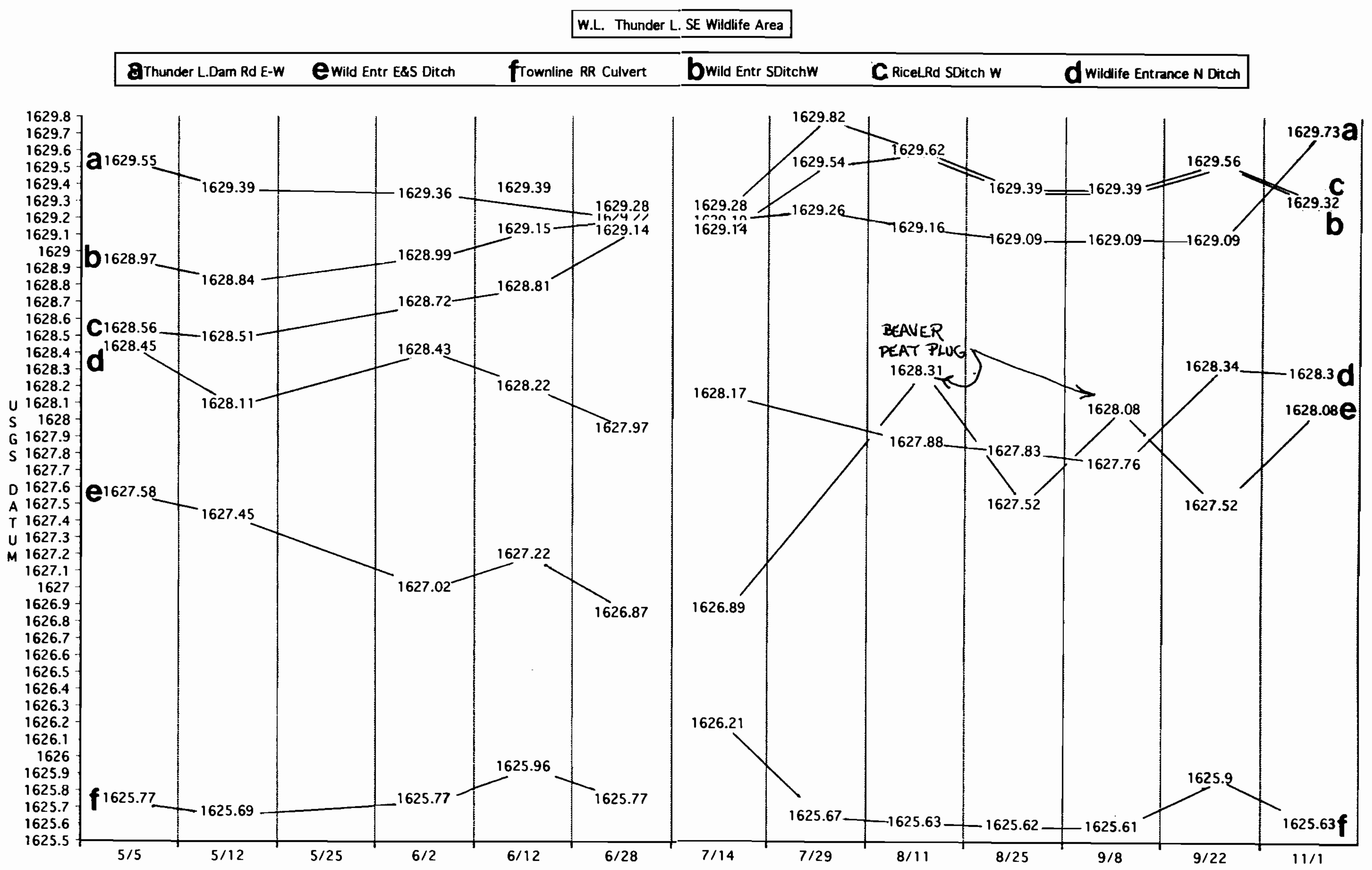


FIGURE 12. Water Levels in the East Thunder Lake Wildlife Area in 1994.

FIGURE 12. Water Levels in the East Thunder Lake Wildlife Area in 1994.

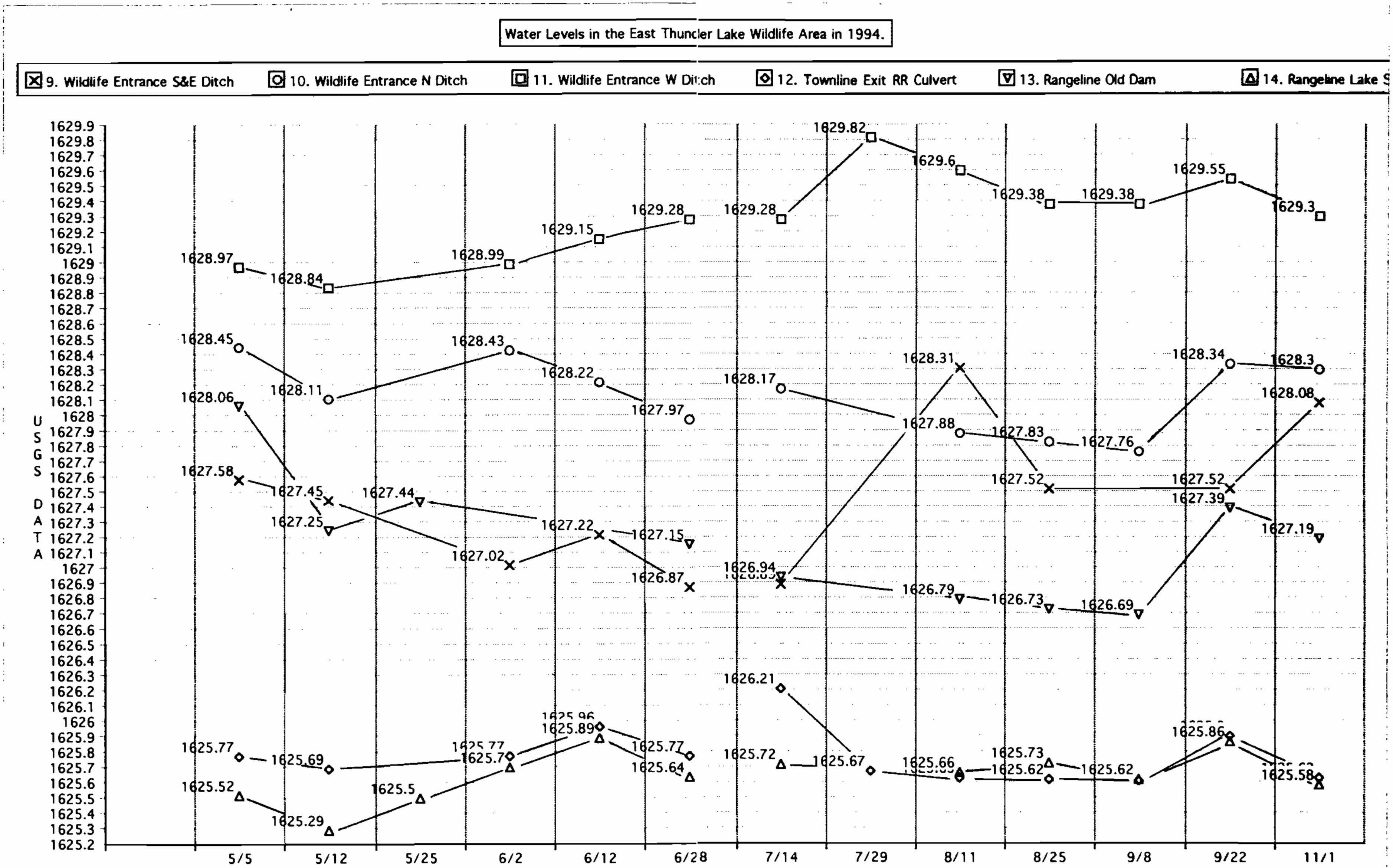
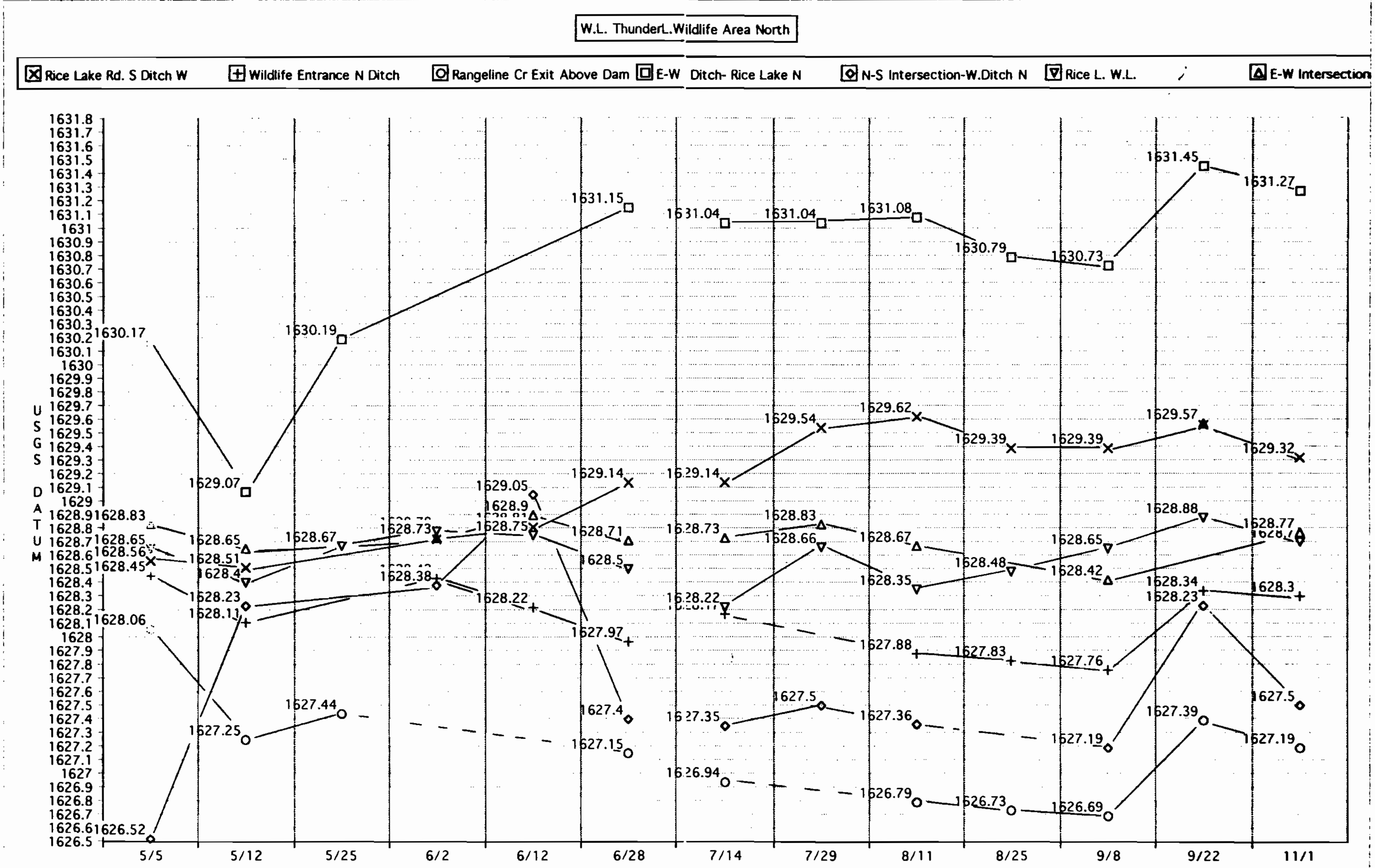


FIGURE 13. Water Levels of the Thunder Lake Wildlife Area North. FIGURE 13. Water Levels of the Thunder Lake Wildlife Area North.



The next east-west ditch is the Rice Lake Road south ditch that varied in water level elevation as follows:

	MIN.	MAX.
East end at Wildlife Entrance:	1628.84 to	1629.82
Center:	1628.51 to	1629.56
West at Thunder Lake Dam Rd:	1628.42 to	1628.83

Until August 11 water level and drainage in this ditch was from east to west through the center ditch culvert. After the Thunder Lake dam boards were added the ditch water levels evened out with a very slightest of pitch from the center towards the east.

These two east- west ditches besides being connected by the north- south Thunder Lake Dam Road ditch are connected by a north-south ditch on the east end of the wildlife area. On the north end at the wildlife area entrance this ditch extends back to the east towards STH 45. On the south end it extends south with one old lateral ditch extending to Thunder Lake- then turns to the southeast away from the Thunder Lake cranberry beds to CTH A. Several old lateral ditches extend towards the cranberry beds but are not connected. Two of the three highest readings in this ditch were when beaver plugged the culvert at the wildlife entrance with peat . The normal range without beaver damming appeared to be from 1626.87 to 1627.52 (about 8") until fall rains and high Thunder Lake water in October increased it to 1628.08 (another 6"). The 1627.52 normal high steady readings were after the stop logs were again placed in Thunder Lake on August 11. This ditch's water level at the wildlife area entrance is 1 to 2' below the east- west ditches and would explain why the beaver were trying to raise the elevation of this ditch to gain access to the east west ditches during the declining water levels of summer.

An open marsh separates this ditch from the old railroad grade crossing drainage exit to Townline Lake. The water level at this culvert crossing is another 2 feet below this ditch and is close to the surface elevation of Townline Lake. A slight flow from the marsh was detected through this culvert at all times but the only water level increase at this location was after several days of successive rain events in early July.

The water levels in the ditches of theThunder Lake Wildlife Area north of Rice Lake Road were all lower than the south ditch that borders this road. See FIGURE 11 &12. The exception is the northern most east- west ditch whose water level was elevated by a beaver dam less than 100 feet above Rice Lake through out the study period. Without this beaver dam even this ditch would have been lower than the south Rice Lake Road ditch. On September 22 heavy rains elevated this north east- west ditch water level at the beaver dam as much as 31 inches above the level of Rice Lake. This maximum elevation was enough to flood the two north south ditches located north of the intersections of Rice Lake Road and Thunder Lake Dam Road. It also increased water levels on the northeast area of the wildlife area raising the water level in the wildlife area entrance north ditch sending water through the Rangeline Creek exit.

The goal of this project was to assess and understand the effects of current water level and drainage patterns on the aquatic habitats of the Thunder Lake ecosystem and then develop management objects to correct any problems recognized in the assessment. Current fluctuating water levels, elevation differences in lakes and ditches, and current water management activities are negatively effecting the system at the present time. The assessment of water levels and drainage patterns indicates that management practices can be changed to address these problems.

Water levels in the ditches of the Thunder Lake Wildlife Area during most of the growing season are far below the levels of the marsh vegetation. Spoil piles adjacent to many of the ditches often intercept the natural lateral flow of water through the marsh from Thunder Lake and other areas of the marsh towards Rice Lake. In other areas the ditches change the hydraulic gradient in a small area and drains water from the marsh vegetation towards the ditch. Standing water in the ditches without vegetative cover increases transporation and evaporation of water from the marsh. The ditches also do not have the hydraulic resistance or water holding power of bog and marsh vegetation; therefore water retention time is lost and water drains quickly from the Thunder Lake system via the network of ditches.

In 1980 long term management objectives were established for the ~~2,240~~ 3,100 acre Thunder Lake Wildlife Area that included:

A. Maintaining 1,500 acres of northern sedge meadow to attract migrating geese in fall, provide habitat for nesting waterfowl, and habitat for various wetland wildlife.
B. Develop pair ponds for use by nesting waterfowl and geese.
C. Maintain the Rice Lake waterfowl closed area/ scientific area and promote wild rice growth.
D. Cooperate with the Thunder Lake P & R District , DNR Fish Management, and other groups to rehabilitate Thunder Lake.

Prior to that time the focus of wildlife management was to dry the area much as possible to maintain an open grassland community for a remnant sharptail grouse population. The existing drainage ditches made this a practical objective. More recently efforts have centered around control burns and brushing to prevent woody vegetation development. These management practices combined with pond construction were used to meet the above wildlife management objectives. Problems that hamper meeting these objectives are that the waterfowl ponds are often dry throughout the growing season and the availability of nutrients for a varied plant community to support wildlife are in short supply.

Culvert and dam structure elevation assessment and water level fluctuations indicated the dam at the exit to Rangeline Lake has the nearly the same water levels control capabilities as the Thunder Lake dam. See FIGURE 9. Operation of these two dams at water levels that retain higher and steadier water levels will eventually stabolize the ecosystem.

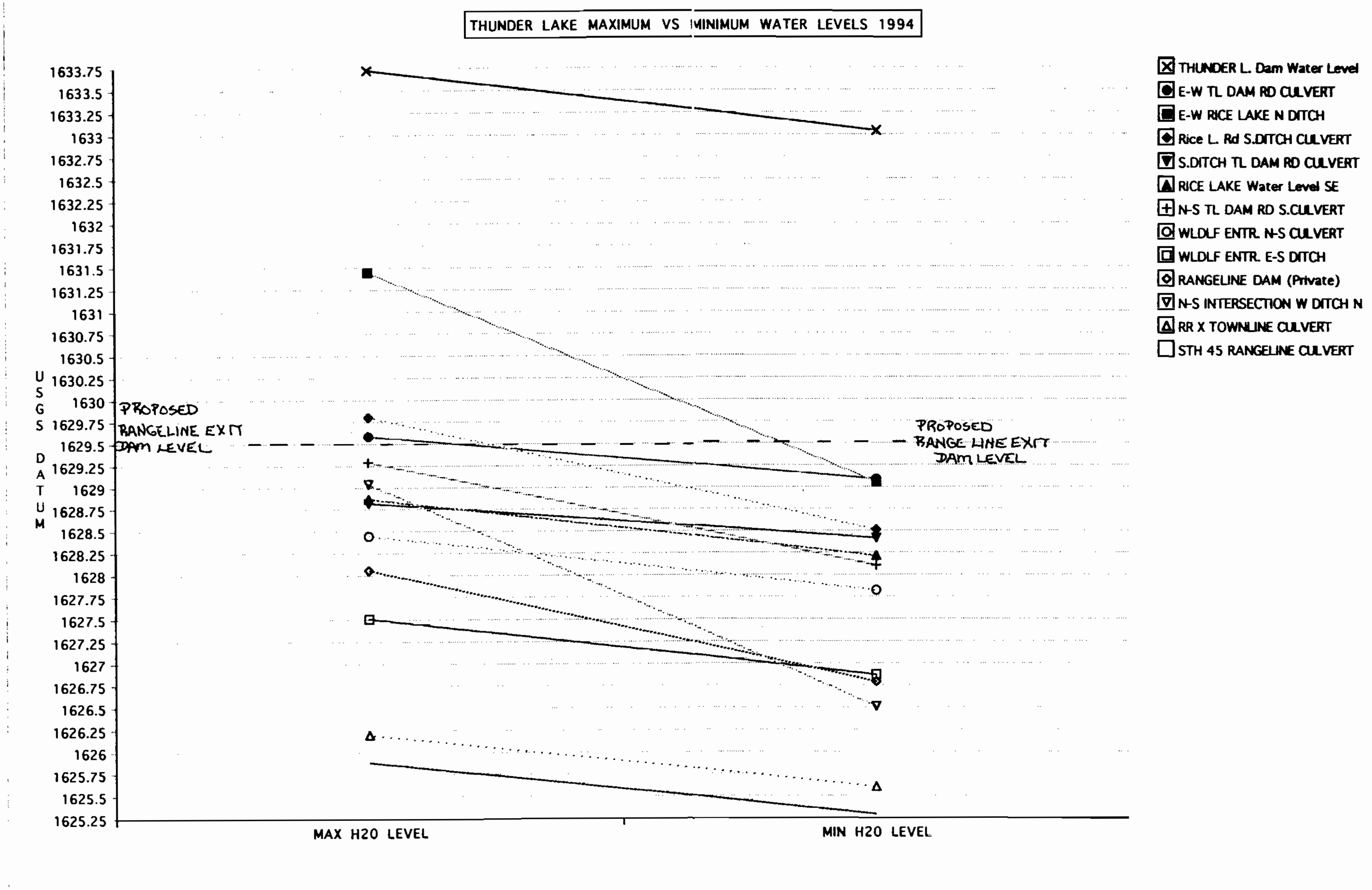
The Thunder Lake spring water levels from May to mid June (two stop logs removed) accelerated drainage through the Thunder Lake Dam Road Ditch to Rice Lake. The highest water levels of the season occurred in Rice Lake during this time period. See FIGURE 10. High water and fluctuating water levels are known to negatively impact early spring development of wild rice. It appears this occurred in Rice Lake in 1994 as Thunder Lake was posted in September to prevent harvesting due to the low levels of rice production. Replacing of one stop log after spring thaw would decrease flows via Thunder Lake Dam Road ditch to Rice Lake at this critical time. At the same time water would be released slowly through the wetland complex that needs the water and mineral/ nutrients for spring growth. Water levels on the Thunder Lake should also fluctuate less at this critical time of the year for fish egg development and plants that stabilize the shoreline and provide fish cover.

The Rangeline exit dam also can be used to benefit the Wildlife Area and Rice Lake. This dam is currently not operated and is located on private property just outside the Thunder Lake Wildlife Area east boundary. Raising of this dam to a water elevation close to 1629.5 USGS Datum would raise the water level throughout the Thunder Lake Wildlife Area. See FIGURES 11, 12, & 13. This increase in water elevation would stabolize water elevations in most of the ditches closer to vegetation levels. The 116 pair ponds on the wildlife area would normally retain water throughout the growing season. More water and nutrients would be also be available to the sedges and other northern wetland plant communities. Higher water levels would hinder the development of the woody vegetation and reduce the need for controlled burns and mechanical shearing . Encroachment of aquatic vegetation would eventually fill the present ditches slowing drainage and evaporation/ transpiration and at the same time increase wetland habitat for waterfowl and other wetland wildlife.

According to the 1994 minimum/ maximum recordings of water levels in the ditches and culverts operating the Rangeline exit dam close to 1629.5 USGS Datum would not breach the culverts in the wildlife area or raise water levels higher than the maximum 1994 levels; with the exceptions where beaver dams or culvert plugging had raised water levels higher than this elevation. See FIGURES 9 &14. Maintaining higher water levels may also minimize water fluctuations caused by beaver as beaver build dams in order to have deep enough water for lodges and underwater food caches. The higher water table created, as mentioned earlier could also hinder the development of woody vegetation- poplar, willow, birch, and alder- the favorite foods of the beaver.

Figure 14. Minimum & Maximum Water levels in The Thunder Lake Ecosystem in 1994.

Figure 14. Minimum & Maximum Water levels in The Thunder Lake Ecosystem in 1994.



CRANBERRY PRODUCTION & THE THUNDER LAKE ECOSYSTEM

Introduction

Two cranberry production companies operate facilities on Thunder Lake and a third production facility is currently being developed southeast of Thunder Lake across CTH A. Operation of the these facilities are very dependent on the resources of the Thunder Lake ecosystem. Cranberry operations are usually located where soil pH is normally between 4.0 and 5.5 and where there is an abundant supply of water and sand. Thunder Lake's peat soils with adjacent sandy soils to the southeast and surface and groundwater reservoir capacities meets these physical needs quite well.

Cranberry plants need a constant supply of water. These operations use water for frost protection, winter flooding, irrigation, and harvesting. Because of this intense use of the water resources the operation of the two facilities on the lake were reviewed so a better understanding of their relationship to the lake's ecosystem could be understood. The operation of the new developing cranberry facility across the road was not a part of this assessment; but it's potential effects were indirectly considered when water flows and water levels were observed in culverts that passes northeast under CTH A connecting a north-south ditch to the area of the new facility.

Procedure

The two cranberry owner/ operators were interviewed on two occasions to gain knowledge of their operations- with a special emphasis on understanding their timing and use of Thunder Lake water. Combining information from the interview with other references regarding cranberry culture calculations were made to estimate water use. The timing and effects on the Thunder Lake system was then evaluated.

The water levels in the ditches along CTH A were recorded at two culverts. The first culvert passed beneath CTH A and was connected to an old north- south ditch that eventually extends to the Thunder Lake Wildlife Area entrance ditch described in the water level section of this report. This same ditch travels approximately 200 feet along the southeast edge of the road right- of -way before passing through a second culvert on a side road that enters the new cranberry facility. Water levels at each of these culverts were recorded from May 5 to November 1 in 1994 and correlated to an assumed elevation at the center of CTH A directly over the underlying culvert. This data was then analyzed in regards to the association between water levels on each side of CTH A.

Results and Discussion

The Thunder Lake Cranberry Marsh has 47 cranberry beds or about 105 acres in cranberries in 1994. Three main ditches are connect this facility to Thunder Lake. The Sampson Cranberry Marsh had 30 beds or about 62 acres of cranberries in 1994. Two main ditches are connected to Thunder Lake from this facility. Water is pumped to and/or returned from these main ditches to the cranberry beds at various times of the year. The developing Dempzy Cranberry Marsh southeast of CTH A would have 37 cranberry beds or about 80.5 acres when complete.

Water use by the Thunder Lake cranberry marshes is described below and categorized by type of use and time of year. This will allow cross referencing with other ecological interpretations in this report.

<u>Winter Flooding</u> January Periodically, 94 & 95, not 96 & 97.

Winter can be particularly damaging to a cranberry marsh. If the soil becomes frozen, a winter wind can kill the vines within 24 hours. To protect the beds the vines are cover with water and froze. This forms an ice blanket that minimizes temperature fluctuations. If winter snows are heavy enough winter flooding for ice production is not necessary.

At the Thunder Lake Cranberry facility 5- 40 h.p. pumps are ran for 12 hour/day for three days (about 3 hours of pumping/ bed) for winter flooding. The calculations are estimated as follows:

at 2.25 acres/bed w/ 1 foot of flooding
=108,,900 cubic feet/ bed = 814,572 gallons
at 3 hrs pumping/bed = 814,572 / 3
=271,524 gal/ hr = 4,525 gal/ min
w/ 5-40 hp pumps
= 22,625 gal/ min = 1,357,500 gal/ hr
w/ 12 hrs of pumping for 3 days
= 16,290,000 gal / day for 3 days
or **4 8,870,000 gal over a 3 day period**
or 105 acres of cranberries at 1'
= 4,573,800 cubic feet
= **34,212,024 gal plus seepage or < 1'(30%)**

At the Sampson Cranberry facility either of two different options are used in winter flooding. The first option is a large diesel that pumps 9-10,000 gal/min for 7 days to fill beds. The second option is 3- 100 hp electric pumps that pump for 32 hours over 3 days at 20,000 gal/min to fill the beds.

Option #1 -Diesel
= 9,500 gal/ min = 570,000 gal/ hr
= 6,042,000 gal/ 10.6 hours/ day
= 42,294,000 gal over 7 days

Option #2 3- 100 hp electric
= 20,000 gal/ min = 1,200,000 gal/hr
=12,720,000 gal/ 10.6 hours
= 38,160,000 gal over 3 days

or 62 acres of cranberries at 1'
= 2,700,720 cubic feet
= 20,201,385 gallons (~ 2 feet of ice? or lots of seepage)

From the above estimates water drawn from Thunder Lake during winters where there is no snow cover would be about 91,000,000 gallons maximum over a 3 to 6 day period in January. In the 1800 surface acres of Thunder Lake this would amount to:

1800 acres at 1" = 1800 acre inches
or in acre feet =1800/ 12 = 150 acre feet
w/ 1 acre = 43, 560 square feet
= 6,534,000 cubic feet
at 7.48 gal/ cubic feet = 48,874,320 gal
Therefore, drawndown would be:
91,000,000/ 48,874,320
=1.86" over 3-5 days maximum
at 5 feet average depth Thunder Lake volume would be:
= 48,874,320 x 60" = 2,932,459,200
or 3.1 % of Thunder Lake's volume would be diverted to create 1 foot of ice blanket on beds (less seepage)

Spring Thaw - Frost Protection- April-May 1994

As spring thaw occurs melt water from winter flooding or heavy snow retained in the cranberry beds is released back to the lake. The dark background of the beds quickly raises water temperatures above Thunder Lake temperatures. Combined with the cranberry bed elevations being 4 to 4.5' higher than the Thunder Lake and main ditch water elevations- this warmer water flows out of the beds to the main ditch. The timing of this spring thaw on the marsh often coincides with the spawning activities of walleye who enter the cranberry marsh ditches to find moving water over sand and gravel adequate for spawning substrate.

Frost damage is one of the greatest concerns of a cranberry grower as their product is grown in lowland areas in which frost can occur almost any time the year. Whenever the possibility of frost exist spray irrigation sprinkles the vines with water at a rate of about 1/10 of an inch an hour. This method of frost protection began to replaced flooding over 30 years ago on most marshes.

At the Thunder Lake Cranberry Marsh 5- 100 hp pumps deliver 2800 gal/ min per pump for spray irrigation and frost protection. On an average these pumps are ran for 10 days during the month of May. A rough calculation of water usage would be as follows:

2800 gallons/ minute/ pump
For 5 pumps at 2800 gpm
= 14,000 gal/ min = 840,000 gal/ hr
For 8 hours of frost protection
= 6,720,000 gal / night
For 10 days / month
= 67,200,000 gallons pass through the beds.

At the Sampson Cranberry Marsh the 3-100 hp electric pumps are operated at 1/3 capacity or 3600 gpm for about 20 days between May 1 & May 30. From May 10-20 the diesel is operated delivering 8,500 gal/ min for the 10 days.

3-100 hp at 3600 gpm/pump		diesel at 8500 gpm
= 648,000 gph		=510,000 gph
For 8 hours of frost protection		For 8 hours of frost protection
= 5,184,000 gallons/night	**or**	**= 4,080,000 gallons/ night**
For 20 days/ month		For 10 days/ month
=103,680,000 gallons pass through		= 40,800,000 gallons pass through

Maximum possible use in single night: 6,720,000 + 5,184,000
= 11,904,000 gallons/ 48,874,320 gal (1" in 1800 ac)
= .244 " maximum drawndown of Thunder Lake

Rain amounts also effect the amount of irrigation, therefore, some years this would increase and other years this amount could decrease. Thunder Lake's watershed or drainage area is 2,230 acres or about 3.5 square miles. It is estimated by the U.S. Army Corps of Engineers that with 30" of precipitation during the average year it will require 6 square miles of drainage area to generate an annual mean flow of of 5 cubic feet / second (cfs) in a stream in northern Wisconsin. Therefore, Thunder Lake's 3.5 sq. miles of watershed would have a mean flow of approximately 2.92 cfs. Out of 30" of rain approximately 18"/ year is lost to evaporation/transporation yearly or around 12" is left to create water flows. Therefore, the 2230 acres of drainage area of Thunder Lake watershed would produce 2230 acre feet(726,647,730 gallons) of water supply annually.

The amount of this water used for cranberry production on Thunder Lake of course varies. The spray irrigation would increase evaporation rates, yet cranberries- being a bog plant- are very efficient in retaining water and stopping water loss through transpiration. Seepage loss in the cranberry beds would transfer surface water to ground water. It is estimated by the cranberry industry that only 50% of the irrigated water is returned to the reservoir- 50% is lost to evaporation and seepage into the soil. With peat soil being from 18 to 25 feet in many areas of the bog complex east of Thunder Lake much of this seepage would enter these peat soils. The cranberry production bog area also has in many places clay ridges beneath the beds that intersect the peat soils in many areas. Overall, the horizontal gradient of groundwater is from south to north; therefore the groundwater from the cranberry bed seepage would move into the peat soil and then toward the wildlife area. Some local seepage through the cranberry bed dikes and banks to inlet and outlet ditches (which are lower than the cranberry beds) woud also occur.

In the interviews with the owner/operators the pumping time in June, July and August 1994 was discussed. On the Thunder Lake Cranberry Marsh irrigation pumping averaged 7 days in June, 3-4 days in July, and 3-4 days in August with their 5- 100 pumps. Movement of water from Thunder Lake.s surface water through the irrigation process would be approximately

2800 gallons/ minute/ pump
For 5 pumps at 2800 gpm
= 14,000 gal/ min = 840,000 gal/ hr
For 8 hours of irrigation = **6,720,000 gal/ day**
For 7 days in June at 8 hours / day = 47,040,000 gallons
50% loss to evaporation & seepage:
7 days June = 23,520,000 gallons
4 days July = 13,440,000 gallons
3 days Aug = 10,080,000 gallons

On the Sampson Cranberry Marsh in June, 3 -100 h.p. pumps were pumping 3600 gpm for 2 hours / day for 3 days to establish new cranberry beds. In July the same pumps were operated 4 days for 8 hours at 3600 gpm. There was no irrigation in August.

3-100 hp at 3600 gpm/pump
= 648,000 gph
For 2 hours = 1,296,000 gallons
For 3 days = 3,888,000 gallons
50% loss to evaporation & seepage:
3 days in June = 1,944,000 gallons
For 8 hours = 5,184,000
For 4 days = 20,736,000
50% loss to evaporation & seepage:
4 days in July = 10,368,000 gallons

Total surface water loss from Thunder Lake to cranberry bog production evaporation and seepage during the summer of 1994 was approximately:

June: 25,464,000 gallons = 78 acre feet = 0.5" water depth
July: 23,808,000 gallons = 73 acre feet = 0.4" water depth
Aug: 10,080,000 gallons = 31 acre feet = 0.17" water depth

Rain in June, July, and August on Thunder Lake was 2.35". 3.4", & 5.3", respectively. This would mean the available surface water to supply the cranberry production facilities and drain to the Thunder Lake Wildlife Area and Rice Lake would be as follows:

June Rain: 2.35" x 40% = .94" x 2,230 acres = 2,096 acre inches
2,096/ 12" = 175 acre feet x 43,560 = 7,623,000 cubic feet
at 7.48 gal/ cubic feet = **57,020,040 gallons**

July Rain: 3.4" x 40% = 1.36" x 2,230 acres= 3,033 acre inches
3,033/ 12" = 253 acre feet x 43,560 = 11,020,680 cubic feet
at 7.48 gal/ cubic feet = **82,434,686 gallons**

August Rain: 2.5" x 40% = 1" x 2,230 acres = 2,230 acre inches
2,230/ 12" =186 acre feet x 43,560 = 8,102,160 cubic feet
at 7.48 gal/ cubic feet = **60,604,157 gallons**

Fall Operation & Harvesting Sept- Oct

September is the beginning of the fall rainy season which includes frost- free weather. No pumping for irrigation or frost protection normally occurs at this time. By mid- October the berries are ripe and ready fo harvest.

Harvesting involves the flooding of the cranberry beds from the main ditch with about 1 foot of water to float the bouyant berries above the vines. After flooding the cranberries are removed from the vines by mechanical raking and/ or water reel harvesting.

In the mechanical raking process a machine (with rows of teeth spaced so the vines can go through but not the berries) gently pull the berries from the vines, deposits them in a container on the raker, and then transports them to the warehouse for cleaning,sorting, and packing. These berries are packaged as fresh fruit.

In water reel harvesting beaters are guided through the flooded bed where the water is agitated with enough force to dislodge berries from the vines. Once freed the floating berries and vine debris are corraled in floating booms that sends them up a conveyer belt into a waiting truck. Berries harvested with water reels are typically processed into juices, sauces and other cranberry products.

On the Thunder Lake Cranberry Marsh harvesting begins near October 15 and last for 10 days. Two to three beds in one section (7 beds) are filled with water at once to float the berries. This takes 1-40 h.p. pump 4 hours to fill one cranberry bed. After one bed is harvested the water is returned to the main ditch which supplies flood water to another bed in the same section for reuse. Estimated water pumpage would be:

1- 40 h.p pumps 3620 gal/min = 217,200 gal/ hr
W/ 4 hours of pumping = **868,800 gallons** (116,150 cu. feet)

2 acre bed @ 43,560 sq ft/acre= 87, 120 sq/ ft
at 1' = 87, 120 cubic feet = **651,658 gallons(plus seepage)**

W/ 3 beds filled at once
868,800 x 3 = **2,606,400 gallons**= 348,449 cubic feet of lake water

Over a 10 day period 4 other 40 h.p. pumps would operate in the same manner on another 4-5 sections(7 beds / section) of the cranberry marsh reusing some same main ditch water or lake water from another main ditch connected to the lake.

On the Sampson Cranberry Marsh harvesting again begins near October 15 and last about 5 days. Large diesel-operated pumps supplies 8-9000 gpm for 24 hours/ day for the 5 days of harvesting. Three 100 hp electric pumps are operated 6 hrs/day over the 5 day period. Estimated water pumpage would be:

Diesel Pump = 9,500 gal/ min = 570,000 gal/ hr = 13,680,000 gal/ day
= **68,400,000 gal/ 5 days**

3- 100 hp electric at 3600 gpm/pump = 10,800 gpm x 60 = 648,000 gal/ hr
at 6 hrs/day
= **3,888,000 gallons/ 6 hours**
for 5 days
= **19,440,000 gallons/ 5 days**

The options and timing of pumping for each cranberry operation at harvest - as at any time of the year - is variable as their management and facilities: so any type of total pumpimg over time on both marshes would take a more detailed study and effort. If one would consider both cranberry operations beginning harvesting on the same day a likely pumping scenario would be as follows:

Total gallons pumped 1st 24 hours

868,800 x 3 beds = 2,606,400 gallons (1st 12 hours w/ 1 40hp)
+13,680,000 gallons (1st 24 hrs w/ diesel)
+ 3,888,000 gallons (1st 6 hours w/ 100 hp)

=20,174,400 gallons within 1st 24 hours
= 2,697,112 cubic feet of water

Therefore:
if 1800 acres at 1" = 6,534,000 cubic feet

Drawdown of Thunder Lake for the 1st 24 hr of pumping would be 2,697,112/ 6,534,000
= 0.41"

Rainfall from August 25 to November 1 in 1994 was 5.8 ". Fall harvesting appears to have little effect on the lake level dring these normally heavy rainfall periods.

CTH A and Water Movement

The construction of CTH A southwest, south, east of the Thunder Lake bog complex divided and separated other large wetland-bog networks from Thunder Lake. A ditch and a 2 culverts connects the largest wetland area southeast of CTH A to the Thunder Lake ecosystem.

The water levels in the ditches along CTH A were recorded at these two culverts. The first culvert passed beneath CTH A and was connected to an old north- south ditch that eventually extends to the Thunder Lake Wildlife Area entrance ditch described in the water level section of this report. This same ditch travels approximately 200 feet along the southeast edge of the CTH A road right- of -way before passing through a second culvert on a side road that enters the area of the new cranberry facility. Was there water movement through these culverts to or away from the Thunder Lake peat bog?

Water levels at each of these culverts were recorded from May 5 to November 1 in 1994 and correlated to an assumed elevation off 100.00 feet at the center of CTH A directly over the underlying culvert. A second question evolved over the evaluation period in relation to this water level site. What were the potential effects on the Thunder Lake peat bog of the developing Dempzy Cranberry Marsh?

The CTH A culvert southeast end is .75 feet lower than the northwest end(Thunder Lake side) of the culvert and 0.9 feet lower than the side road culvert. Therefore, the northwest end of the CTH A culvert is slightly lower (< 2") than the side road culvert. The bottom of the side road culvert is .9 of a foot higher than the bottom of the SE end of the CTH A culvert. See FIGURE 15. The lowest surface water would be in the ditch south of CTH between the two culverts.

Water levels in the old ditch on the Thunder Lake side of CTH A were held higher by a a series of beaver dams before dropping to lower levels in the Thunder Lake Marsh adjacent to Thunder Lake. The first dam is located approximately 300' from CTH A and the second dam approximately 730 feet north of the first. An old ditch that travels southwest to the Thunder Lake cranberry beds is located between the two beaver dams. It is approximately 400 feet south of the first beaver dam. The northern most beaver dam crest was approximately 12" higher than the ditch to the south during freeze up in 1994-95. These beaver dams had been in place for quiet some time raising the water table and flooding the ditches in the culvert areas along CTH A and the ditch that extends west to the Thunder Lake cranberry beds.

There was water in the culverts at all times but no flow could be detected on water elevation sample dates. Only changes in water level were detected. The water level changes over time can be found in FIGURE 16. The changes in water levels corresponded to cranberry marsh irrigation pumping activities.

Figure 15. CTH A Culvert Elevations

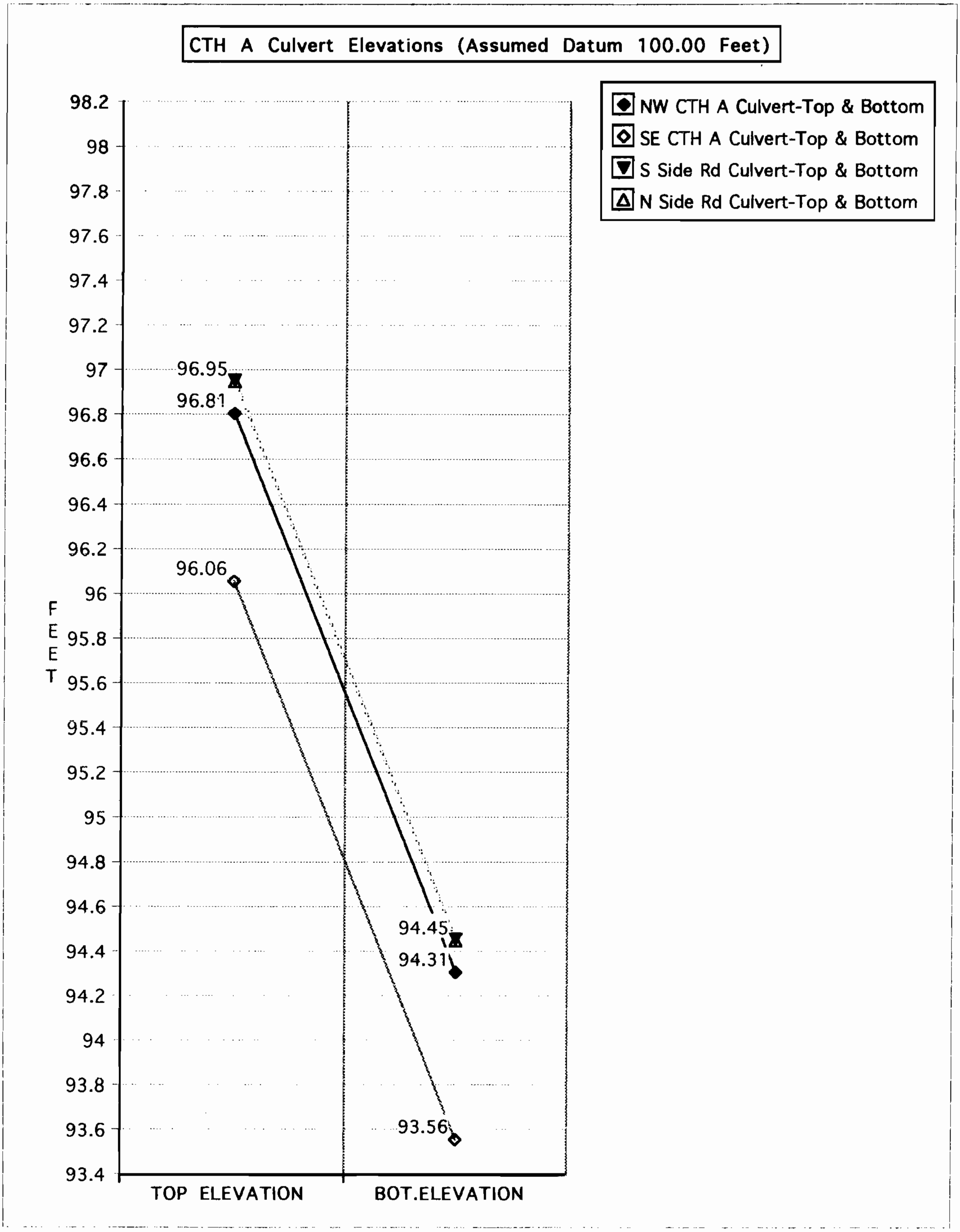
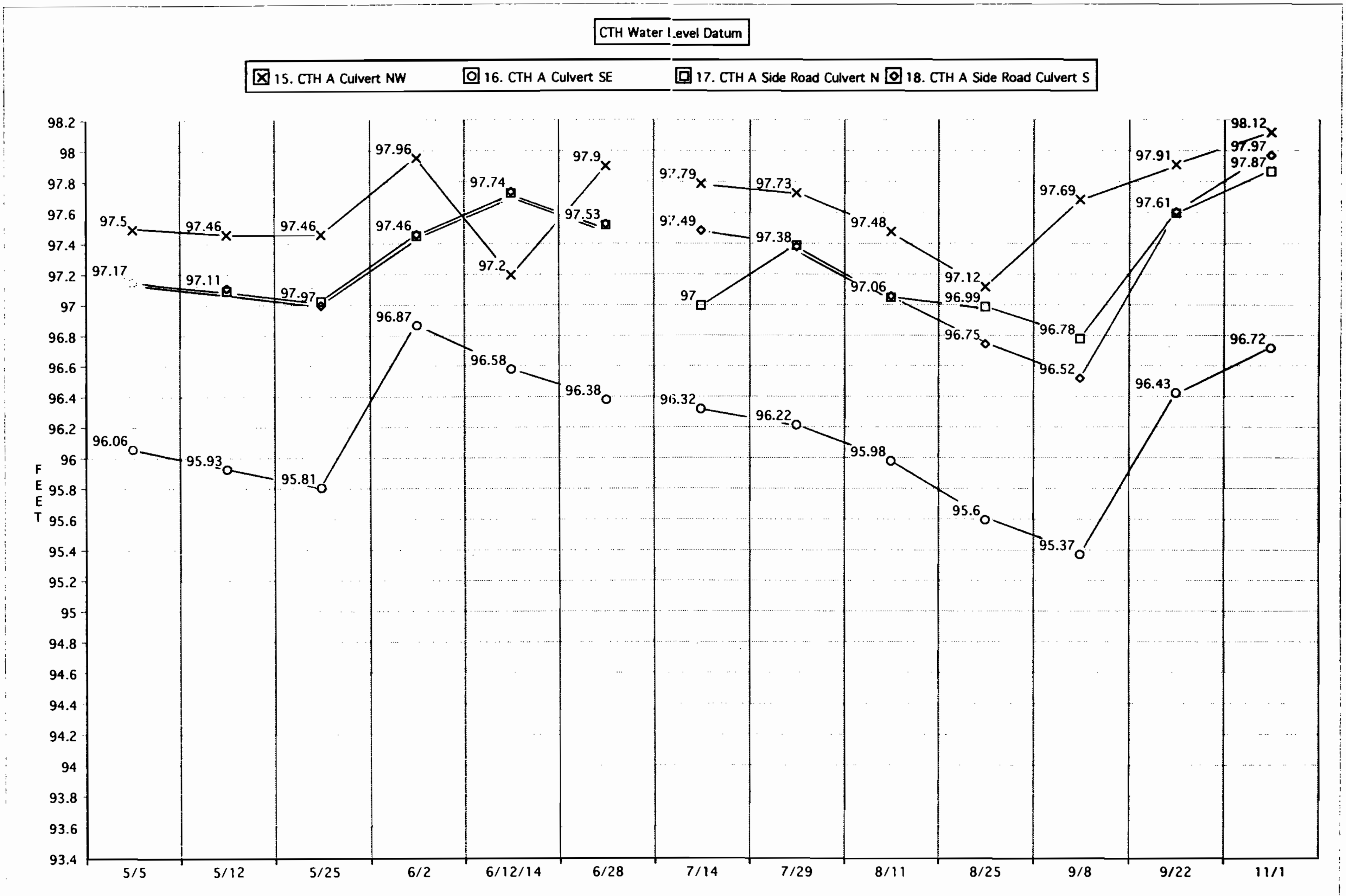


FIGURE 16. Thunder Lake Water Levels In the CTH A Culvert Area

FIGURE 16. Thunder Lake Water Levels In the CTH A Culvert Area



The first noted decrease in the CTH water levels was on the NW Thunder Lake side of the CTH A on June 14. See FIGURE 16. The water level drop was limited to the ditch area behind the first beaver dam which would be connected by the southwest ditch that extends to the Thunder Lake Cranberry bed area. This water level dropped and rebounded 6" from water level sampling dates of June 2 & 28. Rain amounts of 0.9" on June 11 increased water levels in the adjacent Thunder Lake ditches and the side road culvert to the southeast near the developing marsh. This time period corresponds to that summer's highest level of cranberry marsh pumping, the least amount of rain and recharge, and a time when early summer new growth in the marsh consumes the greatest amount of water. It appears this effect was limited to this small area.

The second noticed decrease in the CTH A culvert area was of longer term extending from mid June until September. See FIGURE 16. A steady drop in water levels occurred at all water level locations sampled along CTH A despite adequate rains. This steady dropped corresponded to observed irrigation pumping in the new developing cranberry marsh on every sample date from June 14 to August 25. The area flooded behind the beaver dam affected earlier by the Thunder Lake cranberry bogs pumping was now effected by Dempzy pumping. Water levels dropped steadily on both sides of CTH A but rebounded quicker on the Thunder Lake side when fall rains began. By November 1 after heavy fall rains, water levels increased to seasonal highs- flooding the road bed of the side road. A lift pump on the Dempzy Cranberry Marsh was observed on November 1 lifting floodwater from a main north-south ditch to an east east-west ditch. It was later confirmed that until the reservoir on the Dempzy was filled, pumping on the north end of the cranberry beds were creating a cone of depression that effected the old ditch area on the Thunder Lake side of CTH A.

A review of the Dempzy Cranberry Marsh construction plans submitted to the U.S. Corp of Army Engineers indicated the elevations of constructed cranberry would be the the following:

	USGS (MSL) ELEVATIONS
CRANBERRY BED	1635.5
BED DIKE	1638.5
DITCH BANK	1639.5
DITCH INVERT	1631.5

Surface water elevations in the ditches and Lake water levels in the Thunder Lake ecosystem ranged from 1626.5 to 1633.75. The bottom or invert of these ditches and water bodies would be normally 2- 6' lower than the surface. The normal horizontal movement of ground water would be in this case from the Dempzy Marsh towards Thunder Lake and the Thunder Lake Wildlife Area.

RECOMMENDATIONS FOR LONG TERM PROTECTION & MANAGEMENT

WATER LEVEL CONTROL & SHORELINE STABOLIZATION

Background

Much of this planning effort was spent evaluating the the water levels in the bog ecosystem of Thunder Lake. Thunder Lake is a large drained lake whose ecological stability is very dependent on the immmediate surrounding land. Disturbances over a relatively short period of time - 100 years- has disrupted this stability. Draining of the Thunder Lake Marsh, damming the outlet, and altering the drainage patterns set the stage for the disruptions. Management decisions that often looked at only one aspect of a problem has kept nature from stabolizing the changes made in the ecosystem.

Water levels investigations as part of this appraisal followed these disruptions through a single season while the history review of water levels and lake changes followed it through the past. Current operation and problems with the Thunder Lake dam have been reviewed. Water level effects of the pumping of the adjacent cranberry bogs have been analyzed. The lateral movement and hydraulics of water moving through a bog complex and water control structures have been studied. Rain, nutrient, and water cycling in the system have been evaluated.

Early on in the project it was recognized that a stable water level was needed for the plant community. The plants in the lake, at the water's edge, and on the adjacent wetlands were exposed to changing water levels, wave action, and loss of nutrients & suitable substrates that were effecting their survival. The questions of what water level changes were currently occurring and what water level would be best for the ecosystem had to be answered. After a review of past studies and a water level evaluation, two control structures were recognized as capable of stablizing the system if properly managed.

Management Options

There are several options to the management of the water levels. One option can be done without another but the beneficial effects will not be as great or delayed. These options and their management scenarios are made with the long term protection & restoration of the Thunder Lake system in mind.

The FIRST OPTION is to do nothing. The water quality problems of Thunder Lake will not improve noticeably for a long time. Certain uncontrollable conditions such as weather and climate can return Thunder Lake to the conditions of the 1980's.

The SECOND OPTION is to change the design or operation of the dam. This option is already being considered by the town with it's repair and replacement. After early spring runnoff the lake water level and corresponding water release should be at the elevation created when only one stop log removed from the present dam. This will allow slower release of water to Rice Lake and send water through the bog system of the Thunder Lake Wildlife area. This will stabolize water level fluctuations on Thunder Lake that will in return allow the aquatic plant community in and adjacent to the lake to stabolize. Cooperation and coordination of this effort with the town officials and education of the lake community of the changes in design and operation are part of this option.

The THIRD OPTION is to gain control and operate the Rangeline Exit Dam. This dam is on private property. This option would require cooperation in either purchasing or leasing of dam as well as meet legal requirements of operation and maintenance. The benefits and effectiveness of this option would again be tied to the second option above. Water levels on the Thunder Lake Wildlife area would be stabolized to the benefit of the aquatic plants, waterfowl, and wildlife. Current wildlife management efforts in woody vegetation and beaver control would be reduced or eliminated. Slower release of water to the Rice Lake Natural Area would benefit wild rice production. A combine effort of the lake district, private landowners, theThree Lake's Sportsmen's Club, township, and Department of Natural Resources personnel will be needed for this option to succeed.

The FOURTH OPTION would be to create some type of breakwater barrier on the north to east shoreline of Thunder Lake to help reclaim bog eroded areas. Nature at present is trying to do this farther out from the shoreline as the new submerged aquatic vegetation in the north and northeast bay is slowing wave action created by north to south winds during open water periods. This vegetation by slowing wave energy settles suspended sediment- formally eroded bog material- in the vegetation and on the leeward side. Eventually this process may stabilization the bog shoreline again, however this process could take hundreds of years.

Currently, much of this shoreline drops quickly from the eroded bog edge. Attached submerged peat material extends for several hundred feet lakeward at a depth of 3 to 5- below the depth of wave energy. A gentle sloping shoreline needs to be created to dissipate the energy of the breaking waves against the bog edge. Some type of breakwater barrier needs to be constructed parallel to the shoreline just below water level to stop the wave energy that causes the erosion but at the same time carry suspended peat material over it to settle between the barrier and the shoreline. This practice combined with the water level stabolization in second and third options above will not only stop further erosion but again build the peat shoreline and indirectly deepen other areas of the lake. This option will require significant efforts in planning and construction. A pilot project should be considered first - possibly on either the cranberry bog shoreline area or the extended dam berm area- or both after a better understanding of wind direction and wave/ ice action.

AQUATIC PLANT MANAGEMENT
Background

The aquatic plant community of Thunder Lake- since the first increases in the water levels over 80 years ago- has drastically changed. A healthy plant population has evolved into a population dominated by fine-leaved submergents after a complete loss of the submergent plant population in the early 1980's.

Will the present plant population persist? How do we deal with it if it does not? What happens if the conditions of the early 1980's return? These are the questions that a management strategy for aquatic plants looks at. The following options are a strategies to deal with the present conditions and at the same time combined with the options discussed above can restore the plant community.

Management Options

There are several options in the management of the aquatic plant community. Several of these options have been discussed at several lake district meetings and/or have been presented to the District through the Property Owner's Survey as part of this study. Again, the aquatic plant management plan will be more successful if they are combined with water level and shoreline stabolization options above.

The FIRST OPTION is to do nothing. Nuisance levels of submerged aquatic plants will continue to dominate the lake or under certain weather conditions algae blooms may return to create the water quality conditions of the early 1980's. Fish & wildlife populations that are dependent on a diverse aquatic plant community will fluctuate with these changes in water quality. Stabolization of water levels and stopping of further shoreline erosion probably will do more in the restoration of the plant community than any other option.

The SECOND OPTION would be machine harvesting of the nuisance submergent aquatic plants. This option was favored over chemical treatment and dredging as solutions to Thunder Lake's problems.

Purchase, operation. and maintenance of an aquatic plant harvester is very expensive. Joint purchase and operation with another nearby lake could reduce these expenses. Cost sharing for purchase is also available through the State Waterway Commission. Cost for harvesting and removal equipment ranges from \$39,000 to \$60,000. Operation and maintanence cost are additional.

Several portable machine aquatic plant harvesters are available that can be mounted on a boat and operated by volunteers. The cost of these harvesters start at $3,000 and can exceed $10,000 with additional equipment that aid removal. There are also several water weed cutters and rakes available for hand harvesting. These tools could be purchased by the district and loaned to residents for use. Plants cut can be put on the shoreline, dryed, and used for mulch or compost. Cost is less than $200.

The hiring of a plant harvester may be the most practical alternative at this time. A six foot cutter can cut approximately a half acre in 1/2 hour and haul about 300 cubic feet of plants before having to unload at a landing. This cutting time can very depending on the density of weeds and distance to the landing for unloading. It can cut to a maximum depth of 5 feet but cutting in water less than 2 feet is impossible or very hard on the cutting bar. There is usually a minimum acreage needed to make hauling and operation of the harvester economical for the owner. Prices to hire a contractor are $2,400 for a 20 hour minimum, $120/hr for 20-40 hours, or $100/ hr if over 40 acres are harvested.

A THIRD OPTION would be to help in the restoration of wild rice by planting it in serveral areas of the lake. The periodic small patches that still do appear are quickly eaten by waterfowl and wildlife and seed production of this annual is limited. Rice could be planted in areas where wild plants have been recenty observed. Stabolized water levels will help reestablish this important emergent aquatic plant.

A FOURTH OPTION would be to address excessive algae growth on the lake if nuisance levels return. The dam has restricted fish movement from downstream waters in Thunder Lake for over 60 years. The series of winterkills since this time combined with the dam obstruction probably has decreased the diversity of minnow species in the lake. One minnow species, the northern redbelly dace, that does well in a bog and headwater environment may have been eliminated or reduced during this time. The food of the red belly dace consists mainly of algae including diatoms and filamentous algae. If this species is absent from the system a restored population would contribute to nutrient assimulation at a low trophic level of the food chain. At the next trophic level it would provide excellent forage for perch and other panfish as well as young game fish.

WATERSHED PROTECTION

Background

Most of the watershed is lowland with a combination of open bogs, bog forest, swamp forest, and alder thickets. The upland is mainly forested with communities ranging from second growth mixed- hardwoods to pine forest intermixed with patches boreal forest. This combination and variety of upland and wetland habitats in a relatively small area creates a diversity of plant and animal communities. The aesthetic importance of these watershed resources were identified in the property owner's survey. Scenic beauty & tranquility was recognized as the highest use and value of their lake property.

Disruptions in these plants communities are closely tied to the development and use of these land forms. Cranberry bog contruction,shoreline development, and forestry related activities effect the quality of both surface and subsurface water.

Future shoreline development for lake dwellings is limited as suitable upland sites for construction are also limited. Future watershed protection on the present light residential sites is important. Steep slopes and grades on these sites combined with light soils combine to make these sites very susceptible to erosion. Any tree canopy removal or soil exposure through grading or road building will increase the erodibility of these soils.

These sand and gravel soils are also very porous which makes them suseptible to groundwater contamination from wastewater, pesticides, and fuel /oil products. Wells in the area, described by lake residents in the property owner's survey, are mainly sand points from 14 to 40'. Seven drilled wells were identified ranging in known depth from 32 to 80'. A septic tank and drain field is the most common wastewater system used with many of these being replaced over the last ten years.

Shoreline seepage areas on the southern end of Thunder Lake are an important habitat for fish and aquatic insects. Much of Thunder Lake's shoreline is bog so these sand and gravel shoreline areas are important for reproduction and survival of important plant and animal species that depend on wind swept shorelines. Increased lake use by the present property owner will utilize and develop this areas for recreational uses and can effect these organisms.

The upland watershed away from the shoreline is mostly forested with large tract ownership in the hands of a few individuals or paper companies. Minerals carried by runnoff and soil seepage from these large tracts are important to the wetland and shore communities of Thunder Lake. The potential problems found in the soils of the shoreline described above are the same problems that face the large tracts. Clear cutting and road building without proper planning and reforestation concerns could effect large areas of adjacent wetland communities.

Cranberry bog development and expansion can further change the wetland landscape and affect the water quality of the lateral moving groundwater. Large areas of cranberry beds disrupt natural ground water movement through the bog ecosystem. Pesticides used by the cranberry growers can enter the peat soils and groundwater and through lateral movement of the ground water can be carried to other undisturbed areas of the bog ecosystem and the lake. Large areas of cranberry beds can affect the scenic beauty ot the area and operation of large engines for pumping on these bogs can effect the tranquility of the lake community.

The Thunder Lake Wildlife and Rice Lake Natural Areas are also part of the Thunder Lake watershed. The management of the Thunder Lake water resources directlly effects them. There protection has been discussed under the water level management section of this paper.

A watershed area that is connected to the SSE bay of Thunder Lake east of the south boat landing road could be beneficial to the lake if restored. A large sinkhole pond area that at one time discharged water to the bay was modified to create ponds for minnow culture in the past. A pipe connecting the sink hole to constructed ponds below has become clogged over time stopping this water flow to the bay. Restoration would return this flow once again to this bay.

Management Options

Most of the watershed protection options will depend on good land stewardship of residents and landowners. The property owner's survey indicates a large majority of those responding have been property owner's for less than 5 years. There increased knowledge of the lake and it's resources will be important in understanding their relationship to the land.

The FIRST OPTION is to do nothing. Current shoreline and zoning laws are designed to protect the lake and land resources. Distribution and reading of this document will inform lake district residents of their options and responsibilities and hopefully spur them to become active in the lake district and community.

The SECOND OPTION is to be more proactive in educating district residents at the biannual meetings in regards to shoreline, wetland, and floodplain requirements. This meeting can also be used to educate them on shoreline actitivities that effect the lake and how to utilize their shoreline without destroying it. Water and wastewater system operation and effects on ground water and the lake can also be presented in an educational program.

The THIRD OPTION is to purchase environmental sensitive areas (such as the one described above) or conservation easement areas. Important wetand and shoreland areas adjacent to the lake can be purchased and buffered from upland activities that would effect them. Cost sharing is available for this practice.

FISH MANAGEMENT

Background

The fishery of Thunder Lake is changing quickly with the improved water quality. Low oxygen winter oxygen conditions and excessive nutrients from eroded bogs are still problems that could effect the fishery in the future. Every effort to suppress the bullhead population and maintain oxygen in the lake is being made.

Steps have been taken to protect the recovering gamefish from over fishing. Bag reductions and size limit for bass and walleye at this time have been proposed and pursued. Trolling elimination has also been pursued. Results of these efforts should take affect in 1998.

Panfish populations are healthy with black crappie and yellow perch population thriving. Proposed panfish bag reductions are being considered statewide at the current time. Panfish reduction was also discussed at the fall 1997 meeting. Crappie populations and growth can fluctuate widely affecting the success of other panfish and forage. With the abundance of nutrients in the Thunder Lake flowage a panfish bag limit reduction- especially on black crappie, would not be recommended.

Management Options

Many options in fishery management have been already acted upon during this planning grant period. The stabolizing of water levels - especially in spring and early summer will help the survival of fish spawn and larval fish. Long term stabolization of water levels will improve water quality and habitat for the fishery. Efforts to date have failed at establishing of a self- sustaining walleye population. The management options presented below offer fisheries management options that could help stabolize the fishery.

The FIRST OPTION would be to do nothing at this time except fish management alternatives already set in motion. Walleye populations would then have to be maintained through stocking. Water quality improvements may improve the conditions for better survival of stocked or natural reproducing stocks.

The SECOND OPTION is to identify if walleyes are spawning in cranberry bog ditches. If spawning is occurring identify if eggs are incubating and surviving to the sac fry stage. If they are hatching, are the walleye sac fry surviving and returning to the lake to feed on zooplankton?

A THIRD OPTION would be to create a barrier to stop spawning fish from entering the cranberry ditches and identify other spawning areas that they find suitable for spawning.

A FOURTH OPTION would be to place walleye eggs or fry at probable walleye spawning areas and pursue the possibility of walleye imprinting at that location and returning to spawn at that sight when mature.

A FIFTH OPTION would be to stock and develop a population of northern redbelly dace in Thunder Lake. As discussed under the plant management section, this minnow besides feeding dominately on algae makes excellent forage for game and panfish. The sinkhole area and former minnow ponds on the south end of the lake could be restored not only for water quality restoration but to produce this minnow. Purchasing this minnow specie would be another alternate in their establishment.

A SIXTH OPTION would be white sucker propagation at the above site, depending on the water temperatures after restoration. With limited water quality, limited spawning areas, and a dammed outlet natural production and migration recruitment of the white sucker is probably limited. This fish species can utilize the tremendous amount of bottom organisms available in Thunder Lake during the open water and provide an excellent forage for gamefish. Purchasing this forage specie would be another alternative as part of this option.

APPENDIX I

THUNDER LAKE PROPERTY OWNERS SURVEY 1996

NAME: ____________________ CURRENT ADDRESS ____________________

1. HOW LONG HAVE YOU OWNED PROPERTY ON THUNDER LAKE? _____ years.

2. WOULD YOU CONSIDER YOUR PROPERTY A : a.) Year-round home? _____
   b.) Three seasons home?___ c.)Summer cottage?___d.)Winterized cottage?_____
   e.) Vacant land(acreage)? ______ f.)Business(describe on back) ? _____ .

3. HOW OFTEN DO YOU USE YOUR LAKE DWELLING OR PROPERTY?
   a.) Weekends / year____ b.)Week days/ year____c.) Other (describe on back)_____.

4. ON AN AVERAGE, HOW MANY PEOPLE USE YOUR PROPERTY DURING THE PERIOD(S) CHECKED IN QUESTION #3 ABOVE?
   a.) Weekends_____ Weekdays _____Other(use back if necessary) ________.

5. IN DESCRIBING THE USE AND VALUE OF YOUR LAKE PROPERTY **NUMBER 1 THRU 7 BELOW** THE PRIORITY YOU WOULD PLACE ON THE FOLLOWING?
   a.) Swimming ___ b.) Pleasure Boating ___ c.) Fishing ___
   d.) Duck Hunting ___ e.)Wildlife Viewing ___ f.)Scenic Beauty & Tranquility___
   g.) Water Skiing ___ h.) Jet Skiing ___ Other(describe) ______________ ____.

6. WHAT TYPE OF WASTE DISPOSAL SYSTEM DOES YOUR PROPERTY HAVE?____________________________ HOW OLD IS IT? ____ years
   WHAT MAINTENANCE DOES IT REQUIRE? ____________________.

7. WHAT TYPE OF WELL DO YOU HAVE ON YOUR PROPERTY? Drilled? ____
   Driven sand point? ____ Other(describe)?______________ _____. HOW DEEP IS YOUR WELL? ____ feet. IF KNOWN (FROM WELL DRILLER'S REPORT OR WHEN PUMP HAS NOT RUN) WHAT IS OR WAS THE STATIC HEAD? ____ feet?

8. WHAT DO YOU FEEL ARE THE MAJOR PROBLEMS FACING THUNDER LAKE AT THIS TIME (**PLEASE COMMENT ON BACK**)?

9. THE DEPTH AND FERTILITY OF THUNDER LAKE CAUSE MANY PROBLEMS FOR THE RECREATIONAL USE OF THE LAKE? WHAT PRIORITIES WOULD YOU GIVE TO SOLVE, PREVENT, OR KEEP THESE PROBLEMS FROM WORSENING.
   NUMBER 1THRU 6(#1 being the highest,#6 the lowest) YOUR CHOICES
   ___Water Level and Flow Management ___ Other (Explain) ________________
   ___ Machine Harvest of Aquatic Plants ________________
   ___Chemical Treatment of Aquatic Plants ________________
   ___Dredging/ Removal of Lake Bed Material ________________
   ___Long-Term Shoreline Stabilization, Restoration, & Protection

PLEASE RETURN THIS QUESTIONNAIRE WITHIN 10 DAYS TO AQUATIC RESOURCES,INC.,P.O. BOX 2221, WAUSAU, WISCONSIN 54403.