LPL 671

THUNDER LAKE PLANNING GRANT PHASE 2 FINAL REPORT

December 2001

completed by

THUNDER LAKE PROTECTION & REHABILITATION DISTRICT

AND

RAND ATKINSON AQUATIC RESOURCES, INC.

in cooperation with

WISCONSIN DEPARTMENT OF NATURAL RESOURCES
LAKE PLANNING GRANT PROGRAM

TABLE OF CONTENTS

WATER RESOURCES AND APPRAISAL

Thunder Lake Marsh Water Level Restoration

South Thunder Lake Pond Restoration

Walleye Fishery Restoration

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Thunder Lake is a 1,768 acre lake with a maximum depth of 12 feet and a mean depth of 5.5 feet. The watershed is mainly undeveloped with 2,025 acres mostly covered in wetland or forest. Two cranberry bogs have been developed in an additional 170 acres of the wetland. Approximately 35 acres in the area of the southern shoreline is used for low density residential. There are two public boat landing , two resorts, two state wildlife areas, and approximately fifty private cottages or homes on the shoreline or within the watershed ecosystem.

Thunder Lake, with it's large surface area and adjacent wetlands receives approximately 72% of it's water from atmospheric precipitation. An additional 17% is provided from overland runoff and 11% is received from ground water. The regional ground water movement in the area is from southeast to northwest but ditching and damming of the wetlands and outlet area over the last 80 years has disrupted this general lateral movement. There is is no defined inlet or outlet stream but an outlet ditch does exit the lake from a 4' maximum head dam.

In the past, Thunder Lake, with it's diverse plant community, supported a valuable sports fishery and was heavily used by waterfowl. Over time, the increased water levels from the construction of the dam and wave action have eroded the shoreline bogs, freeing peat and releasing an increased abundance of organic nutrients for fish and aquatic plant growth. It has also decreased the average depth to 5 feet. These combined actions have caused the severe water quality problems the lake community now faces. Water quality problems of fish and aquatic organism winter kill, bullhead population explosions, algae blooms, and loss of valuable submerged vegetation were a result. The lake district took action to install an aeration system, remove bullheads, restock predatory fish, and modify the dam to help the lake recover.

The first phase of the planning grant documented these events, ecologically evaluated the situation, and recognized management alternatives to restore and stabilize the system. There are multiple components in the second phase of the lake planning grant process. Water level stabilization and lateral ground water flow restoration in the Thunder Lake ecosystem are key management components that the Thunder Lake P & R District is addressing as part of the comprehensive lake management plan developed in Phase 1.

The second phase also addresses the restoration of a self-sustaining fishery. The creation of a walleye spawning reef as part of the north shore stabilization project developed by the Thunder Lake P & R district and the DNR will occur in 1998-1999. This new structure will be evaluated along with other fisheries habitat to meet these fish management goals.

The implementation of several management recommendations from the Phase 1 planning report has again involved private individuals and government officials working together to approach the complex and long-term nature of the projects. Thunder Lake, Thunder Marsh Wildlife and Rice Lake Natural Areas, and private lands are effected by the water level and flow management restoration is carried out in this grant. The consultant, Aquatic Resources, has coordinated the restoration efforts and has been the contact between individuals & government officials.

ACKNOWLEDGEMENTS

A special thanks to the Thunder Lake District for initiating and funding this effort to better understand and restore the resources of it's lake community. Chairman, Greg Weinfurter, lead the district to implement management recommendations identified in Phase 1 planning grant study. He and his wife, Ingrid also provided temperatures and watchful eyes during the 2000 & 2001 walleye spawning watches and provided printing/ newsletter support through their print shop, Press Express. A thanks to Ingrid Weinfurter, as secretary of the Lake District for keeping track of the many meetings that were part of the planning grant activities. A thanks also to Pat Brainard, treasurer, for keeping track of the expenditures through the planning grant process.

Another special thanks to the Town of Three Lakes and the Three Lakes Fish and Game Improvement Association for their support of the project from the start. They are present and future partners in the restoration and management of the Thunder Lake watershed and ecosystem.

A personal thanks to Mark & Tim Goldworthy and John Sampson for there efforts in monitoring cranberry bog ditches for temperature and walleye spawning activities.

Thank you, DNR personnel for review, information, and guidance in this planning grant process. Ron Eckstein and Bob Young, and Mike Vogelstang are especially appreciated for their project input.

Rand Atkinson, Aquatic Resources, Inc.

Information and Education

The development and use of effective information and education techniques are essential to the success of completing a lake management plan. Experience has shown that a project success is not only dependent on a well informed public but also in achieving public interest and involvement in carrying out the lake plan.

This Phase 2 planning grant proposal initiatives were presented to the Thunder Lake Protection and Rehabilitation District at their annual meeting on May 2, 1998. The grant proposal was written in June and July of that year and, after DNR comment, was submitted by the August 1 deadline. The grant was not funded during this grant period so a fall meeting between DNR personnel, lake district officials, and the consultant was held to revise the grant to include additional water level information on the Thunder Lake Marsh. The grant proposal and funding was discussed at both meetings of the lake district in 1999.

The grant was finally funded in the fall of 1999. On February 7, 2000, a newsletter was written detailing planning grant activities and time scheduling of the Phase 2 planning grant activities. At the annual spring meeting on May 6, 2000, the details of the planning grant activities were again presented as the preliminary observations of the spring ice out walleye spawning sites provided.

During the fall meeting of the district on October 21, 2000 planning grant activities, including the spring walleye spawning activities, marsh water levels observations, and south restoration, were presented to district members. Winter and 2001 activities were also discussed. The Thunder Lake District at that time choose to replace a pipe on the South Kressman restoration property so water flow could be restored and further evaluated as part of the grant proposal.

At the spring meeting and fall meetings, updates of planning grant activities were made. An updated newsletter was created for each meeting. The second year activities of the south restoration and spring walleye spawning were presented and discussed. The consultant met with Ron Ecstein, DNR Thunder Lake Wildlife Area manager, prior to the fall meeting to discuss the water level observations and changes in the marsh management. Ron Ecstein attended the fall meeting and provided an overview of the marsh management and future management objectives that the district might help with.

The consultant and District chairman have met and discussed planning activities with town board members. The final report was given to Three Lake's town board members at there request rather than give a presentation. The project and final report was presented at the January meeting of the Three Lakes Fish & Wildlife Improvement Association on January 17,2002. Copies of this final report will be made available to all members of the lake district, Town of Three Lakes, The Three Lakes Fish & Wildlife Improvement Association, and the Three Lakes Library.

WATER RESOURCE RESTORATION AND APPRAISAL

Thunder Lake Marsh Water Level Restoration

Introduction

The Phase 1 planning grant gathered data on the water levels in the Thunder Lake ecosystem, analyzed the effects of the water levels and flow patterns on the resources, and presented management objectives that could be initiated to correct current problems. The change in operation of the dams on the north end of Thunder Lake and at the northeast corner of the Thunder Lake Wildlife Area were recognized as important in the stabilization of the Thunder Lake ecosystem.

The Thunder Lake Dam was repaired and modified by the Town of Three Lakes in 1995. This dam now has a reinforced, concrete, right angle notched weir whose bottom elevation corresponds to the elevation created when only one stop log was removed from the former dam. This elevation allows some direct passage of spring runoff waters through the dam but maintains a more constant lake water level. It allows slower release of water to Rice Lake through the marsh of the Thunder Lake Wildlife Area. This renovated dam also was designed to stabilize water level fluctuations on Thunder Lake which will allow the aquatic plant community in and adjacent to the lake to stabilize. During the summer and fall of 1997-98, a breach of a pushup mound on the shoreline west of the dam cut a channel to the Thunder Lake Dam Road ditch. A temporary repair sent water through the marsh to Rice Lake. A shoreline stabilization project to secure this area was completed during the spring of 1999. This study evaluated and compared the restored water levels resulting from the new dam to the levels monitored in 1994.

The restoration and operation of the Rangeline Exit dam was also a recommended option in the 1996 plan. This dam is on private property. This option requires cooperation of the present dam owner and must meet the legal requirements of operation and maintenance. This management option was put on hold until the effects of the new Thunder Lake water levels were evaluated.

Stabilization of the water levels on the Thunder Lake marsh would benefit aquatic plants, waterfowl, and wildlife. Higher, stabilized water levels would compliment current wildlife management efforts to eliminate woody vegetation growth on much of the wildlife area, as well as aid in controlling the beaver population . Slower release of water to the Rice Lake Natural Area would benefit wild rice production. A combined effort of the lake district, private landowners, the Three Lake's Fish & Wildlife Improvement Association, Inc., Town of Three Lakes, and Department of Natural Resources personnel will be needed for this option to succeed.

Procedure

This investigation evaluated what effects the new dam on Thunder Lake had on the water levels' of Thunder Lake marsh and ecosystem. The water levels found in this study were compared to those found in 1994, prior to the stabilization and modification of the dam. New water level locations at the east end of the wildlife area were added to the 1994 monitoring locations to assess possible higher water level effects on Rice Lake and Thunder Lake Dam Roads. Twenty-four locations in the Thunder Lake ecosystems were monitored from May to October 2000 to document water level changes throughout the open water period. Rain data was collected at the south end of Thunder Lake at the same location as in 1994.

Results

Thunder & Rice Lake Water Levels

Thunder Lake, with it's large surface area and adjacent wetlands, receives approximately 72% of it's water from atmospheric precipitation. An additional 17% is provided from overland runoff and 11% is received from ground water. Precipitation amounts during the growing season of 1994 and 2000 varied less than one half inch . Rain events in 1994 were more frequent and lighter than in 2000. See **Figure 1.**

Thunder Lake's water level over the open water period of 2000 did not vary more than 4", ranging from 1633.0 to 1633.3. In 1994, Thunder Lake's water level varied near 9", ranging from 1633.05 to 1633.73. The storm event of July 9, 2000 produced 4.5 inches of rain which was not reflected in Thunder Lake's water level data but probably effected a peak in Rice Lake's water level data. See **Figure 2**.

Rice Lake, in 2000, increased from a water level of 1627.4 on May 10 to a water level of 1628.65 on October 18 due to beaver activity at the outlet. In 1994 Rice Lake's water level ranged from 1628.2 to 1628.8 - only a 7" range. See **Figure 2.**

Thunder Lake Wildlife Area East Exits Water Levels

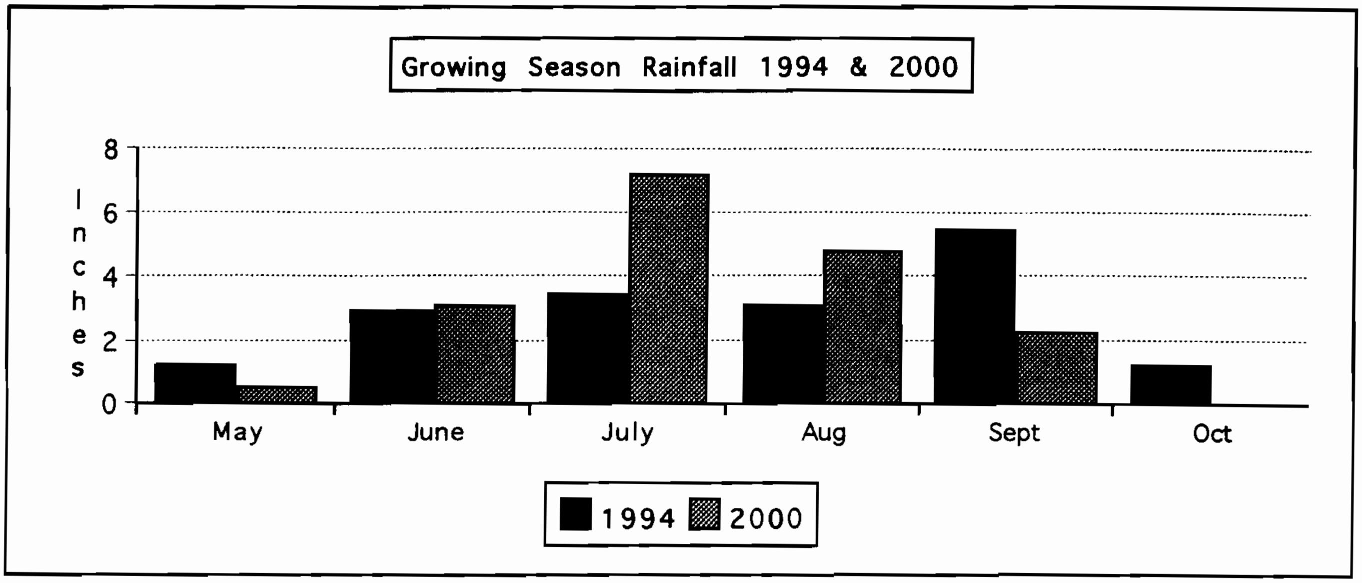
In 2000, the Townline Lake exit - measured at the railroad crossing- ranged from 1625.59 to 1625.86, less than 3 inches. In 1994, water level at this location varied from 1625.62 to 1626.21, or about 6". In 2000, beaver dam's on the north-south ditch on the east border of the Thunder Lake marsh controlled the flow to this exit. The beaver dam pool that releases water to the townline exit varied in elevation in 2000 from 1631.01 to 1632.84 as controlled by the dams on the main ditch. The structural head elevation of the beaver dam above this pool was 1632.51. Heavy rains on August 7th and 8th resulted in both beaver dams to be overtopped on the August 9 sampling date, while Thunder Lake water level was at 1633.2. Water was directed towards the wild life entrance and not towards Townline Lake as beavers increased the elevation of the Townline exit dam in the lower pool. A second heavy rain event on August 14 resulted in water to be directed by the beavers to Townline Lake raising the water at the railroad crossing at the August 22 sampling date but not at the wildlife entrance. See **Figure 3**.

Water levels at the old Range Line dam exit from the Thunder Lake Marsh in 2000 ranged from 1626.9 to 1627.15, less than 3". In 1994 water levels ranged from 1626.69 to 1628.06, or 16". See **Figure 3.** These water levels ranged from a few inches to over a foot higher than the Rangeline Lake water levels that are controlled by the Burnt Rollway dam of the Three Lakes Chain.

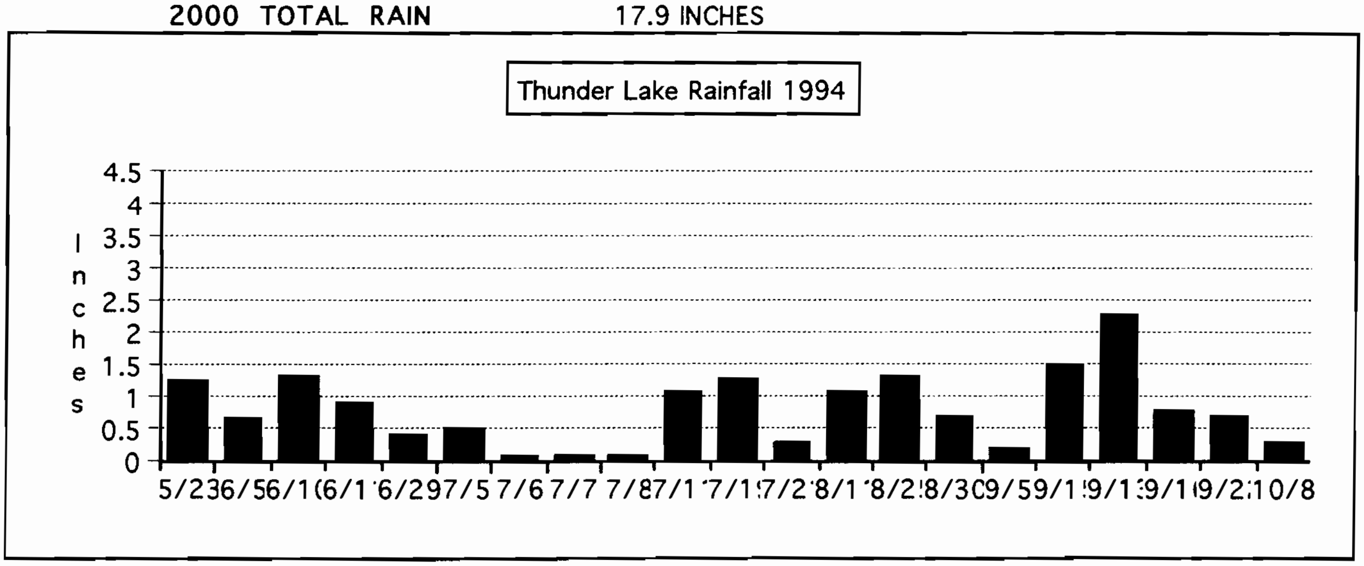
Thunder Lake Wildlife Area West Water Levels

Thunder Lake Dam Road ditch travels south from the dam to the north emptying into the east-west Rice Lake Road ditch at the intersection of the two roads. One major east-west ditch enters the Thunder Lake Dam Road ditch from the east, this ditch drains the south central part of the Wildlife Area east of the north-south divide. A new small culvert has been installed beneath the dam road 100 yards south of the Thunder Lake to drain water from east to west during periods of high water. Little flow was observed in this culvert during the observation period. The new dam on Thunder Lake allows water to enter this ditch only during extremely high water periods.

Figure 1. Thunder Lake Open Water Rain 2000 & 1994



1994 TOTAL RAIN 17.55 INCHES
2000 TOTAL RAIN 17.9 INCHES



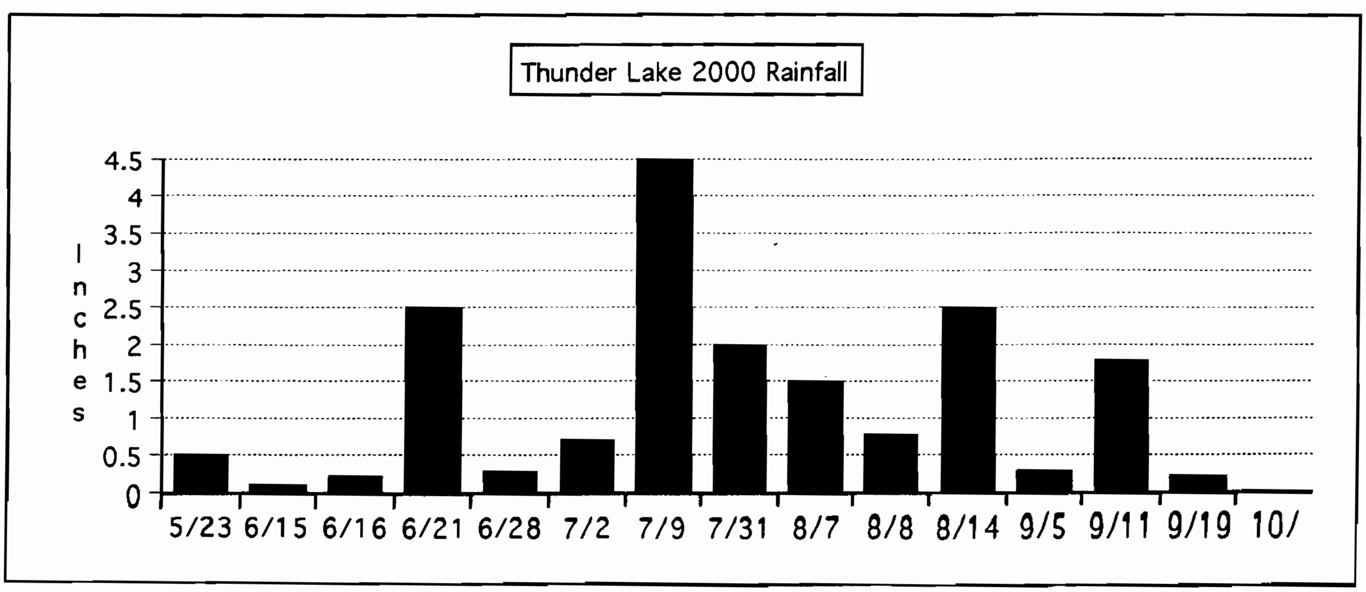


FIGURE 2. THUNDER & RICE LAKE WATER LEVELS 1994 & 2000

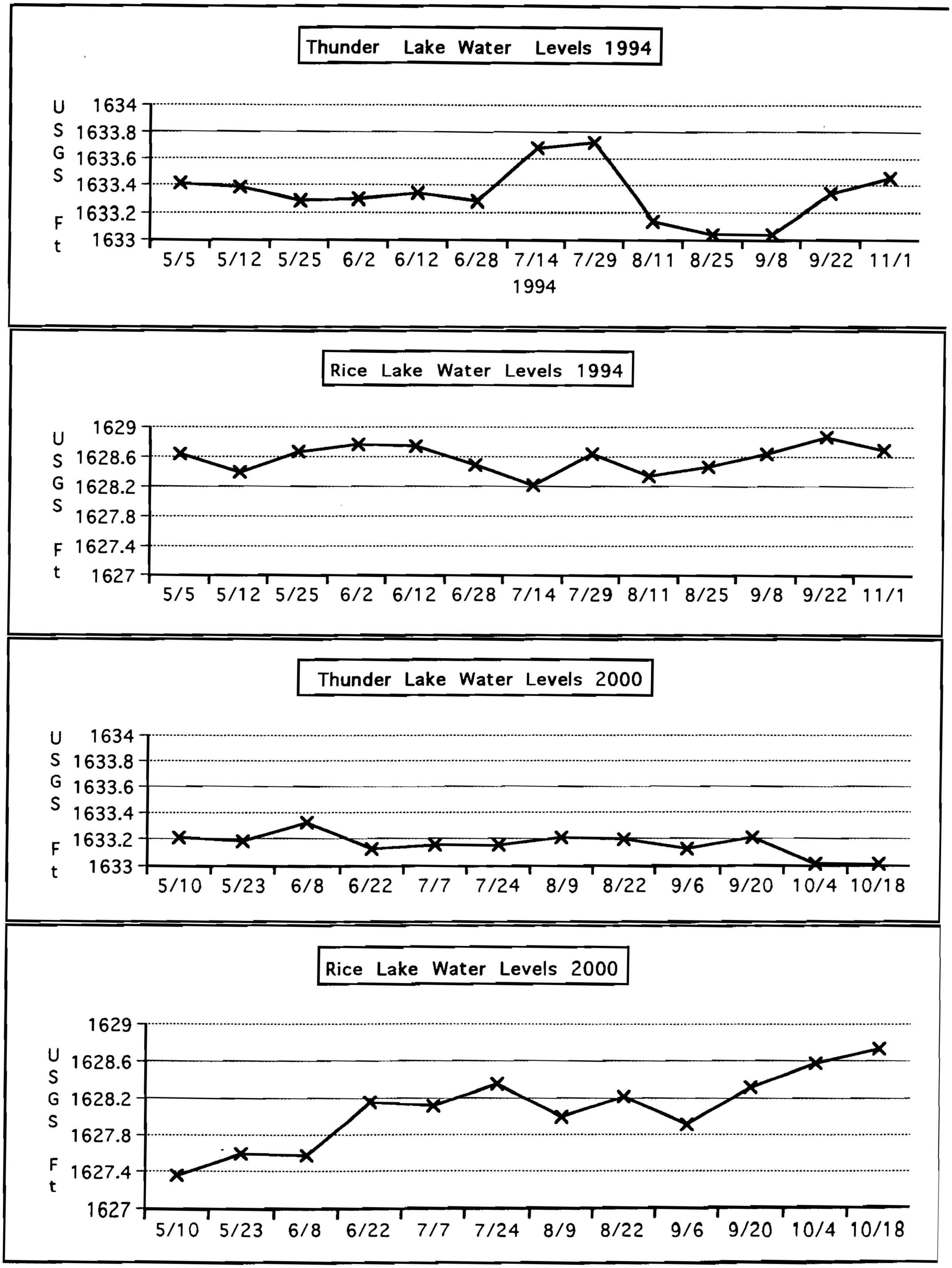
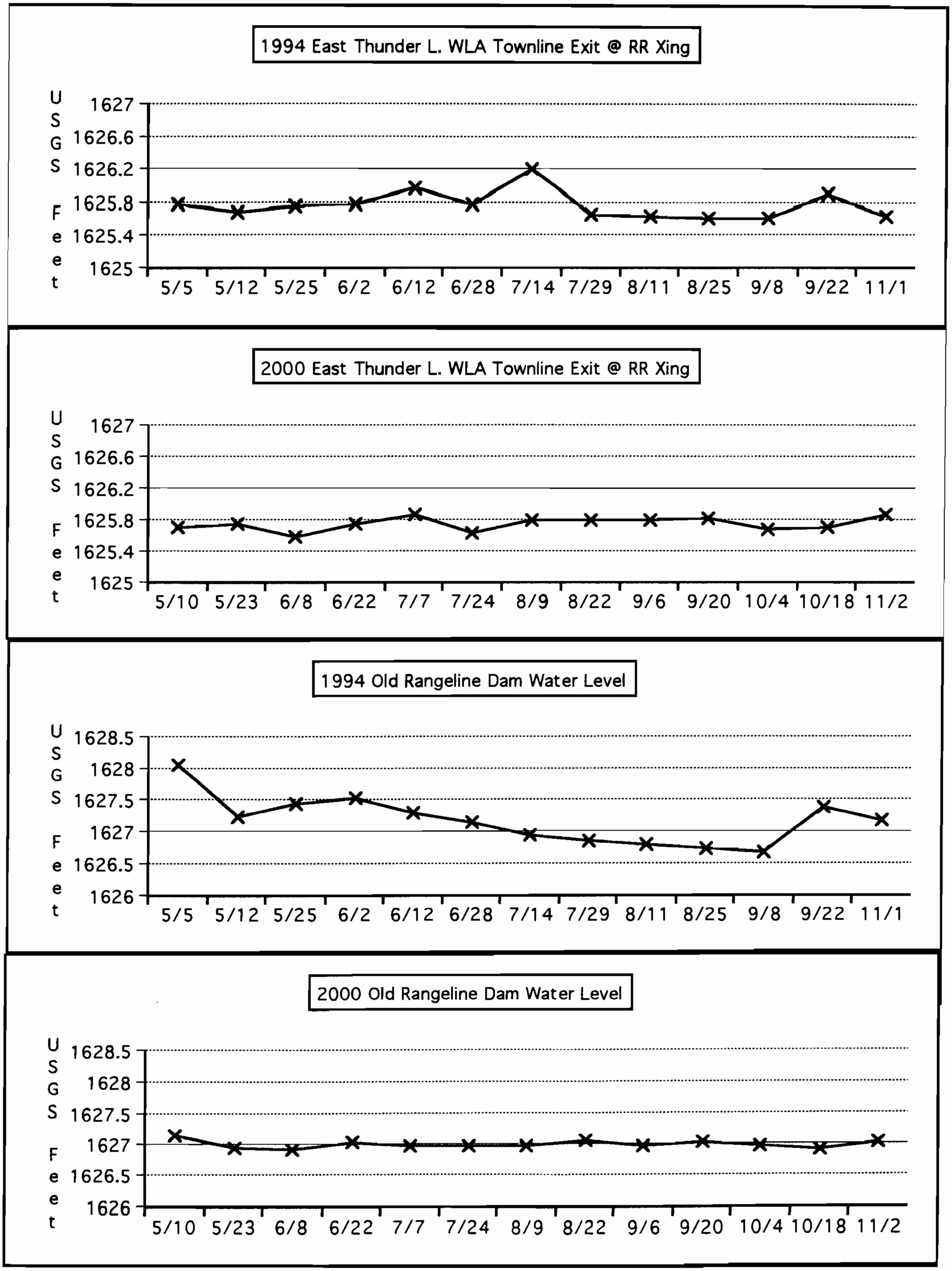


FIGURE 3. WATER LEVELS TL WILDLIFE AREA EAST EXITS 1994 & 2000



Water levels were measured from the top of the culverts. Water level of the east-west ditch was measured at the east end of the culvert beneath Thunder Lake Dam Road. Thunder Lake Dam Road ditch water levels were measured at the west culvert of the crossing, just below the location where the east-west ditch enters.

In 2000, Water elevations in the north-south ditch ranged from 1628.19 to 1630.71 or over 18". In 1994, water elevations ranged from 1628.11 to 1629.73, also about 18". The decreased flow from the dam and lack of culvert debris maintenance, allowed plant growth to clog this water way. Water elevations in the east -west ditch in 2000 ranged from 1628.04 to 1630.58, or about 30". In 2000 this culvert also was allowed to clog with debris as long as the road was not threatened. In 1994, the water elevation range was from 1629.09 to 1629.73, or about 7 inches. See **Figure 4**.

Two parallel north-south ditches, coming from the North, flow to the Rice Lake Road east-west ditch at it's intersection with Thunder Lake Dam Road. These ditches drain the most of the north end of the northwest Thunder Lake Wildlife Area. The most westerly of these parallel ditches was measured on the north side of the culvert under Rice Lake Road. The east ditch was measured on the east end of the culvert that is under the dike that separates the two ditches. In 2000, the west parallel ditch contained two beaver dams whose water elevations were also measured.

In the west north-south ditch in 2000, water levels ranged from 1629.19 to 1630.71, or about 18", at the north end of the Rice Lake Road culvert. In 1994, this same water elevation ranged from 1626.52 to 1629.05. In 2000, the first beaver dam created a pool where water levels ranged in elevations from 1629.27 to 1630.65. At the second beaver dam pool, water levels fluctuated from 1629.59 to 1630.57. See **Figures 5 & 6**.

In the east north-south ditch in 2000, water levels ranged from 1627.37 to 1628.9, or about 1.5 feet. In 1994, water elevations in this same ditch ranged from 1629.07 to 1631.45, or 2.4 feet. Both ditches are now allowed to be dammed by beaver as long as the water levels do not threaten Rice Lake Road. See **Figure 5 & 6**.

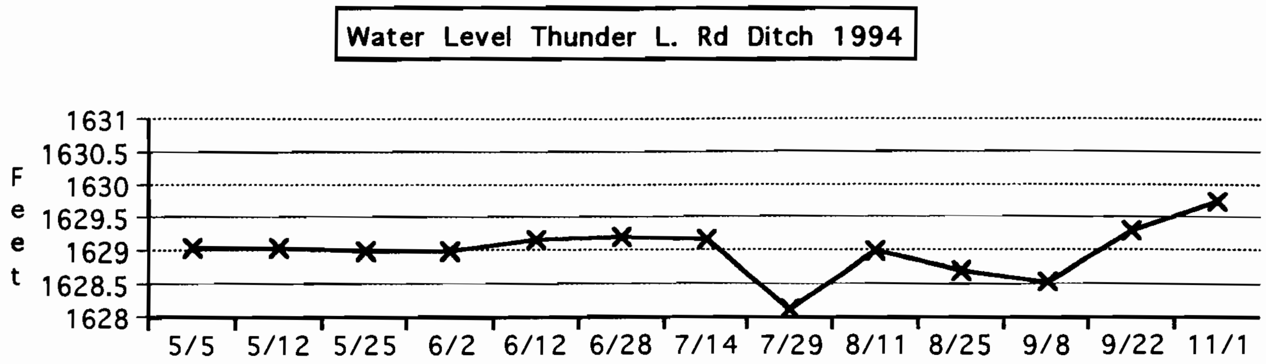
The north-south west ditch at one time was connected to an east-west ditch in the northwest corner of the wildlife area. Beavers have built a barrier where these two ditches intersect. A beaver dam at the west end of this north ditch in 1994, regulated the elevation of this ditch. In 2000, the water level of this ditch fluctuated increasing the water level of Rice Lake. In 2000, the water level in this ditch fluctuated from an elevation of 1626.89 to 1631.32, or nearly 4.5 feet. In 1994, this same ditch fluctuated in elevation from 1629.07 to 1631.45, or nearly 2.5 feet. See **Figure 7**.

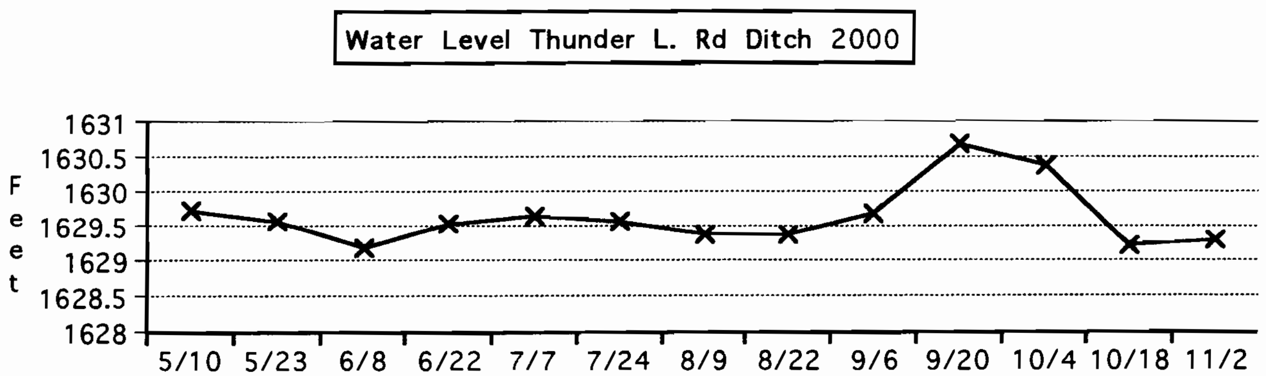
<u>Thunder Lake Wildlife Area Central and East Water Levels</u>

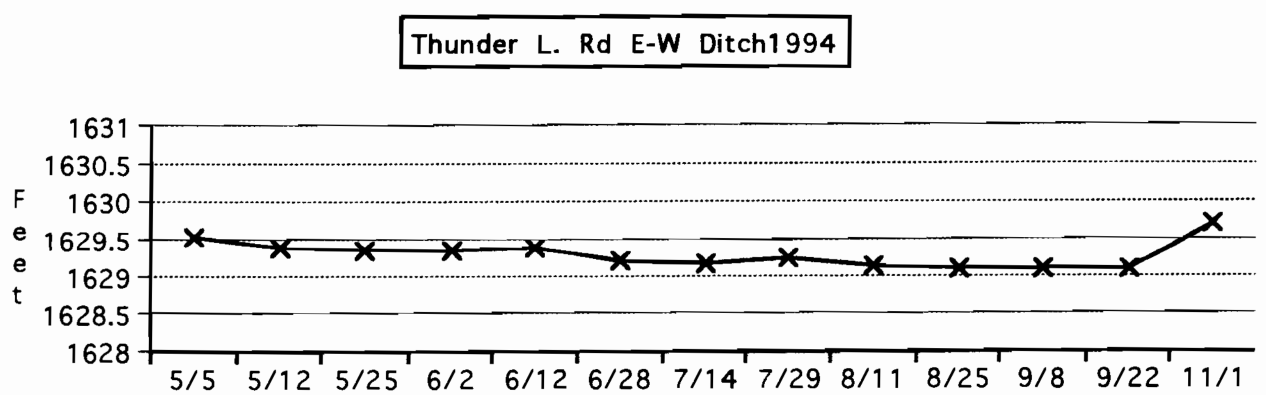
It is presumed that the Thunder Wildlife Area Marsh has an underlying clay ridge that runs north and south through the center of the marsh. It is understood that this ridge can effects water movement and drainage in the marsh. The first major east-west ditch south of Thunder Lake also is presumed affected by this ridge. The central south ditch culvert located on a crossing located in the south ditch on Rice Lake Road approximately one-half way between the wildlife area entrance and Thunder Lake Dam Road is also located near this ridge.

Water levels for the south Rice Lake Road ditch were recorded at this culvert location in 1994 and 2000. The bottom graph in **Figure 8** details water level elevations on each end of the culvert because the culvert was allowed to clog w/ debris and limit low water movement through it in 2000, whereas in 1994 water movement was not restricted. Water

FIGURE 4. THUNDER LAKE DAM ROAD N-S & E-W DITCHES 1994 & 2000







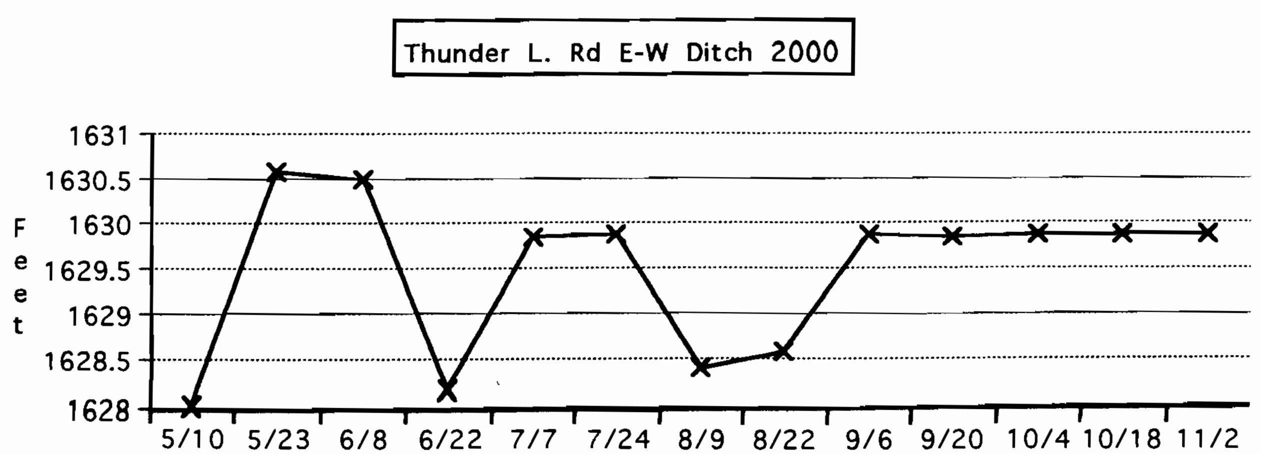
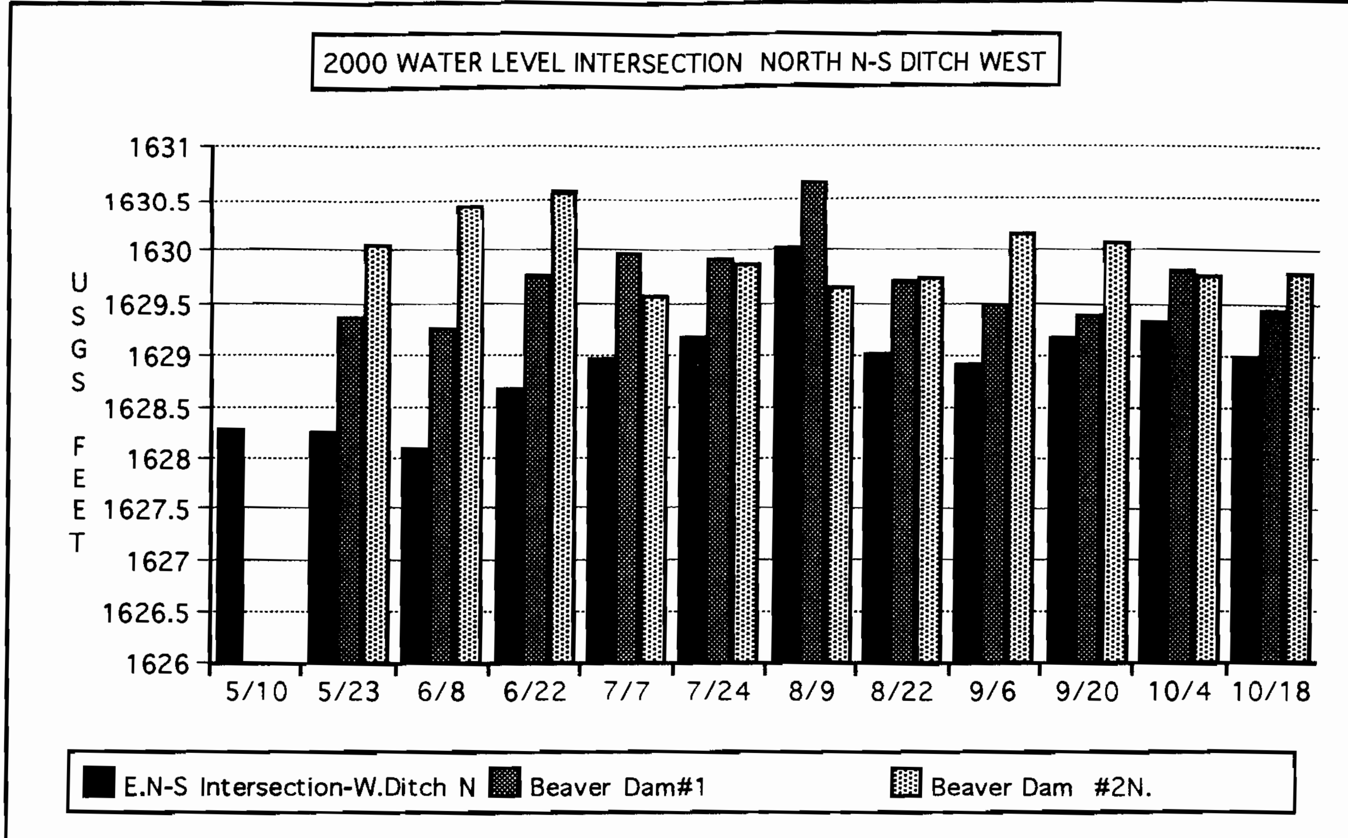


Figure 5. Thunder Lake Wildlife Area Water Levels West & Rainfall



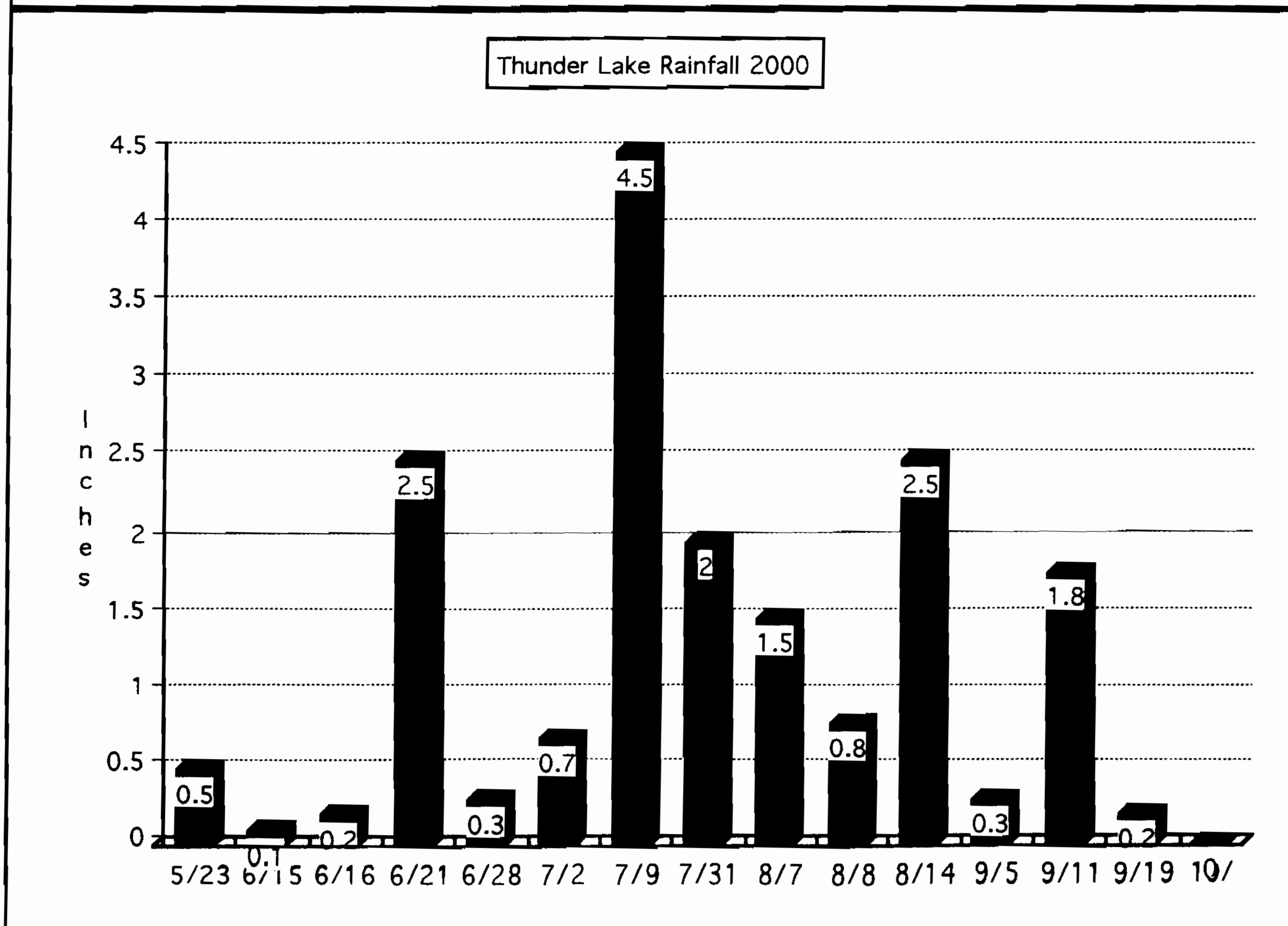
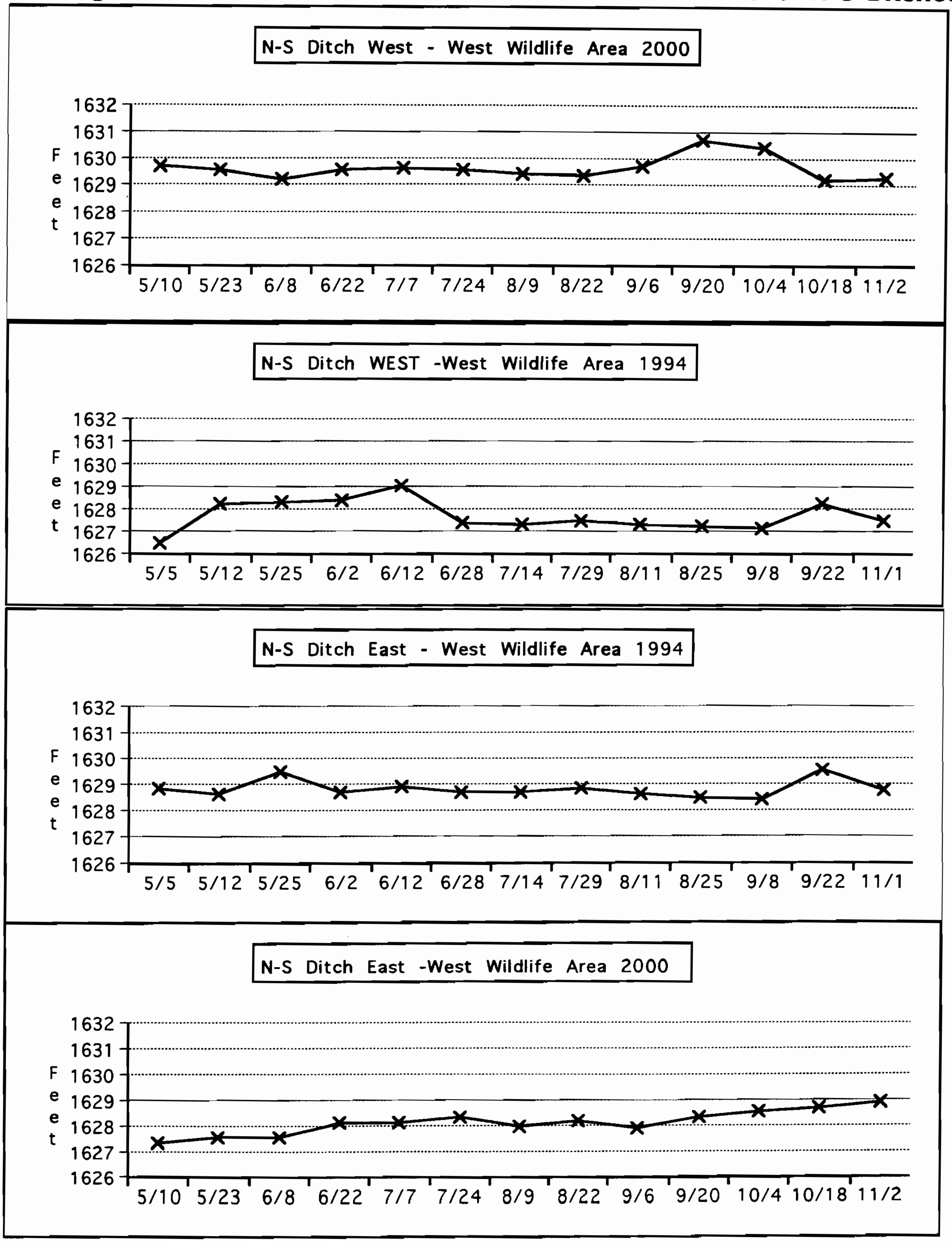


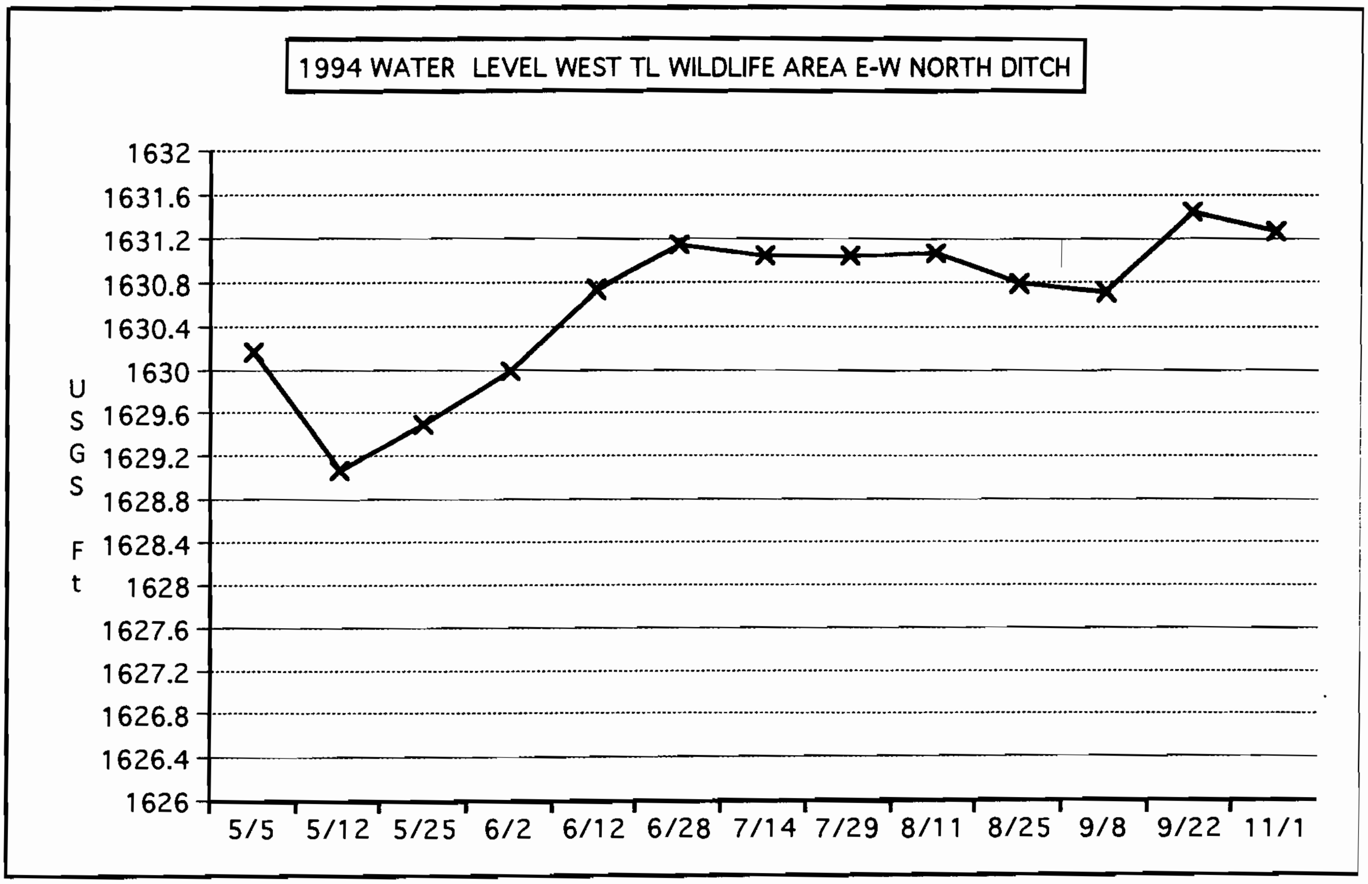
Figure 6. -Thunder Lake Wildlife Area West- Water Level N-S Ditches



- 2001 East Ditch now Plugged by Beaver

- West Ditch plugged by beaver 200yards N

Figure 7.Thunder Lake Wildlife Area West Water Levels E-W North Ditch



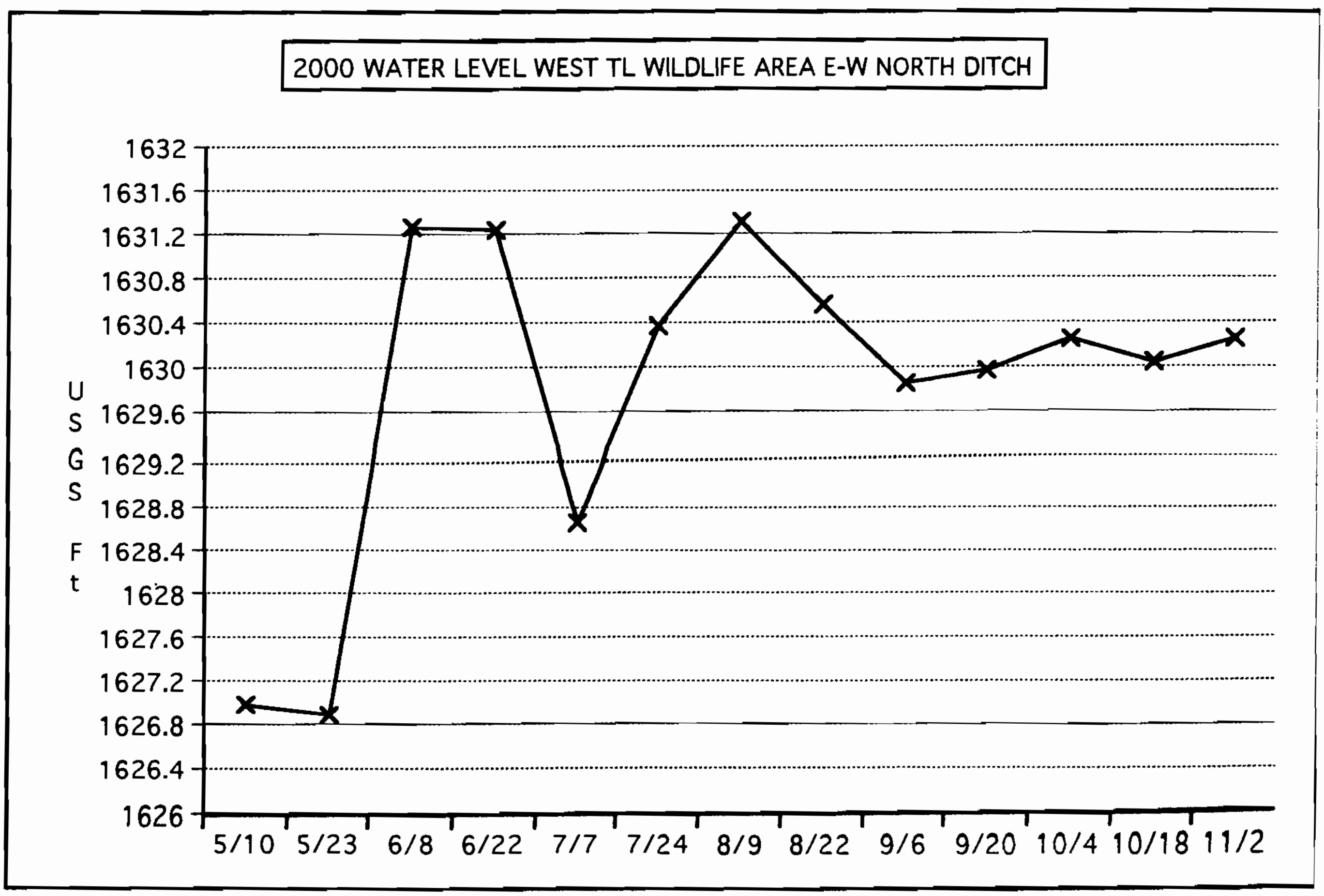
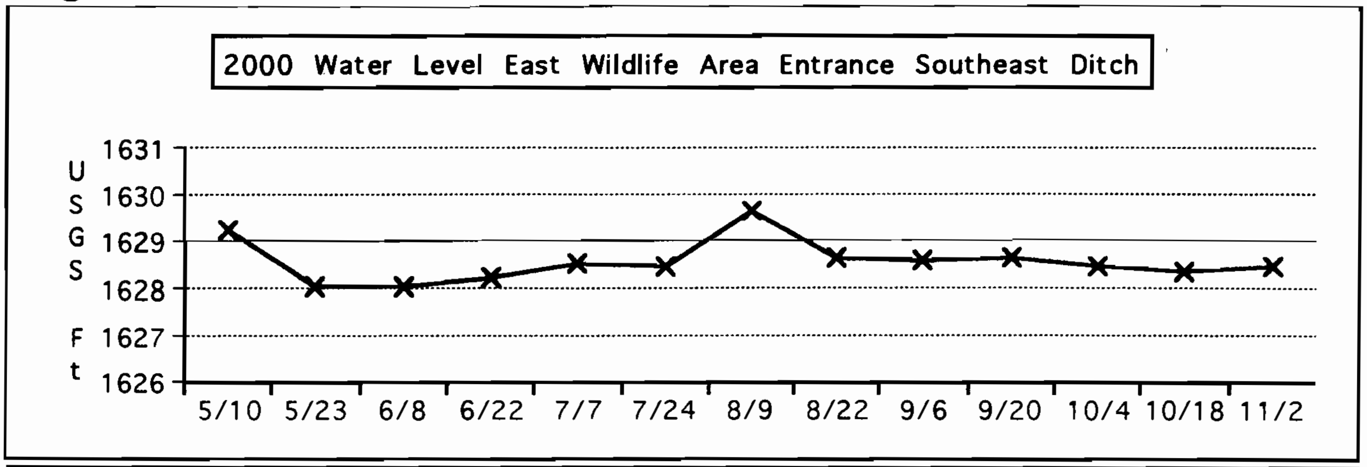
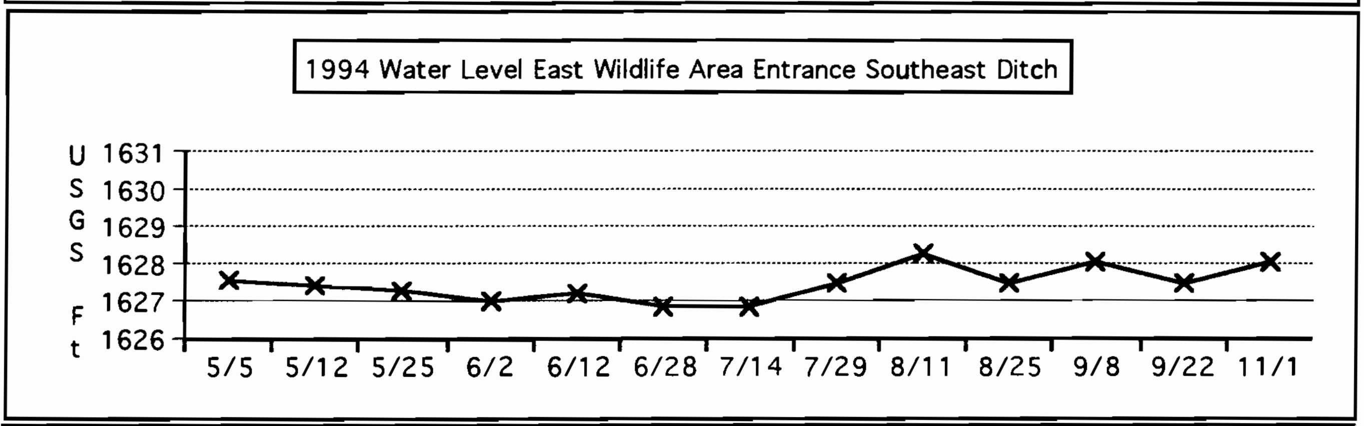
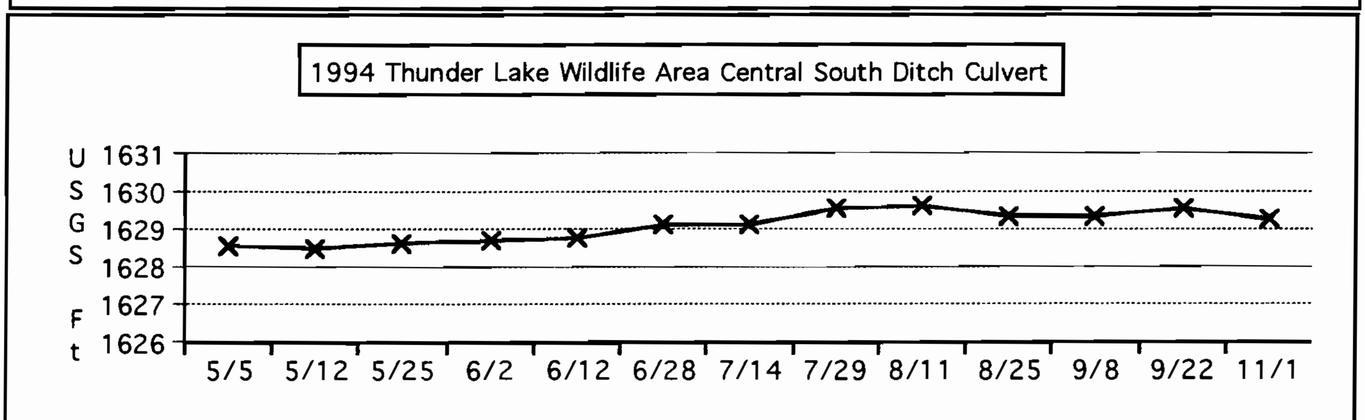
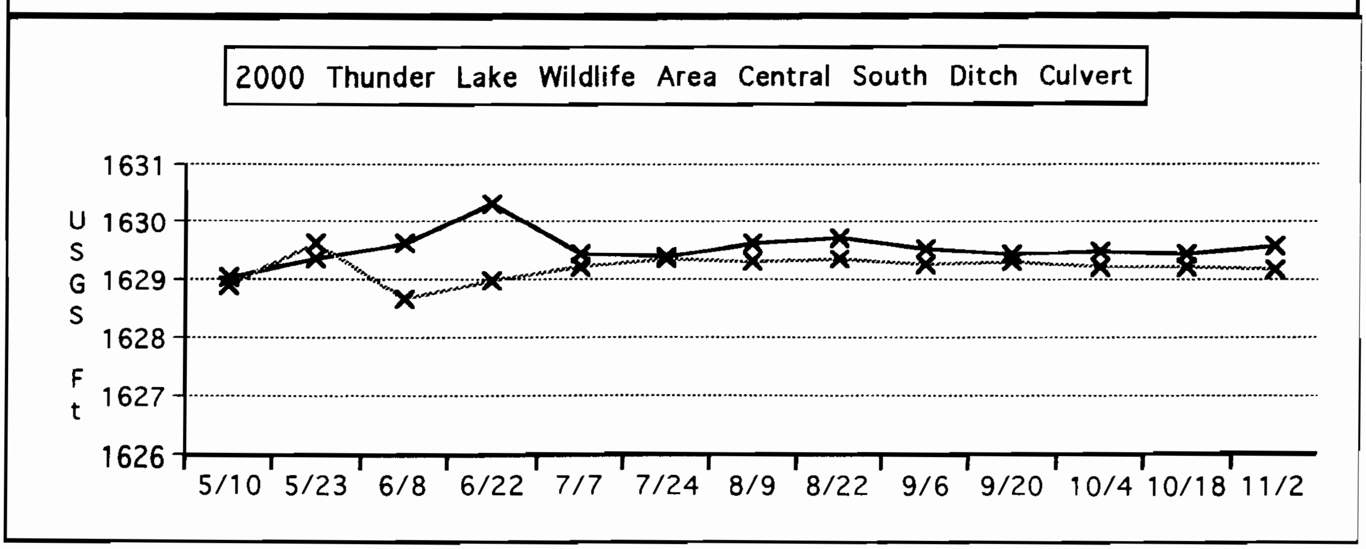


Figure 8. TL WILDLIFE AREA EAST ENTRANCE & CENTRAL WATER LEVELS









levels at this culvert in 2000 ranged from 1628.68 to 1630.3, or approximately 20". In 1994 the water level range was 1628.51 to 1629.56 or approximately 12".

As the water moves to the east it flows through a culvert under the south road at the Thunder Lake Wildlife entrance. In 2000, it ranged from 1628.34 to 1629.21 or about 10.5". The water level at the west end of this culvert, in the south ditch, in 1994 ranged from 1628.84 to 1629.82 or approximately 12". **See Figure 8**.

The southeast ditch of the Thunder Lake Wildlife Area entrance, had water levels ranging in 2000, from 1628.05 to 1629.67, or approximately 20". In 1994, the water level's range was from 1626.87 to 1628.31, or 17". This is the ditch that extends from the entrance towards STH 45. **See Figure 8**.

The water levels in the north ditch at the wildlife area entrance in 2000, ranged from 1628.38 to 1628.86, or less than 6". In 1994, the range was from 1627.76 to 1628.45, or 14". **See Figure 9**. This water exits the marsh at the old Rangeline dam. Water levels at the old Range Line dam exit from the Thunder Lake Marsh in 2000, ranged from 1626.9 to 1627.15, less than 3". In 1994, water levels ranged from 1626.69 to 1628.06, or 16". See **Figure 3.** In 2000, water levels in the ditch that extends north of the Rangeline Dam were measured at a culvert crossing and at two beaver dams to the north. Water levels ranged from 1627.15 at the south end of the culvert on May 5, to 1630.87 at the northern beaver dam on May 23, 2000 a change of over 45". See **Figure 10**.

In 2000, water levels in the ditch extending south of the wildlife entrance ranged from 1632.84 above the beaver dams on the south end, to 628.01 near the north end of the ditch. This ditch is the eastern border for the southeast wildlife area. Two minor ditches drain into this ditch via small culverts from the wildlife area to the west. The major ditch, or third ditch as you go south, is the same ditch that intersects Thunder Lake Dam Road. Water levels in this ditch are represented by the line with the circle symbol in **Figure 11**.

At the same time in 2000, the southeast wildlife area water levels on the other side of the dike- road ranged from 1628.26 to 1630.38, or over 26" Yet most of the fluctuation was due to the water fluctuations in the major east west ditch or the third ditch symbolized by the circle as it appears in **Figure 11.**

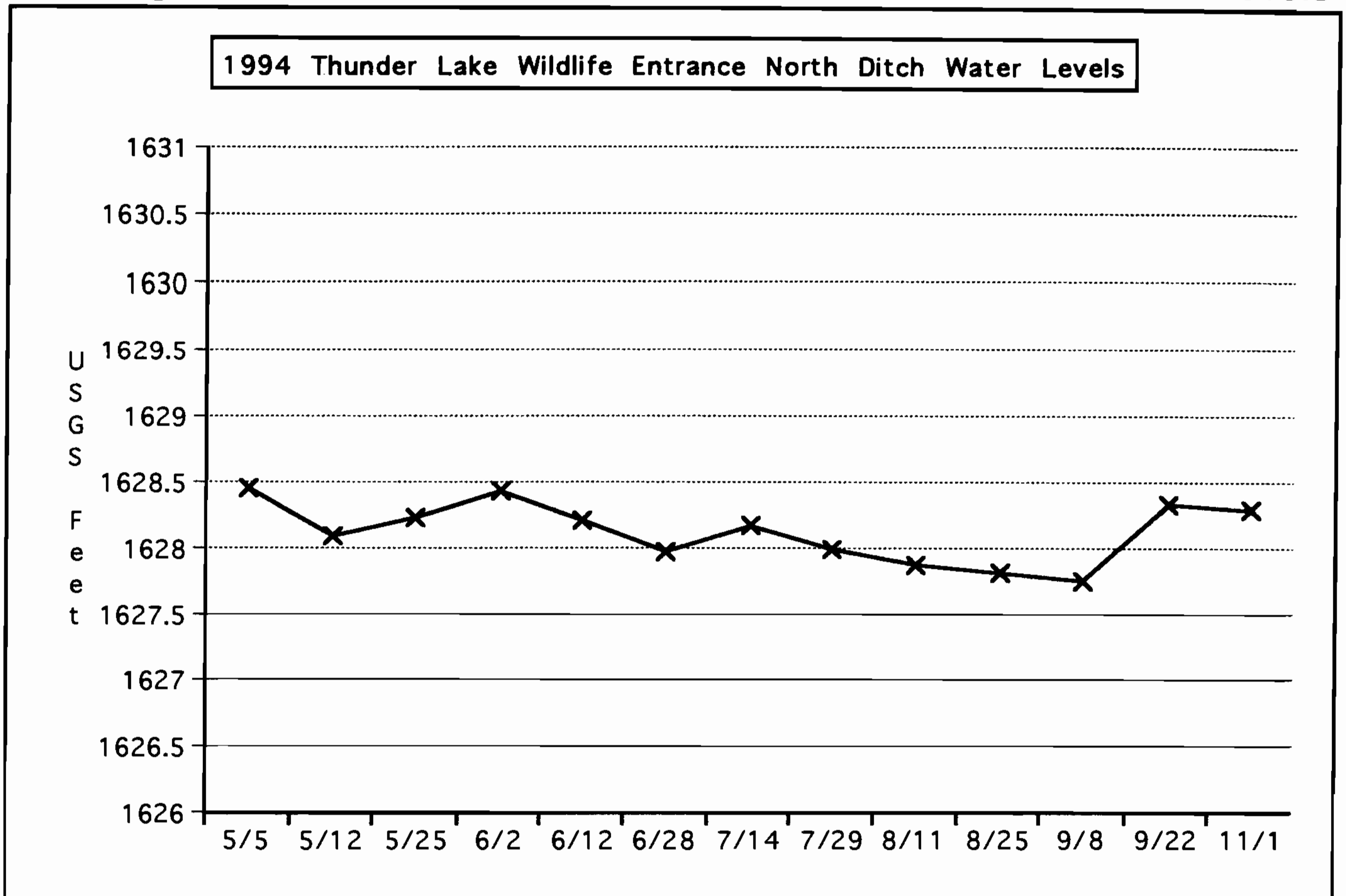
Discussion

This part of the planning grant study was to monitor Thunder Lake and Thunder Lake Wildlife Area water levels as they are effected by the the restored dam. The dam was restored in 1995, a year after the water levels were monitored as a part of the Phase 1 planning grant study. The new dam's permanent concrete sill was set at an elevation of 1633.45, equal to the elevation of the former dam when one 3.5" board was removed. The former dam was operated with periodic addition and removal of two 3.5" boards.

Thunder Lake receives 72% of it's water from atmospheric precipitation. In 1994 the Thunder Lake area had a total rain fall during the growing season of 17.55". In 2000, rainfall varied only .35 of an inch with a total rainfall of 17.9 inches. Rainfall occurred on 21 days in 1994 and 14 days in 2000. The 2000 rainfalls, while less frequent , produced more rain per event.

In 1994 the lake was operated with both boards (elevation 1633.16) removed from May 5 to September 8. It is during this time that the the maximum water fluctuations from 1633.05 to 1633.73 (9") occurred. See Phase 1 Report. At that time water was released

Figure 9.Thunder Lake Wildlife Entrance North Ditch Water Levels



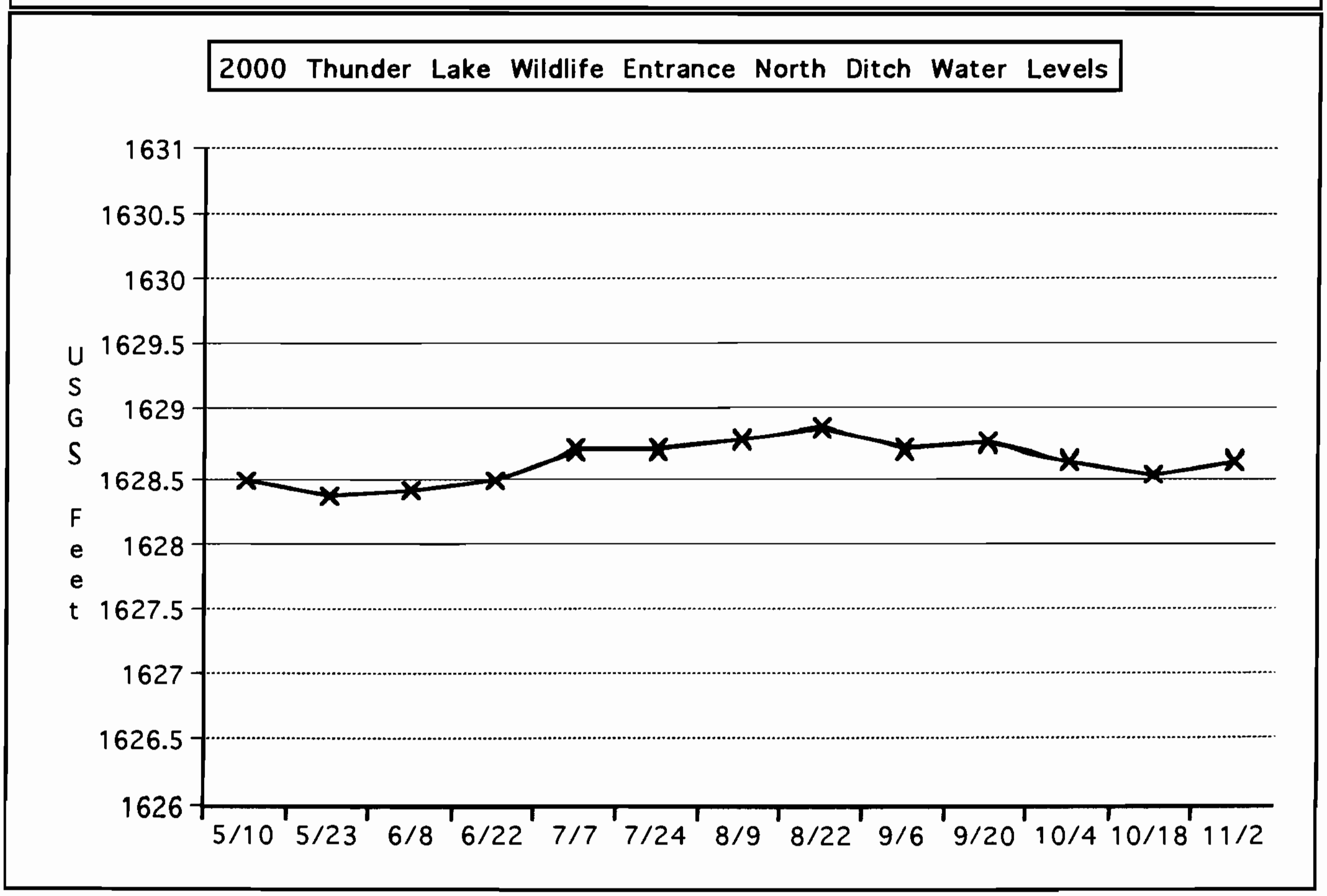


Figure 10. 2000 Thunder Lake Wildlife Area Northeast Water Levels- 2000

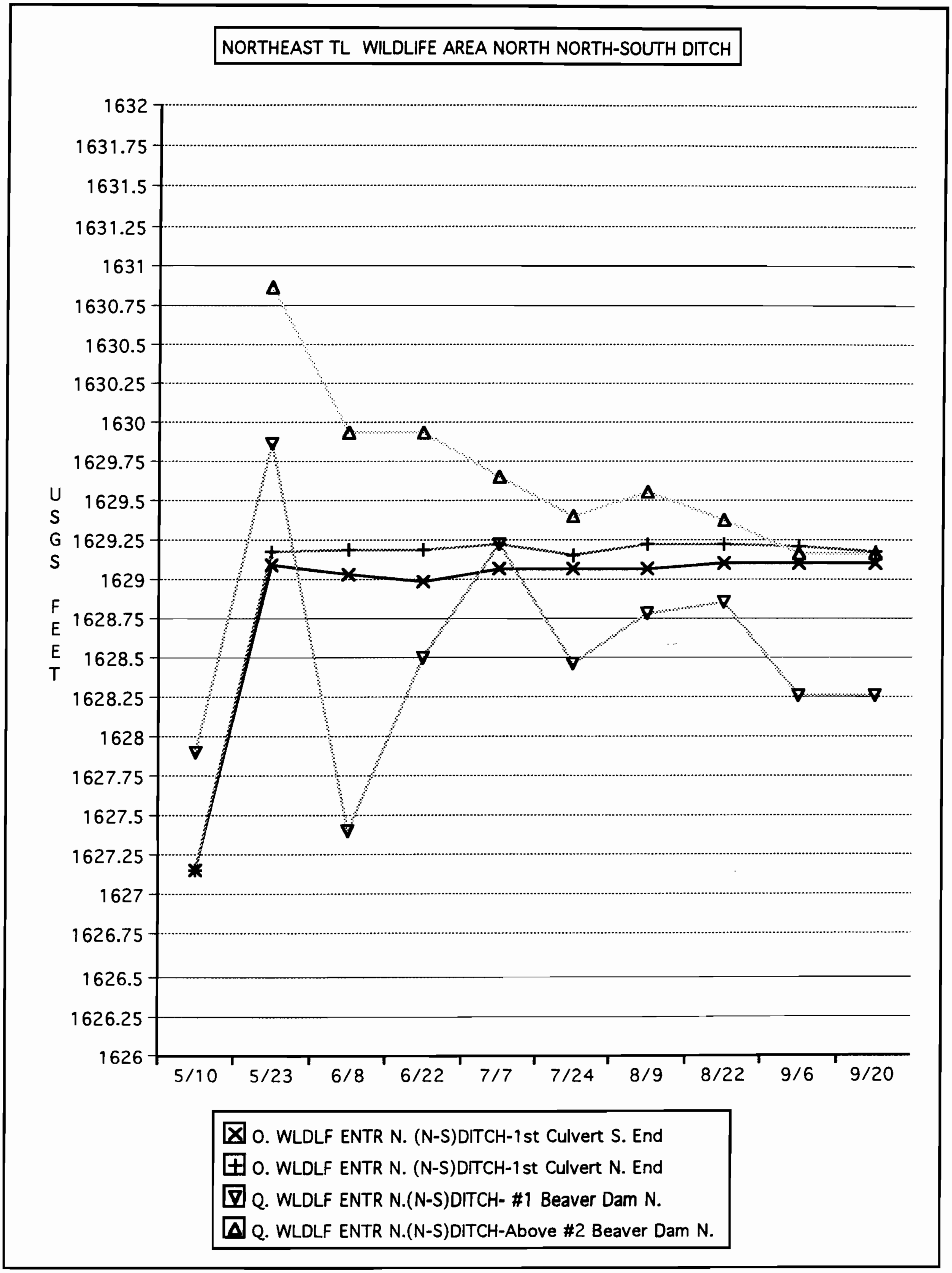
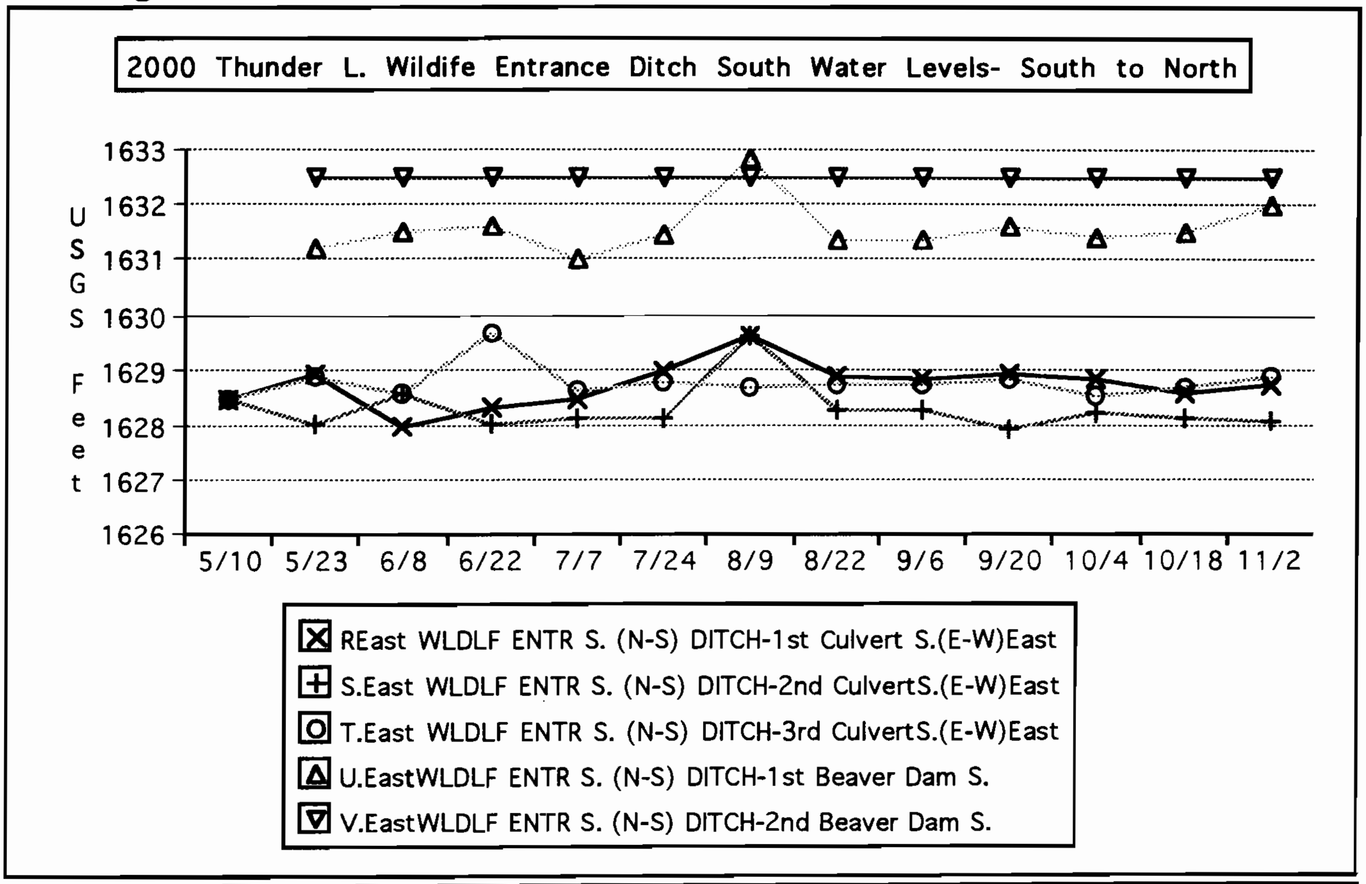
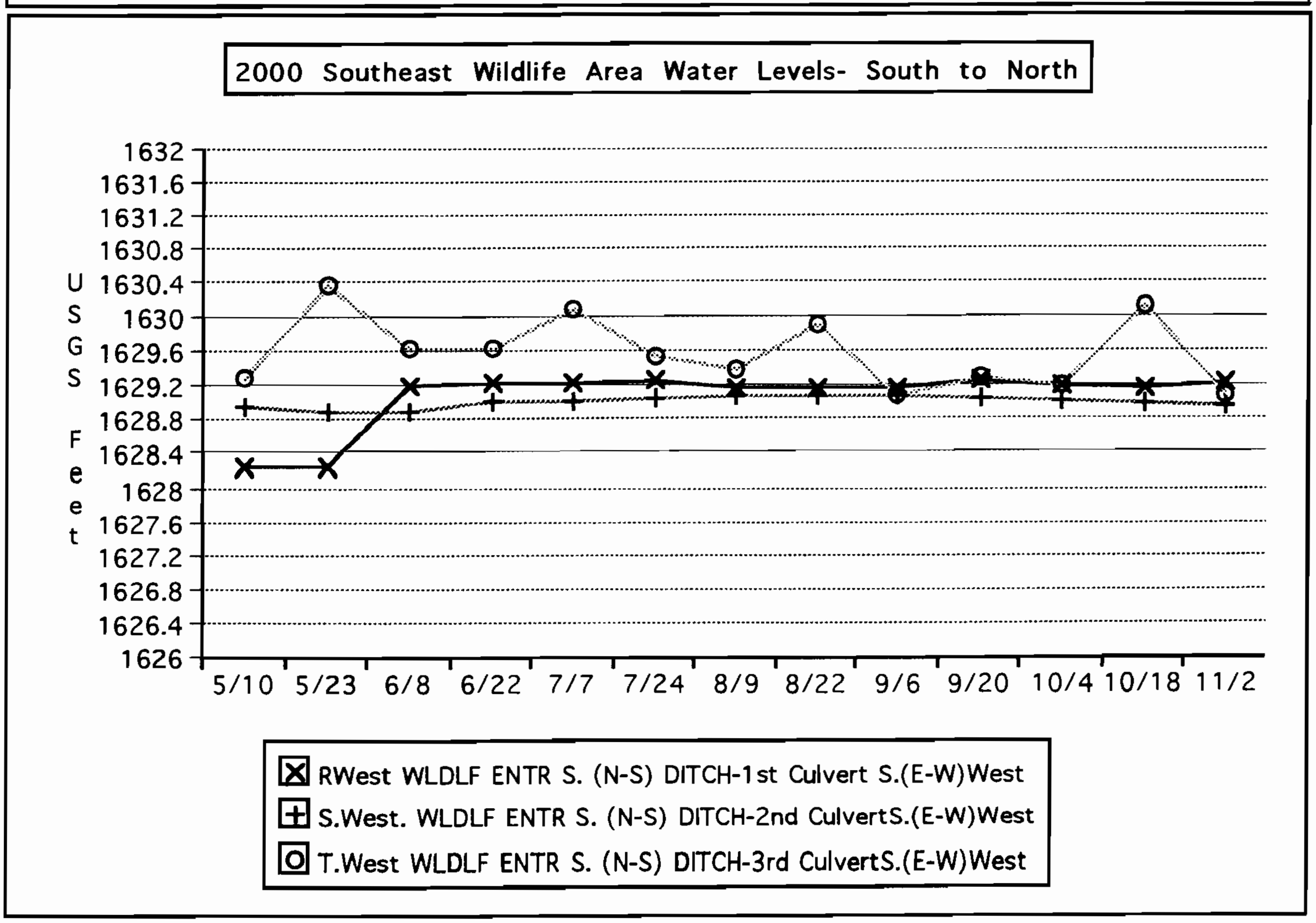


Figure 11. Thunder Lake Wildlife Area Southeast Water Levels 2000





directly to the Thunder Lake Road ditch, a direct route to Rice Lake. High water and fluctuating water levels are known to negatively impact the early spring development of wild rice in Rice Lake. The renovation of the dam to an elevation of 1633.5 would send water slowly through the lowland bog forest tempering water level fluctuations in Rice and Thunder lakes, as well as illuminate flashing of water levels in the ditch system of Thunder Lake Wildlife Area. Water, released slowly through the wetland complexes, carries minerals and nutrients for spring growth in the bogs as well as for the wild rice & other plants in Rice Lake. Stabilized water levels on Thunder Lake would also fluctuate less at this critical time of the year for fish egg development and for plants that stabilize the shoreline and provide fish cover.

The management strategy for the Thunder Marsh Wildlife Area which includes the Rice Lake natural area has changed since the 1994 sampling. The management to keep the entire area marsh open has been reduced to a smaller area of treeless peat land surrounded by wetland forest. The open area is bordered by the main ditches on the north and east sides of the marsh, the first main east-west ditch north of Thunder Lake on the south, and the Thunder Lake Road ditch north of this ditch to Rice Lake Road to the West and north along the Rice Lake Natural area east border. The strategy is to keep this area free of trees encroaching from adjacent areas through higher water levels and control burns (when conditions allow). Allowing ditch culverts to be dammed or clogged by beaver in and adjacent to this area, is one method of implementing this strategy with the restriction that the culvert clogging does not threaten the access roads. Another would be to block ditches in spots to allow more local pooling and less drainage through the ditch system in the same areas.

During the 2000 sampling period this management strategy was evident throughout the marsh. Beaver activity was effecting water levels in the entire marsh. This activity is encouraged in the marsh where roads are not threatened but not at the outlet of Rice Lake. The presence of lower water levels in Rice Lake is a key to more consistent production of wild rice.

In 2000, Thunder Lake dam, with a permanent sill of 1633.45, the water levels recorded fluctuated between 1633.0 and 1633.3, or 4". A higher water level probably occurred after a July 9 storm event that produced 4.5 inches of rain, but water level sampling occurred a day before the event and two weeks after.

In 2000, Rice Lake's water level that should of also have stabilized, increased throughout the summer as beavers raised the water level at several beaver dam's at the exit. Rice Lake began the growing season at a low water elevation of 1624.4 and peaked at 1628.65 October 18. In 1994, existing beaver dam's kept the elevation of Rice Lake between 1628.2 and 1628.6. The present strategy for the management of Rice Lake for good rice production is to keep beaver from damming up the exit and stabilizing the water fluctuations through current releases of water from Thunder Lake through the forested bog.

Water levels in the Thunder Lake Dam road ditch that normally fluctuated with water released from Thunder Lake, now fluctuated with water entering the main east-west ditch just north of Thunder Lake. The Thunder Lake Road ditch between the dam and this east-west ditch is reverting to wetland without the fluctuating channel cutting flows of the past. Culverts in both the Thunder Lake Dam road ditch and the main east- west ditch are allowed to clog to maintain high water levels in the south central area of Thunder Lake unless the road is threatened by extremely high water conditions.

A general comparison of water levels between 1994 and 2000 finds the effects of the Thunder Lake dam, beaver dams, and the clogged culverts are maintaining higher water level ranges as well as decreasing water level fluctuations in much the Thunder Lake watershed.

As the water levels and fluctuations stabilize further vegetation in the open water of Thunder Lake and the marshes of the Thunder Wildlife area will react positively. Conditions will allow plants to grow and change the physical conditions that fluctuating water levels and different water levels did not allow. For Thunder Lake aquatic plant population assessment in 1988,1992, 1995, and 1998- as part of the DNR long term ambient lakes program- have shown specie diversity increasing throughout the period. The 1998 survey results are similar to a plant survey conducted in 1980.

In comparing the 1995 and 1998 surveys several positive observations can be made about the plant community. In 1995, thirty seven aquatic plants were identified, This number of plant taxa increased to 52 in 1998. Also submerged, rooted, wide-leaved aquatic plants have now appeared and increased. Presence and increase of these plants indicate a stabilization of bottom sediments. The increase in these plants and their roots will further stabilize the bottom sediments and increase water clarity. At the same time the submerged wider leaves of these plants provide more surface area and habitat for aquatic invertebrates. Both the invertebrates and roots provide more food for ducks, geese, fish, muskrats. and beaver. The frequency of wild rice has also increase significantly also adding to the food supply and diversity of the Thunder Lake ecosystem.

The DNR ambient lake's water quality monitoring also indicates considerable improvements in water quality during the study period from 1987 to 1998. Water level stabilization and plant community responses have significantly contributed to the water clarity and water chemistry improvements in Thunder Lake.

South Thunder Lake Pond Restoration

Introduction

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 well- oxygenated wind swept shorelines. The south-southeast bay of Thunder Lake is recognized as one of the most biological productive bays in the lake. It is this bay that was the first shallow area on Thunder Lake to regain oxygen under the ice after the severe winter kill conditions of 1993-94.

An area in private ownership north of CTH A and east of the Thunder Lake south boat landing road contains several spring ponds that at one time flowed to this south- southeast bay of Thunder Lake. Over 40 years ago, this flow was impounded by a control structure/ road and two ponds constructed below for minnow production. After the minnow production facility was abandoned beavers plugged the control structure and piping; stopping the flow to the lower ponds and Thunder Lake. Restoration of flow from this area is important to the water quality of this bay and could provide an additional oxygen refuge under the ice for fish and other aquatic organisms.

Besides the water flow restoration the existing ponds may have potential to be restored for fish production as noted in the phase 1 report. Northern redbelly dace or white suckers are two likely forage fish species that could be reared at this site for stocking into Thunder Lake.

Procedure

The consultant, Aquatic Resources appraised the current conditions of the ponds, developed a restoration plan, and prepared a report of his findings. Oxygen and temperature profiles of existing ponds were sampled both during the open water period when water temperatures and biological growth were at there highest and during the winter when ice and snow cover limited oxygen production and temperatures were at there lowest. This assessment was made to determine if it was feasible to restore the ponds and use them for fish production. If it is feasible, the restoration plan was to be added to the comprehensive lake plan.

Results

The pond's are located on private property owned by Al Kressman, Jr. of Addison, Illinois. The headwater pond has a surface acreage of approximately 2 acres and is divided in two basins separated by a narrow and shallow channel. The undisturbed pond edges are lined by a narrow band of open peat bog that quickly gives way to steep upland slopes. This pond at one time had been altered by digging a channel to the southeast to a control structure that could drain water to lower ponds. The lower ponds also at one time had control structures that allowed the raising or lowering of the water level and the releasing of water to Thunder Lake. The 2 lower ponds total acreage is approximately one acre.

Where the upper pond appears to be natural, the lower ponds appear to have been constructed using a dragline. Peat material is still present on the east steep slopes where the bog peat from the valley was deposited by the dragline. Sand and rock fill from beneath the peat in the lower ponds was used to construct the roads adjacent to the lower ponds and fill over the pipe between the two upper ponds.

September 6, 2000 The ponds were evaluated for summer conditions on this date. This evaluation followed three days of 75+ oF air temperatures. Sampling occurred in late afternoon. Both basins of the headwater pond were profiled for temperature and oxygen and the lower pond's temperatures and oxygen was measured at the outlet of each.

Both basins of the headwater pond had poor water clarity due to the dark, tannic color of the water. No submerged vegetation was found throughout the pond. Floating lily pads and emergent vegetation were observed adjacent to the pier and in areas where the shallow sand bottom could be viewed. Temperatures ranged from 70 oF at the surface to 42 oF at 25' in the front basin. Maximum depth found in the front basin was 27 feet. The back basin was only 15' deep and temperature dropped to 54 oF at that depth. Oxygen was adequate in the top 5 feet of both basins but dropped drastically with the temperature below that depth. **See Table 1**.

The 2.5' deep middle pond had an abundance of coontail,elodea, and filamentous algae that created supersaturated oxygen conditions. The late afternoon sampling found oxygen levels of 15.47 mg/ l or supersaturated at 172% at the old control structure that separated it from the lower pond. A small current was viewed passing from the middle pond to the lower pond where the ponds narrowed at this abandoned control structure.

Sampling at the outlet of the lower pond found the water temperature at 73 oF and with a dissolved oxygen of 8.15 mg/l or at 93% saturation. The lower pond is approximately 5 feet deep. A flow of 2-3 gpm was observed seeping around the old beaver clogged spillway at the exit of this pond to Thunder Lake.

October 12,2000 A transect survey of the pond area was completed to understand and describe the elevation changes from the headwater pond to Thunder Lake. Thunder Lake water level was measured at the dam and at the outlet to this pond area for conversion to USGS datum. The surface of the headwater pond was at 1640.32 feet , the middle and lower ponds were at 1635.85 feet , and Thunder Lake was at 1632.97. Therefore the total drop from the headwater pond to Thunder Lake is about 7 feet . The old clogged outlet structure of the headwater pond was dug up to find the elevation of the this outlet. The top of the clogged pipe in the structure was at an elevation of 1640.08 and the bottom of the same pipe was at 1639.08; Therefore, the top of the pipe was less than 3" below the water level of the headwater pond.

October 21,2000 At the fall Thunder Lake District meeting the preliminary evaluations of the Kressman ponds were presented. The lake district, with Kressman's permission, decided to replace the clogged pipe between the headwater pond and the lower ponds to restore flow between the two. Winter evaluation of the pond's would then include documenting the changes in flow after the connection was restored.

In November the old outlet structure and pipe between the headwater pond and middle pond was removed. The outlet structure and pipe was part of an old boiler with a 12" opening welded to a 3" pipe that ran 100 feet to above the middle pond. A new 12" galvanized pipe was placed with the top at an elevation of 1639.08 or at the invert of the former 12" opening. This could allow the upper pond to be dropped approximately 2.5 feet, if necessary. The pipe dropped approximately foot from it's inlet to it's outlet. The inlet of pipe was covered until winter conditions and staff gauges in the pond set. On November 27, 2000 the concrete outlet structure on the lower pond,that had been clogged with peat and beaver cuttings, was cleaned out, allowing flow from the lower pond to cut a clearer channel to Thunder Lake.

Table 1. South Restoration Pond Water Quality, Sept 6, 2000

HEADWATER POND

Front Basin	Temperature	Temperature	Diss. Oxygen	Saturation
	oC	oF	mg/l or ppm	%
S'	21.1	70	6.98	78.7
2'	20.3	69	6.76	74.5
5'	19.2	66	6.56	71
10'	16.7	62	0.42	3.9
15'	8.6	48	0.63	6.3
20'	7.9	46	0.51	3
25'	5.6	42	0 .35	3.1

Notes: Between 8 & 9' was the drastic drop in oxygen & drastic drop in temperature between 10 & 15'.
Water: Dark, Organic, Tannic, Low Water Clarity

Back Basin	Temp. oC	Temp. oF	Diss. Oxygen%	Saturation
	oC	oF	mg/l or ppm	%
5'	19.1	66	5.73	63.2
10'	18.6	66	4.16	44.1
15'	12.5	54	<1.0	<5

MIDDLE POND

	Temp. oC	Temp. oF	Diss. Oxygen%	Saturation
	oC	oF	mg/l or ppm	%
1'	20.5	69	15.47	172

Notes: Aquatic plant choked on Sunny Day creating supersaturation conditions during day
Probably low oxygen at daybreak

LOWER POND

	Temp. oC	Temp. oF	Diss. Oxygen%	Saturation
	oC	oF	mg/l or ppm	%
1'	21.8	73	8.15	93

Notes: 2-3 gpm seeping through old spill way

Weather: Clear and Windy, Air Temperature 65oF at 10:00 am 75oF by 4:00 pm,
-hottest days of summer prior

January 16, 2001 A staff gauge was installed on the upper pond with the 1.5' mark of the gauge set at water level. There was 12" of snow and 9" of ice on the headwater pond. Dissolved oxygen 2' below the ice was 1.09 mg/ l at 33 oF. After a notch weir was placed on the lower end to determine the water flow the new culvert was opened at the upper end to water flow from the headwater pond. After 3 hours only about 10 gallons per minute was flowing through the pipe while the water level did not drop in the headwater pond. The channel that had been dug from the headwater pond to the new pipe 40 years ago was clogged with vegetation. It was a decided to see if a flow would cut a channel to the new culvert and change the level of the headwater pond.

The structure at the outlet to the lower pond was again partially clogged with peat. The structure was again cleaned. The temperature and oxygen in the flowing water at the outlet was 34 oF and 0.43 mg/ l, respectively. There was about 6" of ice and 8-10" snow on the lower pond. A staff gauge was not set as water level was still dropping.

February 19, 2001 By this date the water level on the headwater pond had not dropped, remained a the 1.5 foot mark on the gauge. The oxygen in the upper pond remained low at 0.26 mg/l dissolved oxygen at 33 oF. There was now 12" of ice and 12" of snow on the pond headwater pond. The inlet and outlet of the new culvert was now froze solid. The outlet of the lower pond was partially clogged with 5-10 gpm flowed through the structure. The structure was again cleaned out increasing the flow to approximately 50 gpm as the head pressure was released. The temperature and dissolved oxygen was at 33 oF and at 0.15 mg/l dissolved oxygen. Thunder Lake in the South Southeast bay had 4" of snow cover and 16" ice with very little water under the ice. Temperature at 2' was 33 oF with 0.1 mg/l dissolved oxygen.

March 14, 2001 On this sampling date little change had occurred in the headwater pond. Water level had not changed from the 1.5' foot mark. Snow was still about 12" deep, but the ice had decreased in thickness to 8". The temperature 2 feet below the ice was 32.5 oF with a dissolved oxygen of 0.42 mg/ l. A slight hydrogen sulfide smell was evident in the sampling hole as bubbles were released off the bottom.

A small seep of water was observed passing through the frozen weir in the new pipe leaving the pond. The middle pond had open water at the old structure and springs were observed below the new culvert. Flow at the lower pond outlet was now approximately 30 gpm. The lower pond had about 12" of snow and 8" of Ice. Dissolved oxygen increased to 1.53 mg/l at 32.5 oF.

April 10,2001 Spring thaw had begun and flow was restored to the ponds. Water levels in the headwater pond had not dropped and remained at the 1.5' mark. The pond was still covered by ice and snow. Water entering the new culvert was now at 35.2 oF and had 6.12 mg/l dissolved oxygen for a 43.8 % saturation level. After traveling through the 110 feet of galvanized- corrugated pipe oxygen at the weir was 7.04 mg/l , at the same temperature as above the culvert , increasing saturation to 50%. Approximately 80 gpm was flowing through the culvert.

At the lower pond outlet structure the flow increased to 100 to 110 gpm at 35.6 oF. This pond also was still covered by ice and snow. Dissolved oxygen increased to 7.36 mg/l at a saturation of 52.8%. An open water beaver channel in Thunder Lake adjacent to the discharge area had a temperature of 40.1 oF and a dissolved oxygen of 2.11 mg/l or a saturation of 16.5 percent.

A heavy welded iron screen was placed in front of the new culvert at the outlet channel of the headwater pond and over the outlet structure on the lower pond. These screens will prevent beavers from clogging the structures but will require periodic cleaning to remove leaves and other organic debris.

April 27.2001 Ice was now off the ponds. The headwater pond rose to 0.25 feet or 3 inches to the 1.75 foot mark. The temperature rose to 53 oF with 10.64 mg/l dissolved oxygen or 98% saturation. About 10-15 gpm was flowing through the notch weir at the exit to the culvert. The temperature dropped to 51 oC and dissolved oxygen to 9.04mg/l (82.2 % sat.) after passing through the clogged channel and culvert from the headwater pond. At the exit of the lower pond the screen was partly clogged and about 30 gpm were still passing through the structure. The water temperature was 55 oF with 9.5 mg/l dissolved oxygen(89.9% sat). A gauge was place in the pond west of the outlet with water level at the 1.0 foot mark.

May 4, 2001 By this date spring runoff had ended in this valley. The upper pond dropped to the 1.25 mark or 3" less than the winter level. Two feet below the surface in the headwater pond the water temperature was at 61 oF with 8.56 mg/l dissolved oxygen (86.5% sat.). After traveling through the clogged channel to the new culvert the temperature increased to 61.5 oF and dissolved oxygen dropped to 6.55 mg/i (67%sat.). About 30 gpm flowed through the culvert. After passing through 110 feet of buried culvert the temperature dropped to 60 oF and gained oxygen to 8.16 mg/l (81.5%). Water level of the lower pond did not change - still at the 1.0' mark. Flow out the exit was approximately 40 gpm. Temperature at the outlet was 61 oF with a dissolved oxygen of 8.33 mg/l(84.8% sat.).

Discussion

The evaluation of the Kressman ponds and restoration of water flow provided a better understanding of the water quality of this area. Late winter oxygenated water flow from this valley can enter Thunder Lake when no oxygen is present in the south southeast bay of Thunder Lake. The potential use of these ponds for fish production without extensive renovation and capital expenditures is limited.

There are water quality problems in the ponds during the growing season and under the ice in their present condition. The upper pond has the physical conditions to produce a small biomass of fish similar to a northern bog pond, but periodic winter kill to all but a few species tolerant to low oxygen probably occurs. In the summer adequate oxygen is found in the upper five feet to support fish and other aquatic organisms. The dark tannic water also limits aquatic plant growth below this depth. Fish or aquatic organism production is also likely limited by a low pH.

The middle and lower ponds have both winter and summer water quality problems. Supersaturated oxygen levels from excessive plant growth can kill or stress fish during the day during summer and oxygen depletion at night probably occurs from the pond's oxygen demand at night.

The late winter runoff from these ponds can send oxygenated water to Thunder Lake at a critical time when there is little or no oxygen in the receiving waters. The iron screens and outlet culverts and structures need to be kept operational for this benefit for Thunder Lake to occur. Water levels in the ponds can be raised after ice out if current water levels want to be maintained.

The information gained from the headwater pond creates more questions than answers. At a depth of 27 feet, the bottom of this headwater pond is nearly 8 feet below the deepest water presently found in Thunder Lake or 20 feet below the present surface water level of the lake. The low water temperature of 42 oF at 25 feet in this pond indicates an interception with the water table aquifer. Hydrostatic pressure of the surrounding land or the pressure from below an intercepted clay layer below the lake maintains the water level in this bog pond. When they were putting the footings for the Thunder Lake Cranberry marsh in 1949 after 18 feet of peat they intercepted a 4 foot layer of hard pan blue clay that was underlain by water saturated, solid sand. The bottom of the headwater pond would reach or penetrate this clay layer if the clay layer is at the same elevation or above.

As recently as the 1940's Thunder Lake had a 30 foot deep hole north of the larger island. This deep hole is now only 12 feet. The former depth of 30 feet would have intercepted this same layer of clay of it extends into the lake. The question remains if artesian flow from the sand aquifer from beneath this clay layer flows to or at one time flowed to Thunder Lake or the headwater pond. The depth of this hard pan clay can also change in elevation. These elevation changes coupled with physical changes in the marsh can effect lateral water movement over a large area of the bog and wetland ecosystem of Thunder Lake.

Development of the Kressman's ponds into a fish rearing facility would require expensive renovation and operation changes. Extensive fish culture and fish health depends on well oxygenated clean water. Intensive fish culture has the same requirements but also needs circulation of the water to maintain these conditions throughout the water environment.

Under the present condition of the Kressman facility both water quality and water flow is limited. Organic peat and muck that have accumulated in the ponds create water chemistry problems and oxygen-chemical demands in both winter and summer. A low flow of water through the ponds occurs through most of the year except during spring thaw and during storm events.

The headwater pond is large enough for wind to add oxygen and circulate it to a 5 foot depth during the open water period but once ice covers the pond the oxygen is quickly consumed by the organic matter in the pond. The deep water of this pond is now devoid of oxygen and it is probable that any increase in artesian flow from lowering pond would also have oxygen problems. Oxygen could be added to this pond fairly economically through a compressed air system to improve water quality and prevent periodic winter kill. Periodic liming would also change the water chemistry and make it more productive as an extensive fish pond. Lowering this headwater pond may increase flow by decreasing the hydrostatic head and releasing artesian flow to the lower ponds.

If the flow increases to the lower ponds with the lowering of the headwater pond and artificial aeration added there would also benefit the ponds below. The lower ponds currently has an accumulation of peat and muck that have a high oxygen demand. There are aquatic plants growing in the middle pond that produce excessive oxygen during summer days- but at night this oxygen is probably consumed by the plants and the bottom muck oxygen demand. Dredging of these materials would remove some of the oxygen demanding sediment and perhaps open up some of the springs present. Moving oxygenated water from the upper pond could also improve conditions without the dredging. Also compressed air could be added directly to the lower ponds to improve water quality. Periodic liming would also increase the pH and set off a series of events to increase fish and aquatic organism production in the lower ponds.

If aeration was added and physical improvements made fish production is possible, but harvest of the fish under an extensive system may be difficult. Draining and seining ponds to harvest fish, even with physical improvements, would be difficult. Trap netting would be necessary for removal of fish under this extensive system. Forage fish- minnows and suckers - could be raised and trapped and those remaining allowed to reproduce for next years crop. The raising of game fish would be limited as any remaining would be cannibalize on next years crop. If the ponds were allowed to completely winterkill after the game fish removal the cannibalism problem would be illuminated.

It is possible that fish could be reared intensively by using cage culture. Cages would facilitate harvest and protect fish from predation. The cages would require a certain depth as well as circulation of water by aeration and/or a good flow to provide oxygen and removal of fish waste. Fouling of cages with algae, cost of food, licensing, and health certification are further complications that one would face with both intensive and extensive fish production.

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did Rand not do
a restoration plan
because success
w/out major change
is limited?
(see paragraph 1)
discussion

Walleye Fisheries Restoration

Introduction

Thunder Lake has a small walleye population that has been restored through stocking yearlings, fall fingerlings, summer fingerlings the last 10 years. Attempts have been made to increase the adult population to levels where natural spawning can contribute to a self-sustaining population. Young of the year walleye- whether stocked as fry, summer fingerlings, or from natural reproduction- have only recently been captured in fall shocking surveys that target them. **See Table 2**.

Natural reproduction of walleyes in Thunder Lake may be limited by the amount of suitable spawning areas on the lake as wave-washed or seepage rock rubble-gravel areas are limited. The creation of a walleye spawning reef as part of the north shore stabilization project occurred in 1999. Ditches that connect to adjacent cranberry bogs may also pose as a problem in successful walleye reproduction. At the time of walleye spawning, water from melting ice and snow on the cranberry beds seeps through the sand dikes. This flow in the past drew walleye into the main cranberry ditches during spawning. If spawning occurs incubating eggs could be left under adverse conditions when flow subsides after ice melt .

Procedure

In 2000 and 2001 water temperatures beginning at ice out were monitored and a walleye spawning watch was conducted for the presence of walleyes. See **Figure 12** for monitoring locations. Walleye spawning usually reaches a peak when water temperatures are from 42 to 50 oF. Traditional walleye spawning areas on the east southeast shores of the lake were watched and the new north shore dike area was evaluated. Cranberry bog ditches on the east and southeast shore of Thunder Lake was also monitored for spawning activity. If walleyes were found spawning, D-frame kick net sampling was used to determine if: spawning occurred, if eggs incubated, or survived to hatch to the sac fry stage. Conditions at the spawning sites were assessed to include temperature and oxygen levels.

Results

<u>April 4, 2000</u> In 2000 the ice on Thunder Lake went out during the last week of March. Thunder Lake is a shallow lake and is one of the first lakes to freeze in the fall and one of the first lakes to open the spring. At 2:00 pm on this sunny day the air temperature was 50 oF with a northwest wind at 8-10 mph.

Water level on this date was at 1633.26 or 6.5" from the crest of dam. The north shoreline at 2:00 was calm as it was upwind from the northwest wind. The new north shore dike extends 1200 feet west of dam and was built with pit run outwash rock 2-6" in diameter extending into the lake. Just above water level a recent ice push had stacked the outwash rock creating a 1 foot mound. The only clean rock rubble from wave action extended 1 foot from the water's edge at the base of the pushup mound. The only exception to this was at about 900 feet from the dam where a sandbar extends perpendicular to the dike. Sand from the dike at this location had increased the clean rubble to 2 feet. Rock rubble east of the sand bar had periphyton or "slime algae" below the 1 foot of clean rubble. Rock rubble west of the bulrush sandbar had an accumulation of bog detritus that had washed over the sand bar and accumulated. No eggs were observed along the entire 1200 feet of dike. Water temperature was 43 oF with a dissolved oxygen of 11.54 mg/l(92.9% Sat.)

Table 2. Thunder Lake Fishery Assessments 1995 to 2001

09/11/01 Fall Fingerling GLIFWC Boom Shock Survey- 10.2 miles shocked

WALLEYE		Size Range	Mean Length	Catch/Effort
Total	116	3.2-25.3"	12.9"	11.4/ mile
Age 0+	27	3.2-6.9"	5.3"	2.6/ mile
Age 1+	12	7.4-9.5"	9.5"	1.2/ mile
Age 2++	77	9.6"-25.3"		

9/18/97 Fall Fingerling DNR Boom Shock Survey- 7.6 miles shocked

WALLEYE		Size Range	Mean Length	Catch/Effort
Total	25			
Age 0+	0			
Age 1+	2	9.0-9.1"		0.3/mile
Age 2++	23	9.8" - 25.0"		
LM BASS	5	12.4"-15.4"		
NORTHERN PIKE	1	22.5"		
BL CRAPPIE	Abundant	1.5" -10.0"		
BL BULLHEAD	Present	7.0"-10.0"		
PUMPKINSEED	Present	3.0"-8.0"		
WHITE SUCKER	Present	10.0"-18.0"		
YELLOW PERCH	Common	2.0"-8.5"		
GOLDEN SHINER	Present	4.0"-5.0"		
BLUEGILL	Present	6.0" to 7.0"		
BLTNS MINNOW	Common	1.0"-3.0"		

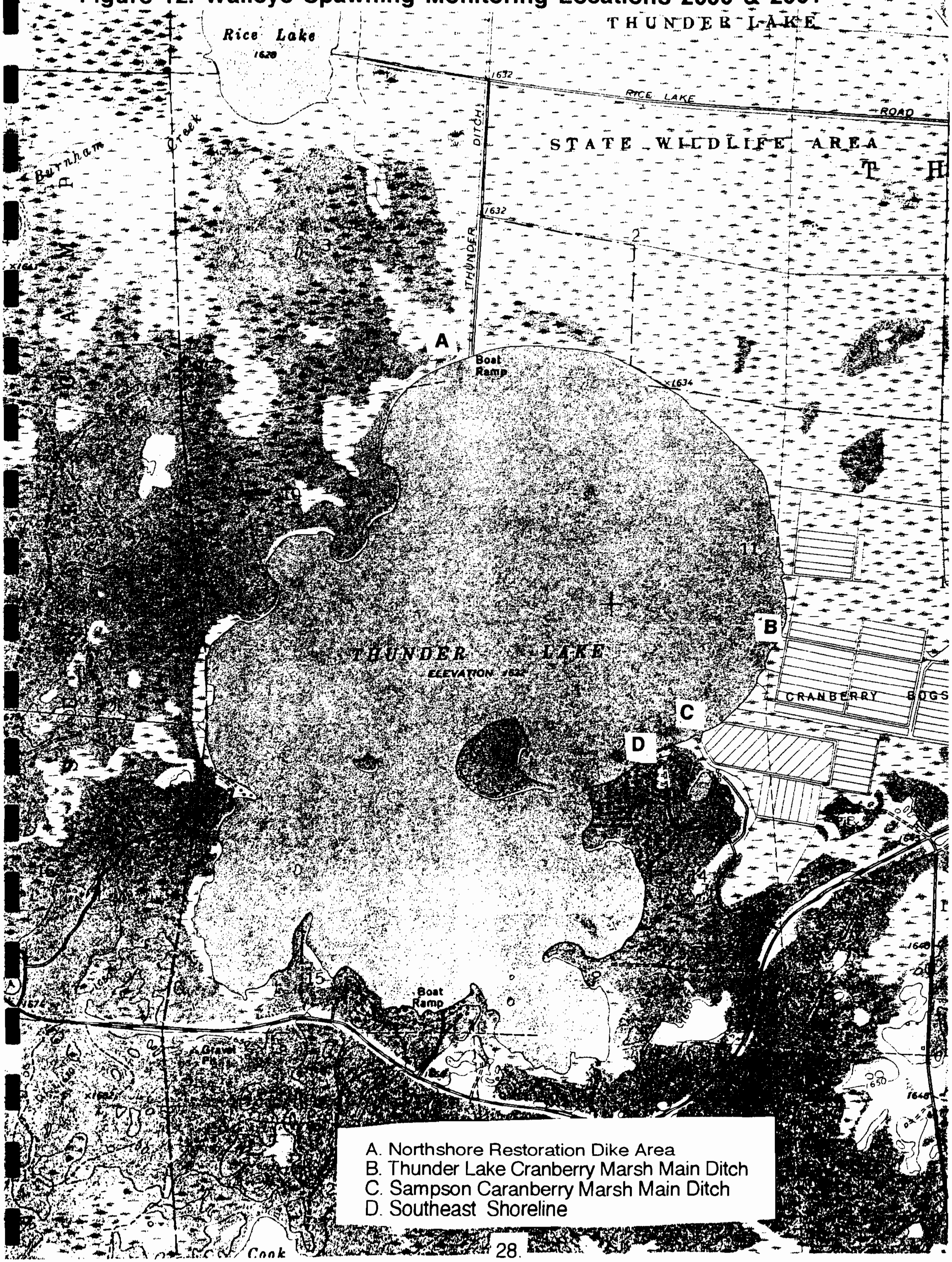
10/15/96 Fall Fingerling DNR Boom Shock Survey- 7.6 miles shocked

WALLEYE		Size Range	Mean Length	Catch/Effort
Total	3			
Age 0+	0			
Age 1+	3	8.3-9.2"	8.3"	0.4/ mile
Age 2++	0			
LM BASS	7	12.4- 18.0"		
NORTHERN PIKE	4	19.0-23.5"		

9/27/95 Fall Fingerling DNR Boom Shock Survey- 10.2 miles shocked

WALLEYE		Size Range	Mean Length	Catch/Effort
Total	88			
Age 0+	9	2.7-6.8"	6.2"	0.9/ mile
Age 1+	32	7.3-10.6"	8.8", 10.6"	3.1/ mile
Age 2++	47	11.2-25.9"		
LM BASS	23	2.6-15.4"		
NORTHERN PIKE	17	17.5-26.9"		
BL CRAPPIE	Abundant	1.5" -12.0"		
BL BULLHEAD	Common	5.0"-10.0"		
PUMPKINSEED	Common-Abundt	1.25"-7.0"		
WHITE SUCKER	Present	6.0"-17.0"		
YELLOW PERCH	Common-Abundt	1.5"-9.0"		
GOLDEN SHINER	Abundant	1.0"-6.0"		
BLUEGILL	Present	1.5" to 6.0"		
YLW BULLHEAD	Prsnt-Common	5"-10"		

Figure 12. Walleye Spawning Monitoring Locations 2000 & 2001



Areas on and near the east southeast shoreline of Thunder Lake were targeted for a walleye spawning watch. The Thunder Lake Cranberry Marsh ditches were monitored by Mark and Tim Goldsworthy. At this time of year the growers are on the marsh in the evening and at night maintaining there systems and monitoring temperatures for the prevention of freezing of the cranberry beds. The Sampson marsh ditches were to be monitored by John Sampson. Both were contacted that day to reassure that observations of any fish spawning would be made and that the consultant would be contacted when it occurred. A third known walleye spawning shoreline belonging to Greg and Ingrid Weinfurter family east of the Sampson's main ditch was also monitored.

At 4:00 the winds from the northwest increased to 25 mph. The wind protected Sampson ditch at 4:48pm had a water temperature of 45 oF with a dissolved oxygen of 10.49 mg/l with a saturation of 87.9 %. At 4:58pm the downwind wave swept shoreline along the Weinfurter property had a water temperature of 42 oF with 12.22 mg/ l dissolved oxygen (97.1% sat.).

<u>April 5 - 25,2000</u> No spawning was observed in any of the cranberry bogs or along the south shore the next three weeks. The water temperature quickly increased to 55 oF in Thunder Lake during the first week without any sign of walleye spawning. Water temperatures in cranberry bog ditches lagged behind the lake temperatures until the third week when they became warmer than the lake. Cranberry bog ditch temperature increased to 62 oF by the third week in April.

<u>April 19, 2001</u> This sunny day brought air temperatures to 50 oF and a south wind of 10-15 mph by 12:30 pm. Ice was now free from the shorelines, and the thin ice sheet was blown to the down wind sides of Thunder Lake where it crumpled at the waters edge. At 10:30 the main ditch near the exit to Thunder Lake at the Thunder Lake Cranberry Marsh was at 43 oF with a dissolved oxygen of 10.18 mg/ l (82.2% saturation). Water was slowly being dropped in the cranberry ditches to slowly release frost from the dikes at that time. The Sampson cranberry bog was not in operation and no one could be contacted to check ditch water temperatures. The northwest facing shoreline of the Weinfurter property at 11:45 am had a water temperature of 41 oF with 10.4 mg/ l (82.2% sat.)of dissolved oxygen. Again, the walleye spawning monitors at the Thunder Lake Cranberry Marsh and at the Weinfurter shoreline were began.

On the north shore water level of Thunder Lake was at 1633.38 or 5 inches below the crest of the dam. Four inches of water was flowing over the sill notch. A 10-15 mph wind from the southwest at 12:30 pm was blowing the ice sheet against the north shore dike west of the dam. This action was stacking ice and rock base material in the bow of the dike 50' west of the dam for 200' and also in another bow extending 300' to 600' from the dam. Rock rubble below the water level was now free of periplankton or "slime algae"- that was present in 2000- except for a short section west of the perpendicular bulrush sand bar where organic peat accumulates. An estimated 200 gpm was flowing from the lake to a tag alder marsh 100' west of the end of the dike. The north shore temperature at the dike was 41 oF with a dissolved oxygen of 8.66 (69.3% sat.).

<u>April 20 - 26,2001</u> On April 20, 12-18" walleye were observed spawning on the Weinfurter south southeast shoreline. Winds were calm. The next night the winds blew out of the northwest and no spawning was observed. The following calm night ,April 22, 12" to 18"' walleye again returned to spawn. The next night high northwest winds returned and spawning was again not observed. On the 24 the northwest brought in a cold front and walleye spawning ended. At the Thunder Lake Cranberry Marsh no walleyes were

found in the main ditch from April 22 to April 30. Water temperatures were three to ten degrees colder than the main lake. A walleye egg daily temperature unit (DTU) model was sent up to predict when to look for egg development and hatch. 1 oF over 32 oF in water temperature would equal 1 DTU. A total of 300 DTU would be needed for walleye egg hatching.

April 27,2001 This date brought sunny and clear skies with an air temperature at 8:00 am of 55 oF with a light southeast breeze. Water temperature at the Weinfurter shoreline was 51 oF with a dissolved oxygen of 10.4 mg/ l (93.3% sat.). D-Frame net sampling found live hardened walleye eggs developing in the rock rubble along there shoreline. Walleye eggs that had developed to the early blastula stage.

At 10:00 am observations were made at the dam and north shore restoration dike area. Water level was 3.5 " below the top of the dam at an elevation of 1633.51. Water level had risen 1.5 inches from April 19. A southeast breeze was lapping water at the base of the dam and dike. Rock rubble beneath the water at the base of the dike was coated with brown peat silt except for the first 3-4" below the surface where the small wave action swept it clean. Thirty D-frame sweeps over there entire length of the dike found no walleye eggs. Crayfish were captured and observed during the sampling. Water temperature at 10:00 am was 54.1 oF with a dissolved oxygen of 10.92 (102 %sat.). The first phytoplankton bloom was observed accumulating along this downwind shoreline.

May 3, 2001 On this date D-frame sampling along the Weinfurter shoreline found more walleye eggs. The wallleye eggs had developed to the eyed up stage. Larger sucker eggs were also found along the shoreline.

May 9, 2001 On this date D-frame sampling on the Weinfurter shoreline found both fully developed sac fry emerging from the egg casing as well as empty egg casings. No sac fry were captured. Several crayfish and giant water bug beetles were captured during the D-frame sampling.

Discussion

Walleye reproduction success is sporadic as the spring weather. Suitable rock rubble and wave swept shorelines are important for walleye spawning and egg development. Prolonged low temperature can delay egg development; while drastic changes in temperature can cause egg mortality. Spring storms or high waves can dislodge and destroy incubating eggs. Water level changes can effect shoreline hydraulics that effect spawning substrate and egg incubation. Despite all of these conditions, if only one strong year class in four survive through the first year a good fishery will be maintained if harvest is not excessive.

Thunder Lake is limited in suitable habitat for spawning walleye to approximately 1000 feet of the east southeast shoreline. At this location rock rubble is exposed to the northwest where open water extends for over 3 miles. Small waves created over this distance can provide an oxygenated environment for egg development, but also can created larger waves with pounding forces as well as carry organic matter that can be detrimental to the incubating eggs. Suckers, that spawn after walleye, appear to use the same area for spawning. This may also disrupt incubating eggs. In 2000 spawning at this location or in the nearby cranberry bog ditches did not appear to occur. Water temperatures also appeared to stay cooler longer that in 2001. Water level during the spawning was also several inches lower in 2000 than compared to 2001.

Observations at the new north shore dike in both 2000 and 2001 identified several problems that may limit the site for egg development. Periplankton or a green slime layer and peat detritus covered the rock rubble in 2001 and peat detritus was found covering it in 2002. The detritus was not present during the observations made near ice out on April 19, 2001, but by the April 27, 2001 the detritus was present. It appears that as the ice disappears wind and wave action can bringing loose peat detritus into the rock rubble. At other times an organic accumulation and the right conditions can cause periplankton production. The presence of accumulated organic matter or periplankton has hindered the use of other artificial spawning reefs at other locations. This accumulation of organic matter is a perfect environment for fungus development on eggs.

The changes in the condition of the rock rubble may also be due to physical changes the dike and the lake are going through. The dike was new in 1999 and ice, wind/wave action in the last few years has created pushup mounds that are later flattened by wave action; which over time is changing the hydraulics of the base of the dike. If the slope of the dike at the water interface is flattened and organic matter in the lake stabilized- then better conditions for walleye and sucker spawning will occur.

Long term monitoring data through the DNR Ambient Lakes Program has indicated great improvements in water quality and the aquatic plant population over the last 20 years. The new dam and it's operation has stabilized the water level and diversified the aquatic plant community. In return the aquatic plant community has stabilized the wind-swept, loose, peat detritus, increased water clarity, and reduce the amount of organic matter dissolved in the water. This dissolved organic matter can be used by the periplankton. As further stabilization occurs the improvements should continue.

Where in the past spawning walleye were observed in the cranberry marsh ditches. none were observed in 2000 or 2001. Operation of the ditches at ice out has also changed. At one time the water from the main ditches, which receives melt water from the ice covered cranberry beds,was released quickly. Now the draw down is done much slower to facilitate a slow release of frost from the dikes. This minimizes damage that occurs to the dikes with a quicker draw down. This change in cranberry bog management would reduce the amount of seepage from the dikes and reduce flow from the main ditches, therefore not draw the spawning walleye to the flowing water. The Sampson Marsh was not operated in 2000-2001 season so it was not evaluated; but spawning did occur in the rock rubble area adjacent to the Weinfurter property just west of it's main ditch. It also appears that the slower draw down with the frost in the cranberry marshes can create temporary cooler water levels than the lake when the warmer winds raise lake temperatures.

In conclusion, these spawning observations prove that walleye are periodically reproducing in Thunder Lake. The spawning substrate for walleye at the present is limited. Hopefully the north shore dike and bottom lake sediments will continue to stabilize and create more suitable spawning habitat for walleye and suckers. Crayfish predation at the present may be a problem in the survival of walleye, suckers, and other fish eggs.

The walleye population may be increasing despite heavy fishing pressure. Young-of the-year walleye have been captured in the 1995 and 2001 fall electroshocking assessments. Where older and larger fish have been present in the electroshocking surveys since 1995- the last survey in 2001 had a substantial increase. Stocking by the Lake District and DNR appears to be responsible for this increase. See **Table 3**. Future otolith staining of DNR fingerlings and fin clipping could provide additional answers on the spawning success of the future walleye fishery.

Table 3. Thunder Lake Fish Recent Fish Stocking History 1995 to 2001.

DATE	SPECIES	SIZE	NUMBER	MARKINGS
6/7/95	YELLOW PERCH	ADLT &YRLG	46	
6/7/95	BLUEGILL	ADLT &YRLG	282	
6/7/95	PUMPKINSEED	ADLT &YRLG	13	
9/5/95	WALLEYE	3"	46004	
1996	WALLEYE*	8-10"*	1670	
1997	WALLEYE	FINGERLINGS	45450	
11/1997	WALLEYE*	8-10"*	1670	
10/98	WALLEYE*	8-10"*	1000	
6 & 7/99	WALLEYE	FINGERLINGS	172734	
11/99	WALLEYE*	5-12"*	1000	
12/99	WALLEYE*	5-7"*	1000	
10/2000	WALLEYE*	8-11"*	1500	FC top caudal
7/2001	WALLEYE	FINGERLINGS	183500	
11/2001	WALLEYE*	6-8"*	2300	FC bottom caudal

*LAKE DISTRICT STOCKING