PRELIMINARY ENGINEERING REPORT

LOWER MAUVAIS COULEE IMPROVEMENTS

SWC NO. 1614
DEVILS LAKE BASIN

NORTH DAKOTA
STATE WATER COMMISSION

June 1994

PRELIMINARY ENGINEERING REPORT

Lower Mauvais Coulee Improvements
SWC Project #1614

June 1994

North Dakota State Water Commission
900 East Boulevard
Bismarck, North Dakota 58505-0850

Prepared by:

C. Gregg Thielman
Water Resource Engineer

Submitted by:

Dale L. Frink, P.E.
Director of Water Development

Approved by:

David A. Sprynczynatyk, P.E.
State Engineer

TABLE OF CONTENTS

TABLES

TABLE OF CONTENTS (CONT.)

FIGURES

APPENDICES

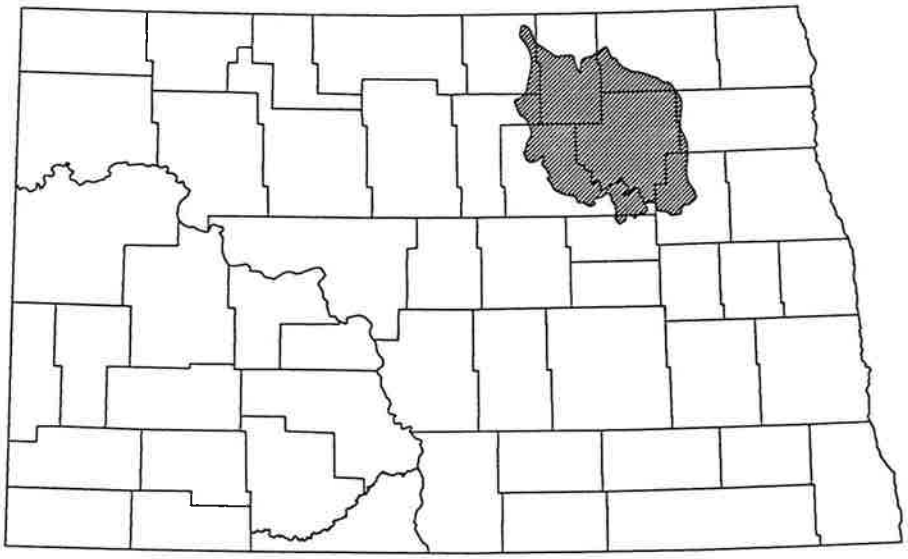
I. INTRODUCTION

Study Objectives:

In June of 1993, the North Dakota State Water Commission and the Devils Lake Basin Joint Water Management Board entered into an agreement to conduct a hydraulic study of Lower Mauvais Coulee (also known as Big Coulee) from Lake Irvine to the West Bay of Devils Lake. The agreement called for the State Water Commission to conduct a field survey of the project area, including cross sections of the coulee; modify and update existing hydraulic studies of Lower Mauvais Coulee; recommend potential road crossing and channel improvements; test the effects of the proposed improvements using the hydraulic model; estimate the effects of the proposed improvements on the Chain of Lakes using information derived from the 1991 Chain Lakes Improvement Study; prepare preliminary cost estimates for the various alternatives; and prepare a written report documenting the findings of the investigation. A copy of the agreement is contained in Appendix A.

Project Location and Purpose:

Lower Mauvais Coulee is located in the Devils Lake Basin in western Ramsey and eastern Benson Counties. The reach of the coulee modelled for this study is approximately 21 miles long. It originates at Lake Irvine, located near the city of Churchs Ferry, and flows southeast to the West Bay of Devils Lake, approximately 5 miles east of the city of Minnewaukan, North Dakota. Figure 1 shows the location of Lower Mauvais Coulee within the state of



LOWER MAUVAIS COULEE IMPROVEMENTS

SWC # 1614

LOCATION MAP

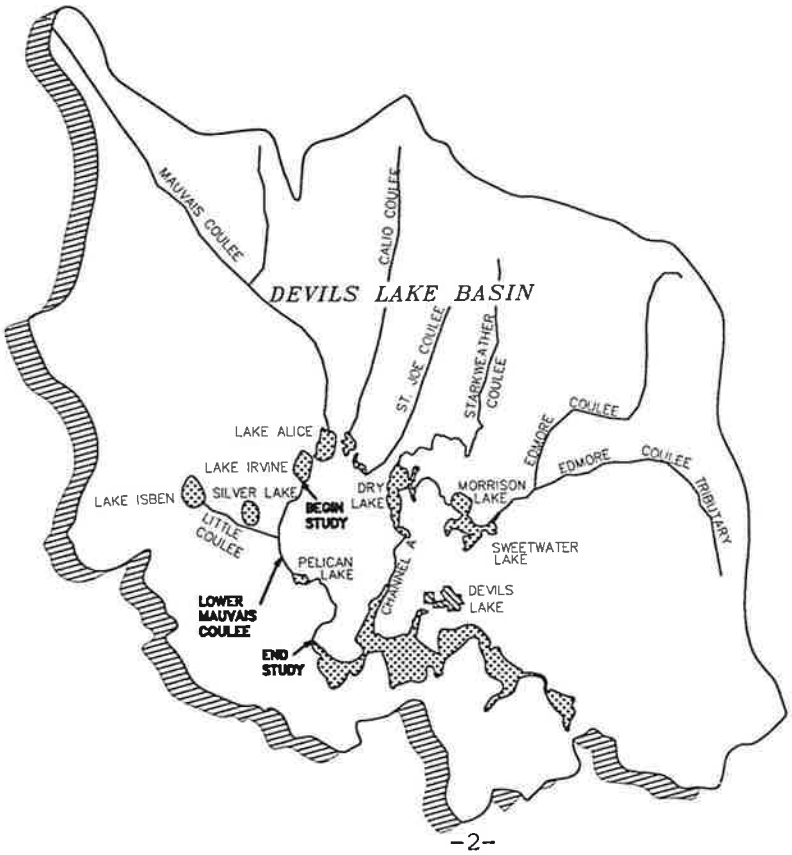


Figure 1 - Location of Lower Mauvais Coulee

North Dakota. Figure 2 shows the study area, including the structure locations.

The channel slope of Lower Mauvais Coulee is relatively flat, particularly at the upper end of the coulee. Any obstructions that cause an increase in water level can increase flooding farther upstream. The purpose of this study is to identify areas of restriction along Lower Mauvais Coulee and to propose corrective measures that will reduce flooding, both along the coulee and in the Chain of Lakes area.

Historical Background:

Several studies of the Devils Lake Basin have been completed in recent years. In December 1980, a study titled Lower Mauvais Coulee Water Surface Profile Study was completed by the State Water Commission. This study determined the effects of existing channel conditions and road crossings on selected flows. The study also recommended improvements to the channel, culverts, and bridges. Appendix B contains a summary of the recommendations of the 1980 study and their associated costs. The study recommended improvements in two phases. The phase one improvements included projects that would provide the greatest benefits. The phase two improvements would provide additional flood relief, but would involve several projects and considerable cost.

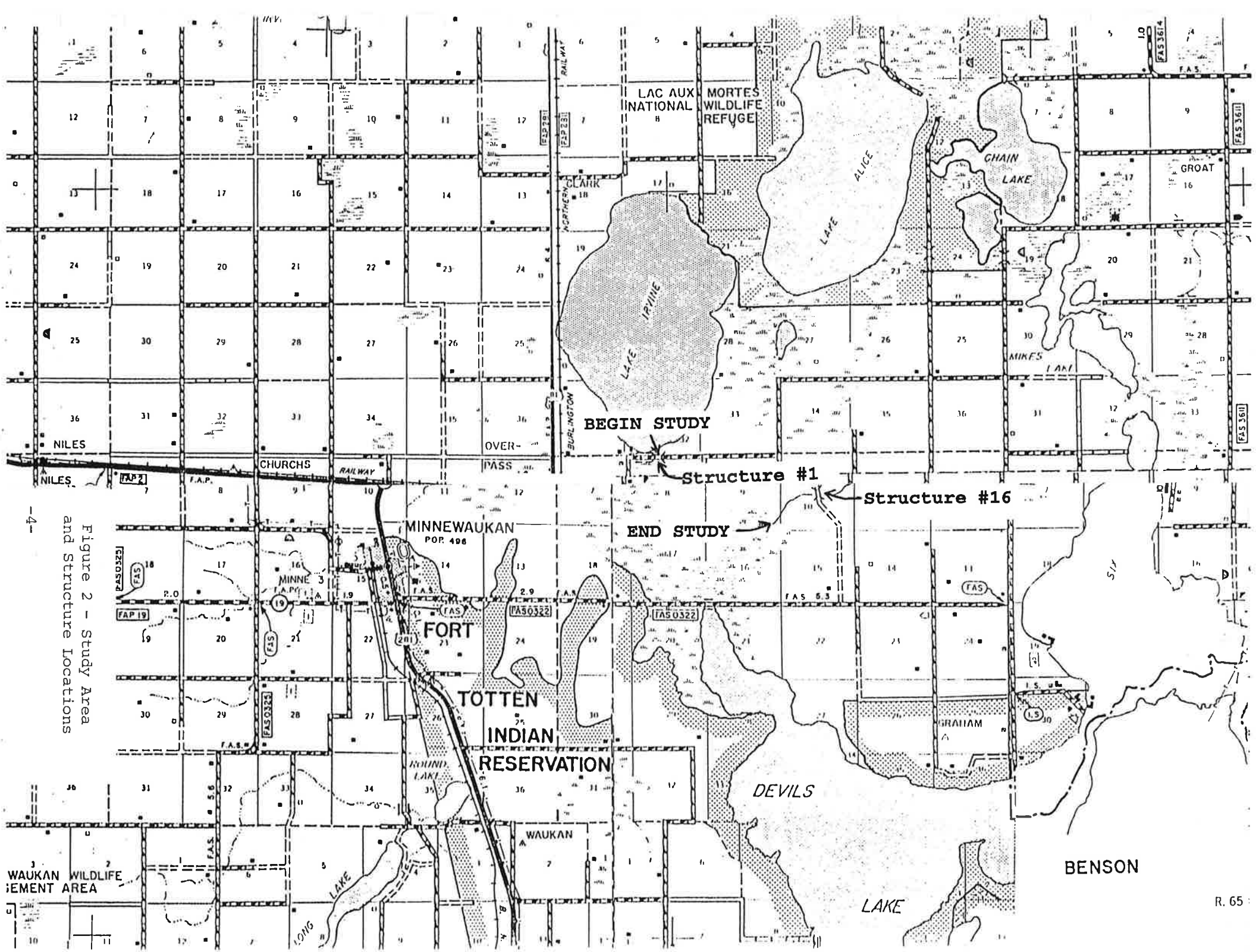


Figure 2 - Study Area and Structure Locations

Since the 1980 study was completed, few of its recommendations have been implemented, mainly due to a lack of funds. In one instance, Structure #9, where an increase in the size of the roadway crossing was recommended, the existing bridge was replaced by two 10-foot diameter corrugated metal pipe (CMP) culverts with a smaller flow area than the bridge they replaced.

In September 1991, a study titled Chain Lakes Improvement was completed by the North Dakota State Water Commission. This study evaluated the feasibility of certain hydraulic improvements to the watercourses in the vicinity of Mikes Lake, Chain Lake, Lake Alice, and Lake Irvine to reduce flood damages. The study resulted from recommendations made by the Lake Alice Study Group.

The study recommended the installation of a new control structure at the downstream end of Lake Irvine. It also recommended that Lakes Irvine, Alice, and Chain be drawn down to an elevation of approximately 1439 mean sea level (msl) each fall. Another recommendation of the study was the construction of a channel in the Duck Road area to improve flows out of Chain Lake and Mikes Lake. Reconsideration of the improvements to Lower Mauvais Coulee suggested in the 1980 study was also recommended.

The improvements evaluated in the 1991 Chain Lakes Study would reduce flooding during 5-year and 10-year floods. The improvements would have little effect on flooding during larger events because

during larger events there is too much water in the area to move downstream to Devils Lake without causing flooding problems. At this time, none of the recommendations of the 1991 study have been implemented.

II. HYDROLOGY

The Devils Lake Basin covers a total of about 3,814 square miles involving all or portions of eight counties. Devils Lake itself has a drainage area of approximately 3,320 square miles, with the remainder of the basin entering Stump Lake. About 2,010 square miles of the Devils Lake Basin drains into the Chain of Lakes system. Channel A has a drainage area of approximately 890 square miles. The remaining 1,120 square miles of drainage area enters Devils Lake via Lower Mauvais Coulee. The three main tributaries above Lower Mauvais Coulee are St. Joe, Calio, and Mauvais Coulees.

Channel A was completed in 1978. It allows Sweetwater Lake, Morrison Lake, and Dry Lake to outlet directly to Six Mile Bay of Devils Lake. The flow from these lakes formerly exited the northwest corner of Dry Lake and entered Mikes Lake, eventually entering Devils Lake via Lower Mauvais Coulee. Prior to the construction of Channel A, water flowed out the northwest corner of Dry Lake at elevation 1447.5 msl. Following the construction of Channel A, the northwest outlet of Dry Lake was raised to elevation 1449.5 msl. Channel A is operated so that Dry Lake is maintained at elevation 1447.5 msl during the summer. In the fall, the gates on the Channel A control structure are opened and Dry Lake is drawn down to elevation 1445 msl to allow flood storage for the upcoming spring runoff, as stipulated in the Channel A operating plan.

Hydrology for Current Lower Mauvais Coulee Study:

This study evaluated the effects of potential road crossing and channel improvements on Lower Mauvais Coulee for a range of flows from Lake Irvine. The discharges from Lake Irvine that were evaluated ranged from 18 cubic feet per second (cfs) to 1,080 cfs. The various improvements were modelled for this range of flows and rating curves at Lake Irvine were developed from this information. These rating curves are contained in the following sections of this report.

The flows below the confluence of Lower Mauvais Coulee and Little Coulee were increased to account for the added flow from Little Coulee. Little Coulee has a drainage area of approximately 400 square miles. Hydrographs from high flow events for Lower Mauvais Coulee and Little Coulee were compared to quantify the contribution of Little Coulee to Lower Mauvais Coulee below the confluence. The events that were compared occurred after the installation of Channel A. This comparison indicated that on average, the peak flow on Little Coulee occurs prior to the peak flow on Lower Mauvais Coulee. For the events analyzed, when the peak flow on the reach of Lower Mauvais Coulee below the confluence with Little Coulee occurs, approximately 10 percent of the flow is being contributed by Little Coulee and 90 percent comes from Lake Irvine. Considering this distribution, the flows on Lower Mauvais Coulee that were modelled for the reach of channel below the confluence with Little Coulee ranged from 20 cfs to 1,200 cfs

corresponding to the range of flows of 18 cfs to 1,080 cfs for the upper reach of coulee.

Hydrology from 1980 Lower Mauvais Coulee Study:

The 1980 water surface profile study on Lower Mauvais Coulee approximated the 1979 flood as a 100-year event. This was based on the observation that at the time of the study, the 1979 flood provided the highest volume of inflow to Devils Lake since 1867.

In 1979, 285,000 acre-feet of water flowed into Devils Lake. Of this, approximately 170,000 acre-feet entered the lake through Lower Mauvais Coulee. Channel A carried an additional 56,000 acre-feet of water. In 1979, the peak discharge from Lake Irvine was 1,030 cfs. Below the confluence with Little Coulee, the peak flow on Lower Mauvais Coulee was 1,400 cfs. Channel A was only operated for part of the year in 1979, and the northwest outlet of Dry Lake had not been raised to elevation 1449.5 msl.

For the 1980 Lower Mauvais Coulee Study, a flood equal to 50 percent of the 1979 flood volume, adjusted for a fully operational Channel A, was estimated to be a 25-year event. Based on this assumption, a 25-year flood would yield a peak discharge from Lake Irvine of 700 cfs, and the flow below the confluence with Little Coulee would be 900 cfs. The 25-year flood was used to determine the structure size needed for the stream crossings.

Hydrology from 1991 Chain Lakes Improvement Study:

The 1991 Chain Lakes Improvement Study determined inflows for Mikes Lake, Chain Lake, Lake Alice, and Lake Irvine using the USGS stream gage on Mauvais Coulee near Cando, North Dakota. A Log Pearson Type III analysis was performed using the gage records to develop 5-year and 10-year peak flows and the runoff volume at the gage. The HEC-1 computer model was used to develop 5-year and 10-year hydrographs for the basin above the gage and the model was calibrated using the gage records. The HEC-1 computer model was also used to develop hydrographs for the confluence of Mauvais Coulee and Lake Alice, as well as the mouth of Calio and St. Joe Coulees. The hydrographs were input into the National Weather Service's DWOPER model. The DWOPER model was used to analyze the effects of various hydraulic improvements to the watercourses in the vicinity of Mikes Lake, Chain Lake, Lake Alice, and Lake Irvine.

The DWOPER model used for the 1991 Chain Lakes Study generated flow and stage hydrographs for the outlet of Lake Irvine. A review of these hydrographs indicates that the flow from Lake Irvine into Lower Mauvais Coulee for a 5-year precipitation event is 360 cfs for existing conditions, and 390 cfs if the recommendations of the 1980 Lower Mauvais Coulee Study are implemented. The flow for a 10-year precipitation event is 560 cfs for existing conditions, and 620 cfs if the recommendations of the 1980 Lower Mauvais Coulee Study are implemented.

III. HYDRAULICS

A hydraulic analysis of Lower Mauvais Coulee was performed using the HEC-2 computer model, developed by the U.S. Army Corps of Engineers. HEC-2 computes water surface profiles for steady, gradually varied flow in natural or man-made channels for various flows. The data needed to perform these computations include: flow regime, starting water surface elevation, discharge, loss coefficients, cross-section geometry, and reach lengths. The computational procedure used by the model is based on the solution of the one-dimensional energy equation with energy loss due to friction evaluated with Manning's equation. This computation is generally known as the Standard Step Method.

The HEC-2 computer model for Lower Mauvais Coulee was developed using survey information obtained by the State Water Commission's survey crew in the fall of 1993. This included cross sectional data, bridge and culvert geometries, and water levels along the coulee. The HEC-2 computer model was developed and calibrated to the conditions experienced at the time of the survey. This computer model was used to develop a rating curve for Lower Mauvais Coulee for the conditions experienced during the 1993 flood. Table 1 contains a rating curve for Lower Mauvais Coulee at Lake Irvine for the 1993 flood conditions.

Table 1 - Rating Curve for 1993 Flood Conditions

Lake Irvine Level (msl)	Discharge (cfs)
1441.6	0.0
1442.0	81.0
1443.0	148.0
1444.0	228.0
1445.0	317.0
1446.0	415.0

IV. ALTERNATIVES

Several improvements to increase the capacity of Lower Mauvais Coulee were evaluated. These improvements are summarized in three alternatives. Alternative One involves reducing the amount of vegetation in the channel of Lower Mauvais Coulee and maintaining a pilot path through the high cattail areas below Pelican Lake. Alternative Two involves reducing the amount of vegetation in the channel of Lower Mauvais Coulee and maintaining a pilot path through the high cattail areas below Pelican Lake; installing new bridges to replace Structures #9, #8, #6, and #1; and installing a new control structure at Lake Irvine. Alternative Three is essentially the same as Alternative Two except that it also involves excavating a 60-foot wide channel from Structure #4 (the Highway 2 Bridge) to the confluence with Little Coulee. The following sections describe these alternatives in detail.

Alternative One:

This alternative involves reducing the amount of vegetation in Lower Mauvais Coulee and maintaining a pilot path through the high cattail areas below Pelican Lake. The flooding experienced during the summer of 1993 in the Devils Lake Basin was compounded by the large amount of vegetation that existed in many of the waterways at the time of the flooding. A cattail cutter was used to remove some of the vegetation from these waterways. The use of the cattail cutter helped improve the channel conditions to some extent, but the amount of vegetation in the channels was still high. The

effect of the cattails was perhaps most evident along Lower Mauvais Coulee due to its relatively flat slope. Table 2 shows a rating curve for Lower Mauvais Coulee at Lake Irvine for Alternative One.

Table 2 - Rating Curve for Alternative One

Lake Irvine Level (msl)	Discharge (cfs)
1441.6	0.0
1442.0	101.0
1443.0	240.0
1444.0	369.0
1445.0	558.0
1446.0	756.0

The current high levels in Devils Lake will help control the vegetation in some areas, such as below Pelican Lake. This area is now essentially part of Devils Lake and the high water may kill most of the cattails. As the lake rises and recedes this high vegetation area will move upstream and downstream, respectively. It is important, however, to always maintain a pilot path through the vegetation in this area.

Reducing the amount of vegetation in Lower Mauvais Coulee and maintaining a pilot path through the high cattail areas below Pelican Lake will have a significant effect on water levels in the coulee and the lakes above it. During the summer of 1993, the peak flow on Lower Mauvais Coulee below the confluence with Little Coulee was 347 cfs on August 31. Of this flow, approximately 31 cfs came from Little Coulee and 316 cfs came from Lake Irvine. This corresponds to a level of approximately 1445 msl at Lake

Irvine. Based on the results of the HEC-2 model, if the amount of vegetation were reduced in Lower Mauvais Coulee and a pilot path were maintained below Pelican Lake, the coulee would have been capable of passing a flow of 316 cfs with Lake Irvine at a level of approximately 1443.6 msl.

The most effective method of reducing the amount of vegetation in Lower Mauvais Coulee is to develop a regular maintenance program. When the channel is dry, the vegetation can be controlled by mowing. When there is water in the channel, it may be necessary to control the vegetation using an herbicide such as Rodeo (registered trademark of Monsanto Company, St. Louis, MO), or in some cases a cattail cutter. The annual cost to control the vegetation in Lower Mauvais Coulee is estimated to be approximately $10,000.

In addition to improved channel maintenance, a 75-foot wide pilot path should be maintained through any cattail area in the upper reaches of Devils Lake. In 1993, the area below Pelican Lake was overgrown with cattails. Higher lake levels will move the problem area farther upstream. If Devils Lake recedes, it is likely that the area below Pelican Lake will again develop a cattail problem.

Maintaining the pilot path will require that the vegetation be dredged, cut, or sprayed. Dredging will be difficult and costly

due to the wet conditions that occur through this area. A cattail cutter could be used to develop the pilot path, but this would also be very costly. A simpler solution may be to spray the cattails with an herbicide such as Rodeo using an aerial sprayer.

Alternative Two:

This alternative involves reducing the amount of vegetation in the channel of Lower Mauvais Coulee and maintaining a pilot path through the high cattail areas below Pelican Lake, as recommended in Alternative One. It also involves replacing four roadway crossings with new bridges and installing a control structure at Lake Irvine.

The portion of Lower Mauvais Coulee above the confluence with Little Coulee has a flat slope. On average, the slope in this reach is approximately 9 inches per mile. Any obstructions that cause an increase in water level will cause the water level to increase in the coulee through Lake Irvine. Several structures located along this reach of the coulee are undersized and cause an increase in water level. Table 3 shows the existing crossings along Lower Mauvais Coulee and the net flow area associated with each of them.

Table 3 - Existing Structure Summary

Structure #	Description	Net Flow Area (sq.ft.)
16	Section 10 Bridge	300
15	Highway 19 Bridge	310
14	Pelican Lake Bridge	295
13	Soo Line Railroad	-
12	New Bridge	317
11	South Highway 281 Bridge	650
10	Brinsmade Road Bridge	310
9	Two 10-foot Diameter CMP	157
8	Normania School Crossing	228
7	North Highway 281 Bridge	470
6	Straabe Bridge	215
5	Bridge South of Churchs Ferry	500
4e	Eastbound Highway 2 Bridge	555
4w	Westbound Highway 2 Bridge	542
3	Churchs Ferry Railroad Bridge	650
2	Old Highway 2 Bridge	530
1	Lake Irvine	492

Structures #9, #8, and #6 are undersized and cause water level increases during high flows. Structure #1 is deteriorated and should be replaced for structural reasons. The replacement of Structure #1 will also allow a new control structure for Lake Irvine to be installed. The design of the replacement structures is based on the size of the other structures on Lower Mauvais Coulee and the ability of the new bridges to pass flow without causing a significant water level increase.

Structure #9 currently consists of two 10-foot diameter CMP culverts. The culverts will cause a water level increase of approximately 1.20 feet during a 1979 equivalent flow in Lower Mauvais Coulee. The culverts should be replaced by a bridge. The bridge will have a 30-foot bottom width and 2:1 (2 Horizontal to 1

Vertical) side slopes. The width across the underdeck of the bridge will be approximately 66 feet, resulting in a net flow area of approximately 432 square feet. The channel invert below the bridge will be at an elevation of 1434.0 msl and the bridge low chord elevation will be 1443.0 msl. The cost to install a new bridge at Structure #9 is estimated to be $140,000. Table 4 contains a preliminary cost estimate to replace Structure #9.

Table 4 - Cost Estimate to Replace Structure #9

Item	Quantity	Unit	Unit Price	Total
Mobilization	1	LS	$5,000.00	$ 5,000
Remove Culverts	1	LS	3,000.00	3,000
Concrete Bridge	1,980	SF	45.00	89,100
Fill	2,000	CY	1.20	2,400
Gravel	200	CY	15.00	3,000
Traffic Control	1	LS	5,000.00	5,000
Seeding	1	Ac.	300.00	300
Subtotal				$107,800
Contingencies			(+/- 10%)	10,733
Contract Administration			(+/- 10%)	10,733
Engineering			(+/- 10%)	10,734
TOTAL				$140,000

Structure #8 currently consists of five 54-inch x 72-inch CMP, one 48-inch x 72-inch CMP, one 60-inch diameter CMP, and one 120-inch diameter CMP. The culverts will cause a water level increase of approximately 1.2 feet during a 1979 equivalent flow in Lower Mauvais Coulee. The culverts should be replaced by a bridge. The bridge will have a 30-foot bottom width and 2:1 side slopes. The width across the underdeck of the bridge will be approximately 70 feet, resulting in a net flow area of approximately 500 square

feet. The channel invert below the bridge will be at an elevation of 1434.5 msl and the bridge low chord elevation will be 1444.5 msl. The cost to install a new bridge at Structure #8 is estimated to be $148,000. Table 5 contains a preliminary cost estimate to replace Structure #8.

Table 5 - Cost Estimate to Replace Structure #8

Item	Quantity	Unit	Unit Price	Total
Mobilization	1	LS	$5,000.00	$ 5,000
Remove Culverts	1	LS	5,000.00	5,000
Concrete Bridge	2,100	SF	45.00	94,500
Fill	2,200	CY	1.20	2,640
Gravel	100	CY	15.00	1,500
Traffic Control	1	LS	5,000.00	5,000
Seeding	1	Ac.	300.00	300
Subtotal				$113,940
Contingencies			(+/- 10%)	11,353
Contract Administration			(+/- 10%)	11,353
Engineering			(+/- 10%)	11,354
TOTAL				$148,000

Structure #6 currently consists of a 26-foot long bridge. With the existing Structures #8 and #9 in place, Structure #6 will be overtopped during a 1979 equivalent flow in Lower Mauvais Coulee. If Structures #8 and #9 are replaced, Structure #6 will cause a water level increase of approximately 0.25 feet during a 1979 equivalent flow. Structure #6 should be replaced by a new bridge. The new bridge will have a 30-foot bottom width and 2:1 side slopes. The width across the underdeck of the bridge will be approximately 72 feet, resulting in a net flow area of approximately 536 square feet. The channel invert below the bridge

will be at an elevation of 1435.0 msl and the bridge low chord elevation will be 1445.5 msl. The cost to install a new bridge at Structure #6 is estimated to be $153,000. Table 6 contains a preliminary cost estimate to replace Structure #6.

Table 6 - Cost Estimate to Replace Structure #6

Item	Quantity	Unit	Unit Price	Total
Mobilization	1	LS	$5,000.00	$ 5,000
Remove Existing Bridge	1	LS	5,000.00	5,000
Concrete Bridge	2,160	SF	45.00	97,200
Fill	1,500	CY	1.20	1,800
Gravel	220	CY	15.00	3,300
Traffic Control	1	LS	5,000.00	5,000
Seeding	1	Ac.	300.00	300
Subtotal				$117,600
Contingencies			(+/- 10%)	11,800
Contract Administration			(+/- 10%)	11,800
Engineering			(+/- 10%)	11,800
TOTAL				$153,000

Structure #1 currently consists of an eight barrel timber box culvert with sluice gates (approximately 5-foot x 5-foot), a 20-foot long bridge, and a 20.5-foot x 13.0-foot structural plate arch pipe. Structure #1 is large enough to pass flow without causing a significant water level increase; however, the condition of the 20-foot long bridge is deteriorated and the sluice gates on the timber box culverts are inoperable. In addition, the sluice gates on the control structure and the earthen weir that control Lake Irvine at an elevation of 1441.6 msl, which the State Engineer has determined to be the normal elevation of Lake Irvine, were removed during the 1993 flood.

The existing Structure #1 should be replaced by a new bridge and control structure. The new bridge will have a 40-foot bottom width and 2:1 side slopes. The width across the underdeck of the bridge will be approximately 70 feet, resulting in a net flow area of approximately 547 square feet. The channel invert below the bridge will be at an elevation of 1437.6 msl and the bridge low chord elevation will be 1447.0 msl. In conjunction with the bridge replacement, the road south of Lake Irvine should be raised to elevation 1448.0 msl to prevent overtopping during a 1979 equivalent flow. This will involve raising approximately 5,500 feet of road.

A new control structure will be incorporated into Structure #1 directly upstream from the bridge. The control structure will be a 70-foot wide concrete weir. The crest of the weir will be set at elevation 1441.6 msl. The weir will be located approximately 10 feet upstream of the bridge and will tie into the wingwalls. Three 6-foot wide stop log bays will be incorporated into the weir to allow the drawdown of Lake Irvine to elevation 1437.6 msl. The proposed drawdown structure will allow Lake Irvine to be drawn down to elevation 1439.0 msl in approximately 142 days. Three stop log bays were installed since the capacity of the three bays is near the capacity of Lower Mauvais Coulee for both existing conditions and conditions involving the channel improvements evaluated in Alternative Three.

The cost to install a new bridge and control structure at Structure #1 is estimated to be $265,000. Table 7 contains a preliminary cost estimate to replace Structure #1. Figure 3 shows an isometric view of the proposed Structure #1.

Table 7 - Cost Estimate to Replace Structure #1

Item	Quantity	Unit	Unit Price	Total
Mobilization	1	LS	$5,000.00	$ 5,000
Remove Existing Structures	1	LS	8,000.00	8,000
Bridge Replacement				
(a) Concrete Bridge	2,100	SF	45.00	94,500
(b) Fill	15,000	CY	1.20	18,000
(c) Gravel	2,000	CY	15.00	30,000
(d) Rock Riprap	125	CY	25.00	3,125
(e) Filter Material	45	CY	15.00	675
Control Structure				
(a) Excavation	500	CY	2.50	1,250
(b) Concrete	52	CY	300.00	15,600
(c) Reinforcing Steel	7,280	Lbs.	0.50	3,640
(d) Sheet Piling	530	LF	25.00	13,250
(e) Rock Riprap	60	CY	25.00	1,500
(f) Filter Material	20	CY	15.00	300
(g) Misc. Materials	1	LS	2,000.00	2,000
Traffic Control	1	LS	5,000.00	5,000
Seeding	6	Ac.	300.00	1,800
Subtotal				$203,640
Contingencies			(+/- 10%)	20,453
Contract Administration			(+/- 10%)	20,453
Engineering			(+/- 10%)	20,454
TOTAL				$265,000

The total cost to perform the structural improvements evaluated in Alternative Two is estimated to be $706,000. Funding of approximately $500,000 is currently available from the Office of Intergovernmental Assistance through the Federal Flood Disaster Assistance Program for the bridge and control structure installation. The North Dakota Department of Transportation has

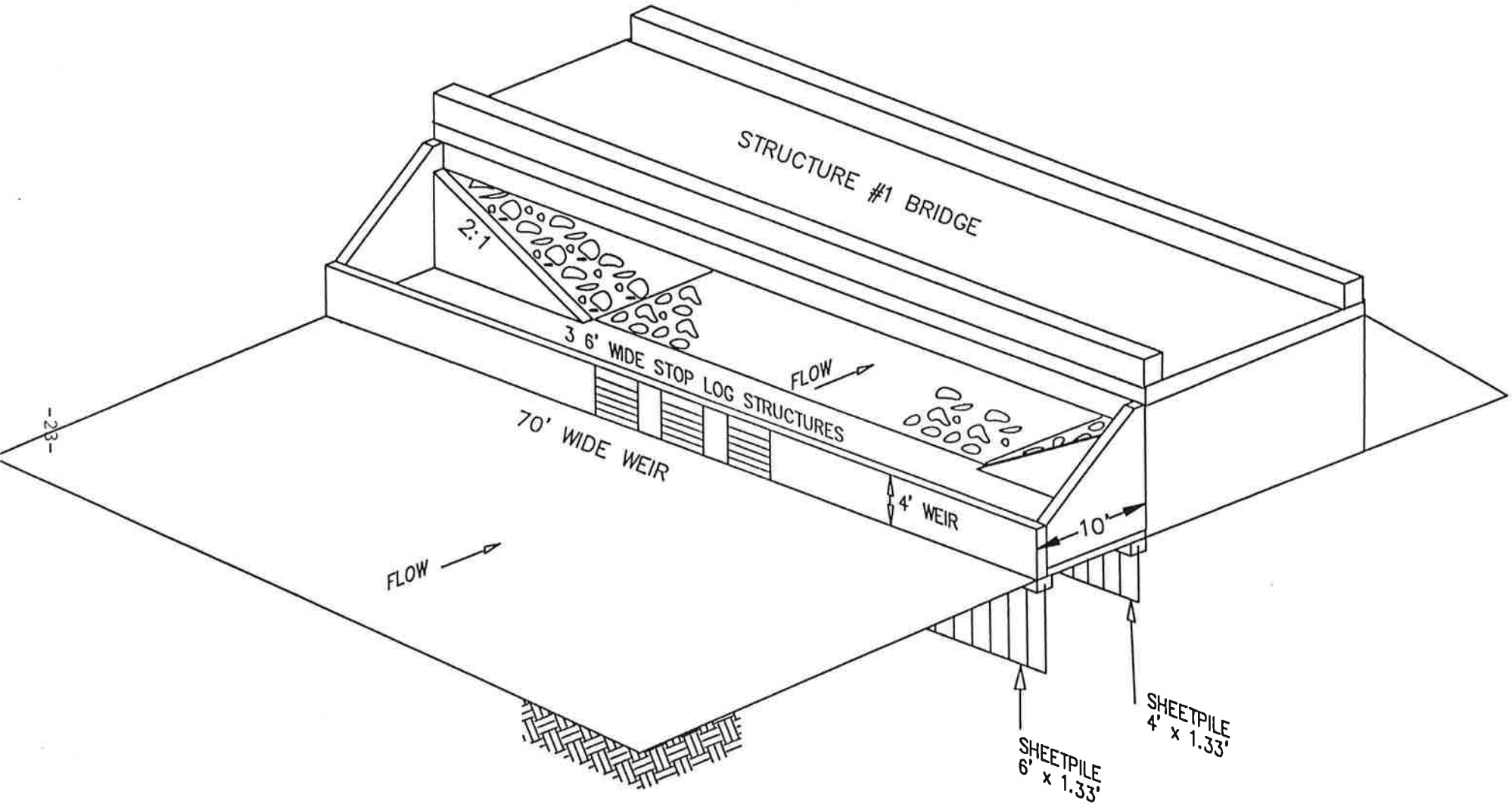


Figure 3 - Isometric
View of Structure #1

agreed to fund 80 percent of the cost to replace Structure #6, contingent on Structures #8 and #9 being replaced at the same time.

Alternative Two will increase the capacity of Lower Mauvais Coulee, particularly during high flows. Figure 4 shows a comparison of the water surface profiles of Lower Mauvais Coulee for Alternative One and Alternative Two for a 1979 equivalent flow. It should be noted that the effectiveness of the structure replacement will be reduced if the vegetation is not reduced in the channel as recommended in Alternative One. Table 8 shows a rating curve for Alternative Two.

Table 8 - Rating Curve for Alternative Two

Lake Irvine Level (msl)	Discharge (cfs)
1441.6	0.0
1442.0	47.0
1443.0	234.0
1444.0	383.0
1445.0	588.0
1446.0	848.0

Removing the stop logs from the control structure on Lake Irvine will allow the lake to be drawn down and will also increase the capacity of the coulee during low flows. Table 9 shows a rating curve for Alternative Two with the stop logs removed from the control structure.

Figure 4 - Water Surface Profiles of
Lower Mauvais Coulee for 1979 Equivalent Flow

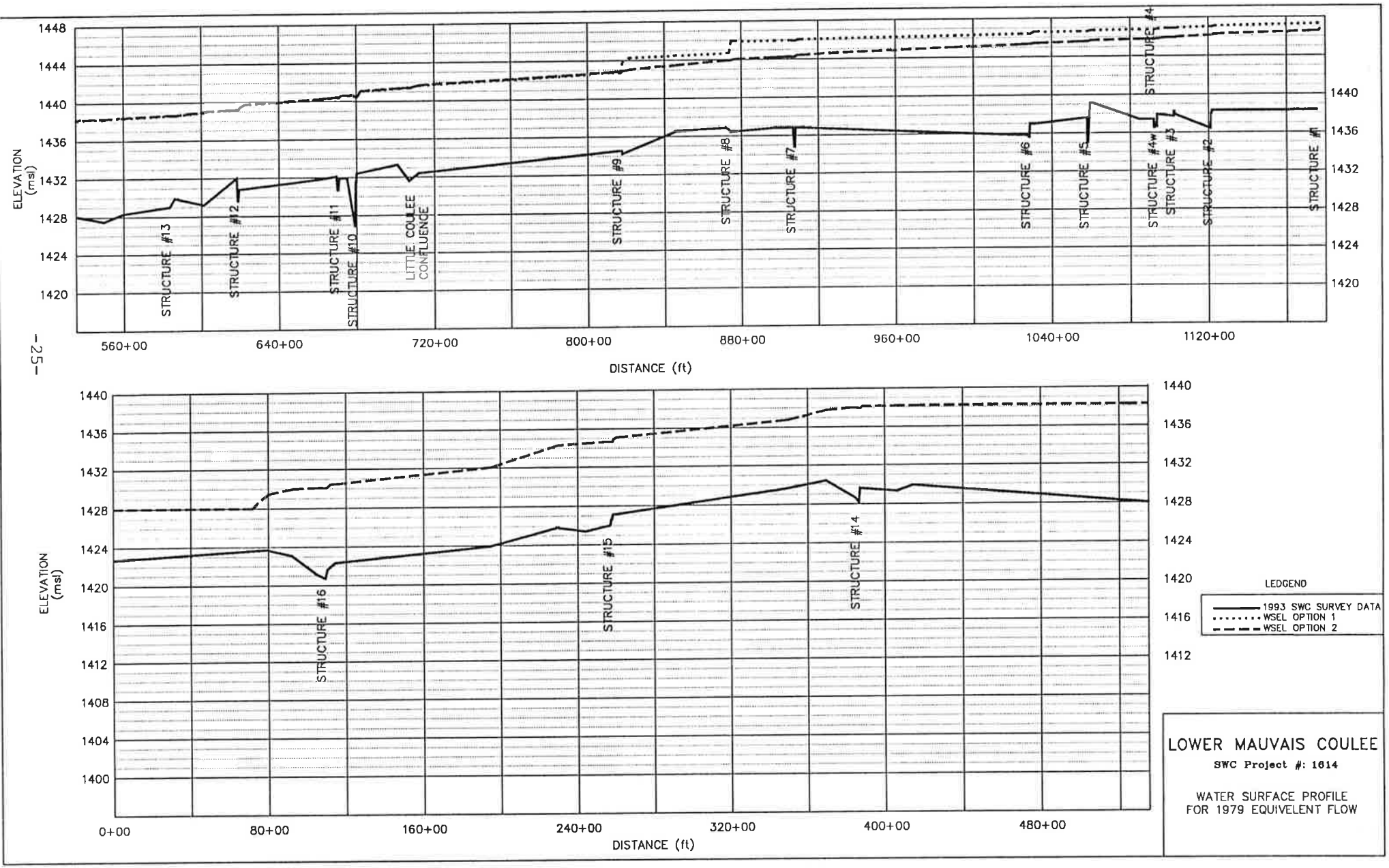


Table 9 - Rating Curve for Alternative Two with Stop Logs Removed from Control Structure

Lake Irvine Level (msl)	Discharge (cfs)
1437.6	0.0
1438.0	3.0
1439.0	11.0
1440.0	21.0
1441.0	68.0
1442.0	134.0
1443.0	246.0
1444.0	391.0
1445.0	597.0
1446.0	859.0

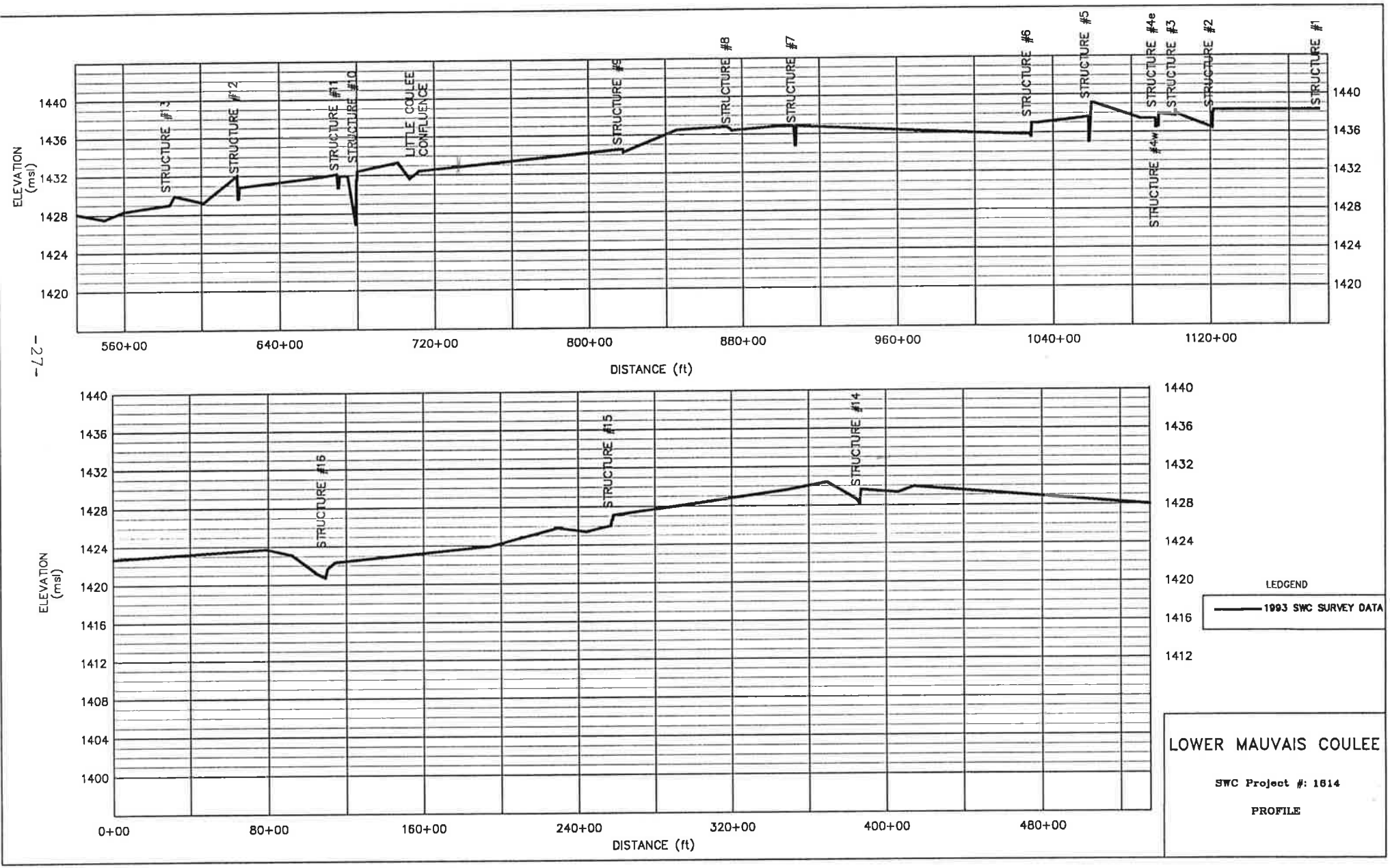
Alternative Three:

This alternative involves reducing the amount of vegetation in the channel of Lower Mauvais Coulee and maintaining a pilot path through the high cattail areas below Pelican Lake, as recommended in Alternative One; installing new bridges at Structures #9, #8, and #6, and installing a new bridge and control structure at Structure #1, as recommended in Alternative Two; and excavating a 60-foot wide channel with 3:1 side slopes from Structure #4 to the confluence with Little Coulee.

Figure 5 shows a channel bottom profile of Lower Mauvais Coulee for existing conditions. Performing the proposed channel improvements will remove several high spots from the channel and increase the capacity of Lower Mauvais Coulee.

The proposed improvements to Lower Mauvais Coulee will extend from Structure #4 (the Highway 2 Bridge) downstream to the

Figure 5 - Channel Profile of
Lower Mauvais Coulee for Existing Conditions



confluence with Little Coulee. This reach of coulee was selected due to its flat slope. The channel slope below the confluence with Little Coulee increases, resulting in a higher channel capacity. The channel slope upstream of Structure #4 is currently at the maximum achievable slope, limited by the invert elevations of Structures #3 and #2. The slope of the improved channel will tie in to the invert elevations of the existing structures and proposed new structures. Figure 6 shows a channel bottom profile of Lower Mauvais Coulee after the improvements in Alternative Three are implemented. Table 10 shows a rating curve for Alternative Three.

Table 10 - Rating Curve for Alternative Three

Lake Irvine Level (msl)	Discharge (cfs)
1441.6	0.0
1442.0	47.0
1443.0	297.0
1444.0	506.0
1445.0	714.0
1446.0	984.0

Table 11 contains a rating curve for Alternative Three with the stop logs removed from the Lake Irvine control structure.

Figure 6 - Channel Profile of Lower
Mauvais Coulee for Alternative Three

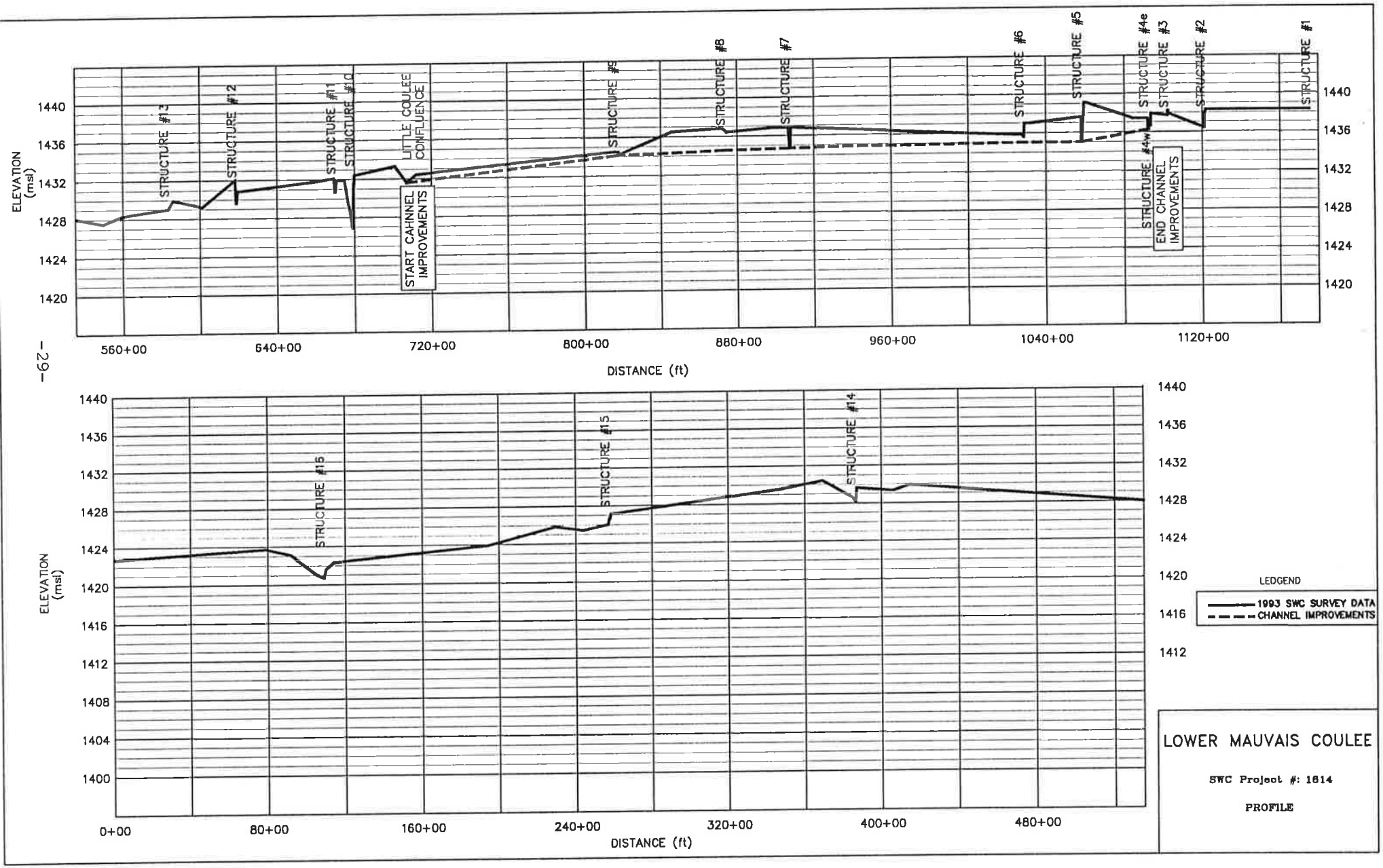


Table 11 - Rating Curve for Alternative Three with Stop Logs Removed From Control Structure

Lake Irvine Level (msl)	Discharge (cfs)
1437.6	0.0
1438.0	3.0
1439.0	12.0
1440.0	31.0
1441.0	99.0
1442.0	212.0
1443.0	345.0
1444.0	519.0
1445.0	725.0
1446.0	999.0

The cost to perform the channel improvements evaluated in Alternative Three is estimated to be $930,000. Table 12 contains a preliminary cost estimate for the Alternative Three channel improvements.

Table 12 - Cost Estimate for Alternative Three Channel Improvements

Item	Quantity	Unit	Unit Price	Total
Mobilization	1	LS	$10,000.00	$ 10,000
Excavation	272,000	CY	2.50	680,000
Seeding	85	Ac.	300.00	25,500
Subtotal				$715,500
Contingencies			(+/- 10%)	71,500
Contract Administration			(+/- 10%)	71,500
Engineering			(+/- 10%)	71,500
TOTAL				$930,000

V. PERMIT REQUIREMENTS

No permits should be required for Alternative One, although, if the vegetation is removed from the channel through mechanical means and sediment is removed along with it, a Section 404 Permit may be required from the U.S. Army Corps of Engineers. Once the vegetation is removed from the channel, it should be removed from the wetland and deposited so that it cannot reenter the waterway. If the vegetation is controlled through the use of chemicals, the North Dakota State Health Department must be notified prior to the application of the chemicals.

The bridge replacements evaluated in Alternative Two will require a Section 404 Permit from the U.S. Army Corps of Engineers. The installation of the control structure on Lake Irvine in conjunction with the replacement of Structure #1 will also require a Section 404 Permit. The installation of the control structure will also require a dam permit and a sovereign lands permit, both issued by the State Engineer. An operating plan for the drawdown structure must be included with the state permit applications.

The channel improvements evaluated in Alternative Three will require a Section 404 Permit from the U.S. Army Corps of Engineers. State permits may also be required from the State Engineer, depending upon the scope of the channel improvements that are pursued.

VI. SUMMARY

Lower Mauvais Coulee is located in the Devils Lake Basin in western Ramsey and eastern Benson Counties. It originates at Lake Irvine, located near the city of Churchs Ferry, and flows southeast to the West Bay of Devils Lake. The purpose of this study was to identify areas of restriction along Lower Mauvais Coulee and to propose corrective measures that will reduce flooding, both along the coulee and in the chain of lakes.

Other recent studies of the Devils Lake Basin relative to Lower Mauvais Coulee include a December 1980, study titled Lower Mauvais Coulee Water Surface Profile Study, and a September 1991, study titled Chain Lakes Improvement. Both of these studies were completed by the North Dakota State Water Commission.

This study evaluated the effects of potential road crossing and channel improvements on Lower Mauvais Coulee. These improvements were evaluated for a range of flows using the HEC-2 computer model, developed by the U.S. Army Corps of Engineers. The computer model was used to develop rating curves for the outlet to Lake Irvine and these rating curves were used to evaluate the effectiveness of the various improvements. Figure 7 shows a graphical comparison of the rating curves for the 1993 flood conditions (existing) and for the three alternatives that were evaluated. Figure 8 shows a graphical comparison of the rating curves for the 1993 flood conditions (existing), for Alternative

LAKE IRVINE RATING CURVES

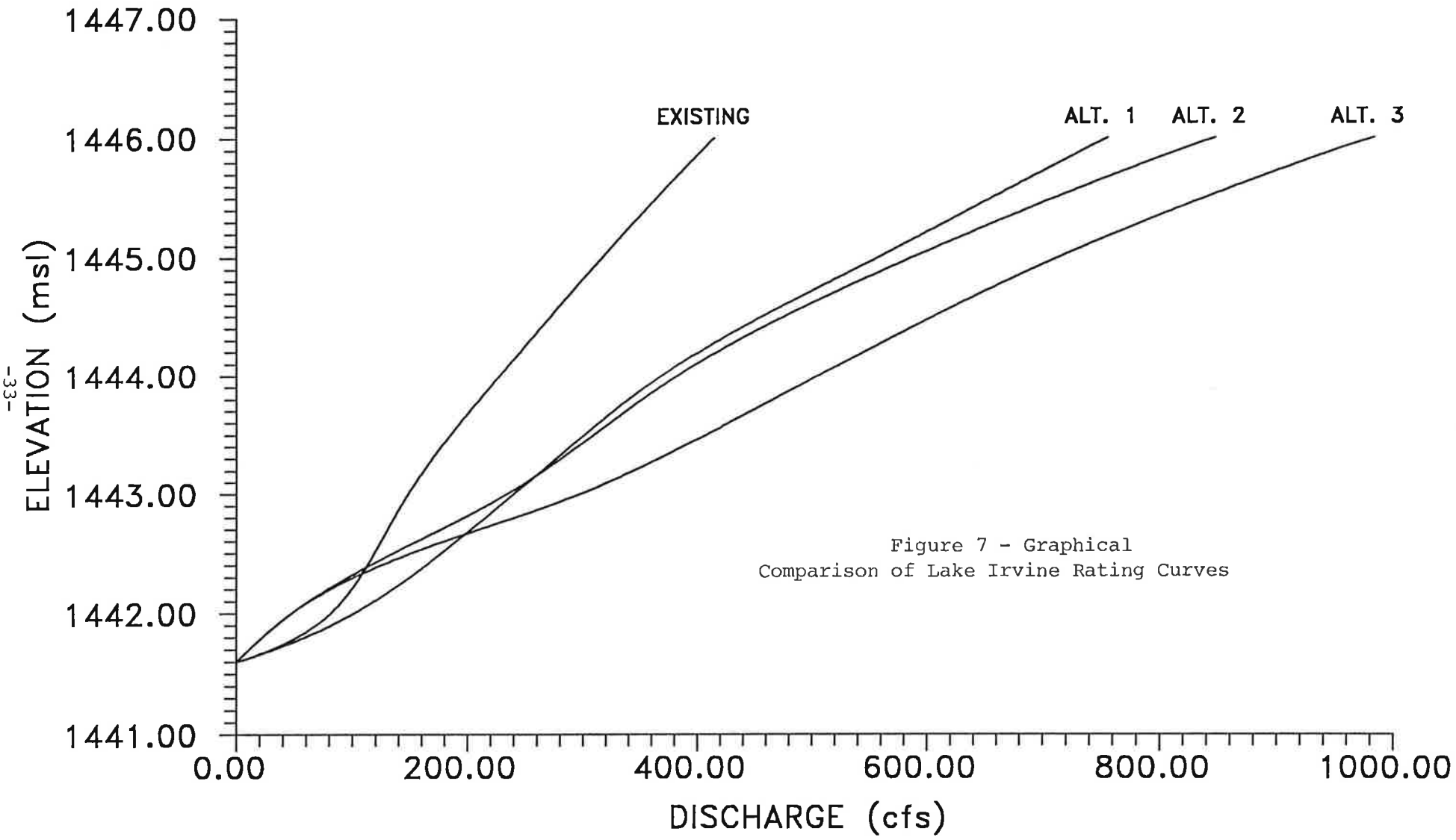


Figure 7 - Graphical
Comparison of Lake Irvine Rating Curves

LAKE IRVINE RATING CURVES FOR DRAWDOWN CAPABILITIES

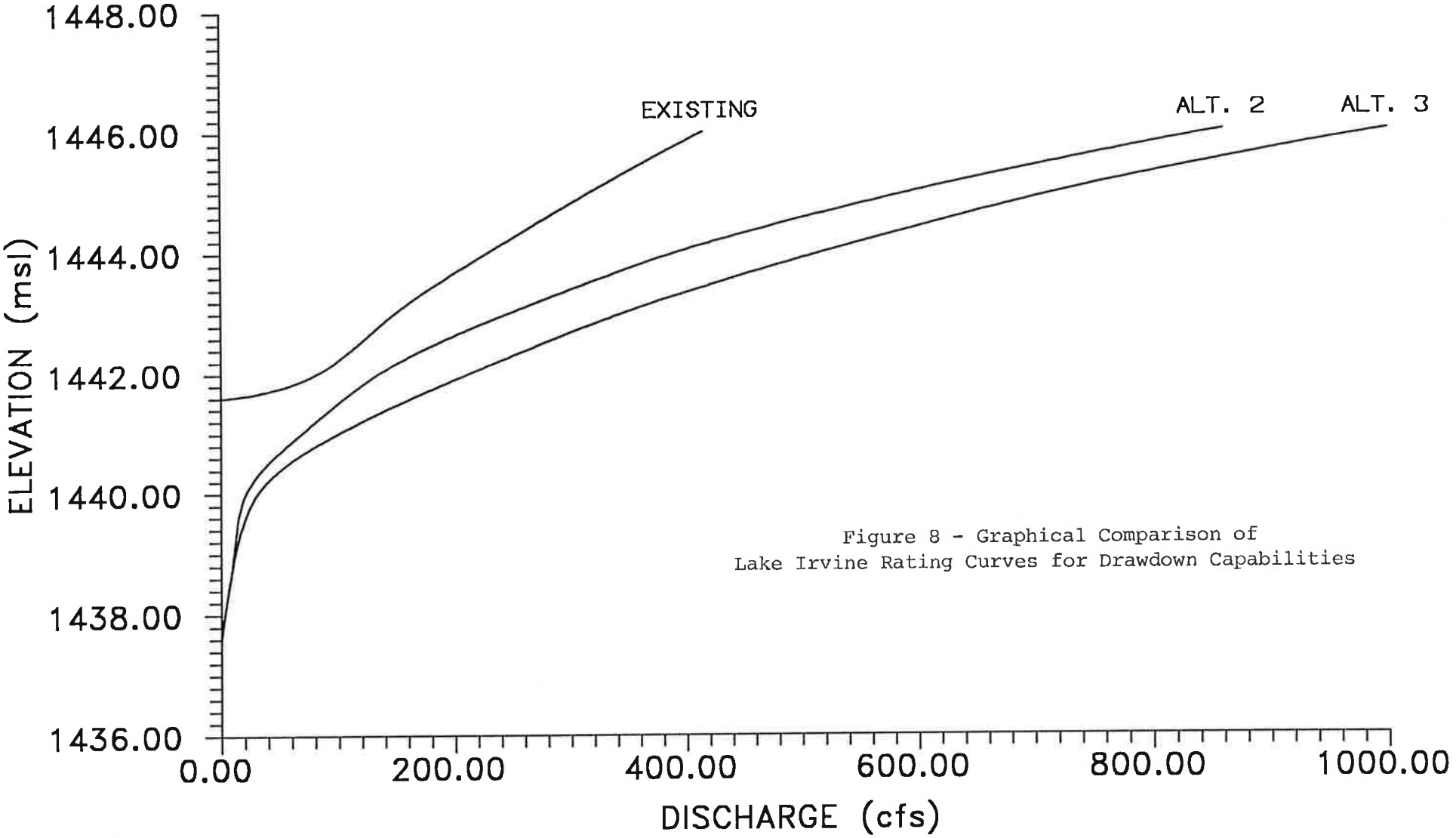


Figure 8 - Graphical Comparison of
Lake Irvine Rating Curves for Drawdown Capabilities

Two with the stop logs removed from the control structure, and for Alternative Three with the stop logs removed from the control structure.

The improvements that were evaluated are summarized in three alternatives. Alternative One involves reducing the amount of vegetation in the channel of Lower Mauvais Coulee and maintaining a pilot path through the high cattail areas below Pelican Lake. The most effective way of reducing the vegetation in the channel is through the development of a regular maintenance program. This can be done through mowing when the channel is dry or through the use of chemicals during wet years. The annual cost to control the vegetation in Lower Mauvais Coulee is estimated to be $10,000 per year.

Alternative Two involves reducing the amount of vegetation in the channel of Lower Mauvais Coulee and maintaining a pilot path through the high cattail areas below Pelican Lake, as recommended in Alternative One. It also involves installing new bridges at Structures #9, #8, and #6, and installing a new bridge and control structure at Structure #1. The new bridge at Structure #9 will have a net flow area of approximately 432 square feet and is estimated to cost $140,000. The new bridge at Structure #8 will have a net flow area of approximately 500 square feet and is estimated to cost $148,000. The new bridge at Structure #6 will have a net flow area of approximately 536 square feet and is

estimated to cost $153,000. The new bridge at Structure #1 will have a net flow area of approximately 547 square feet. The control structure consists of a 70-foot wide weir located directly upstream from the bridge. The control structure will control Lake Irvine at an elevation of 1441.6 msl with drawdown capabilities to elevation 1437.6 msl. The cost to construct the new bridge and control structure at Structure #1 is estimated to be $265,000.

Alternative Three involves reducing the amount of vegetation in the channel of Lower Mauvais Coulee and maintaining a pilot path through the high cattail areas below Pelican Lake, as recommended in Alternative One; installing new bridges at Structures #9, #8, and #6, and installing a new bridge and control structure at Structure #1, as recommended in Alternative Two; and excavating a 60-foot wide channel with 3:1 side slopes from Structure #4 to the confluence with Little Coulee. The slope of the excavated channel will tie in to the invert elevations of the existing structures and proposed new structures. The cost to perform these channel improvements is estimated to be $930,000.

VII. RECOMMENDATIONS

Several improvements to increase the capacity of Lower Mauvais Coulee were analyzed during this study. Alternative One, which involves reducing the amount of vegetation in the channel of Lower Mauvais Coulee and maintaining a pilot path through the high cattail areas below Pelican Lake, will provide the greatest flood reduction benefits. Therefore, it is recommended that a regular channel maintenance program be developed for Lower Mauvais Coulee.

The bridge replacements and control structure installation evaluated in Alternative Two will provide flood reduction benefits during high flows. Funding of approximately $500,000 is currently available from the Office of Intergovernmental Assistance through the Federal Flood Disaster Assistance Program for the bridge and control structure installation. The North Dakota Department of Transportation has agreed to fund 80 percent of the cost to replace Structure #6, contingent on Structures #8 and #9 being replaced at the same time. Therefore, it is recommended that new bridges be installed at Structures #9, #8, and #6, and a new bridge and control structure be installed at Structure #1.

The channel improvements evaluated in Alternative Three will also provide flood reduction benefits along Lower Mauvais Coulee and in the Chain Lakes. The cost to perform these improvements is high and it may be difficult to obtain the permits necessary to perform the channel improvements. The decision to proceed with any

of these improvements is the responsibility of the Devils Lake Basin Joint Water Resource Board.

APPENDIX A - COPY OF AGREEMENT

1614
SWC Project ~~#416~~
May 13, 1993

A G R E E M E N T

Investigation
of
Lower Mauvais Coulee Improvements

I. PARTIES

THIS AGREEMENT is between the North Dakota State Water Commission, hereinafter Commission, through its Secretary, David A. Sprynczynatyk; and the Devils Lake Basin Joint Water Management Board, hereinafter Joint Board, through its Chair, Benhart A. Varnson.

II. PROJECT, PURPOSE, AND LOCATION

The Joint Board has requested the Commission to conduct a hydraulic study of the Lower Mauvais Coulee from Lake Irvine to the West Bay of Devils Lake. The study will identify areas of restriction along the Coulee, and propose corrective measures to reduce flooding, both along the coulee and in the chain of lakes area.

III. PRELIMINARY INVESTIGATION

The parties agree that further information is necessary concerning the proposed project. The study will primarily update information in the 1980 Lower Mauvais Coulee investigation. Therefore, the Commission will:

1. Conduct a field survey of the project area, including cross sections of the coulee.

2. Modify and update existing hydraulic studies of the Lower Mauvais Coulee.

3. Recommend potential road crossing and channel improvements.

4. Test the effects of the proposed improvements using the hydraulic model.

5. Estimate the effects of the proposed improvements on the Chain of Lakes using information derived from the 1991 Chain Lakes Improvement Study.

6. Prepare preliminary cost estimates for the various alternatives; and

7. Prepare a written report documenting the findings of the investigation.

VI. COSTS

The Joint Board shall deposit a total of $2,900 with the Commission to help defray the field costs associated with this investigation.

V. RIGHTS-OF-ENTRY

The Joint Board agrees to obtain written permission from any affected landowners for field investigations by the Commission, which are required for the preliminary investigation.

VI. INDEMNIFICATION

The Joint Board agrees to indemnify and hold harmless the State of North Dakota, the Commission, and any employees or agents of those entities, from all claims for damages to property, rights or persons, as a result of any act or omission by the Joint Board,

its agents, contractors, or employees. In the event a suit is initiated or judgment entered against the State of North Dakota, the Commission, or any of their employees or agents, the Joint Board shall indemnify them for all costs and expenses, including legal fees, and any judgment arrived at or satisfied or settlement entered, to the extent that such cost and expenses are caused by or resulting from any act or omission by the Joint Board, its agents, contractors or employees.

VII. MERGER CLAUSE

This agreement constitutes the entire agreement between the parties. No waiver, consent, modification nor change of terms of this agreement shall bind either party unless in writing, signed by the parties, and attached hereto. Such waiver, consent, modification or change, if made, shall be effective only in the specific instance and for the specific purpose given. There are no understandings, agreements, or representations, oral or written, not specified herein regarding this agreement.

NORTH DAKOTA STATE WATER COMMISSION

By: David A. Sprynczynatyk

DAVID A. SPRYNCZYNATYK
Secretary

WITNESS: Todd Sando

DATE: 6/15/93

DEVILS LAKE BASIN JOINT WATER MANAGEMENT BOARD

By: Benhart A. Varnson

BENHART A VARNSON
Chair

WITNESS:

DATE: 6-3-93

APPENDIX B - RECOMMENDATIONS OF 1980 LOWER MAUVAIS COULEE WATER SURFACE PROFILE STUDY

Recommendations from 1980 Lower Mauvais Coulee Study

Phase One Improvements:

	Item	1980 Cost
1.	Replace the culverts with a bridge on the Normania School Road (Structure #8)	$149,000
1A.	Install a 10-foot diameter culvert from Channel A at the Normania School Road Crossing (Structure #8)	12,500
2.	Snag and clear 3 miles of coulee between Structure #7 and the confluence with Little Coulee	12,000
3.	Develop a pilot path below Pelican Lake.	12,300

Phase Two Improvements:

1.	Perform Phase One improvements	$173,000
2.	Replace Structure #6 Removal only of Structure #6	155,000 10,000
3.	Replace Structure #9 Removal only of Structure #9	151,000 10,000
4.	Replace Structure #14 Removal only of Structure #14	221,000 10,000
5.	Install a 75-foot wide control structure at Lake Irvine	51,000
5A.	Replace Structure #1 and raise the road	230,000
5B.	Remove Structure #1, install a control structure, and raise the road as a dike	114,000
6.	Raise the dikes between Lake Irvine and Highway 2	182,000
7.	Replace the old Highway 2 bridge (Structure #2) Remove the old Highway 2 bridge (Structure #2)	182,000 12,000
8.	Replace Structure #10 (Low Priority)	182,000

Phase Two Improvements (Cont.)

9.	Widen the channel between Structure #11 and Pelican Lake	$ 50,000
10.	Remove the culverts and install a bridge on the Minnewaukan Flats Road (Low Priority)	182,000
11.	Raise Highway 19 and raise Structure #15 (Low Priority)	208,000
12.	Raise Highway 19 and replace Structure #15 (Low Priority)	325,000
13.	Remove Structure #16	6,500

APPENDIX C - SYMBOLS AND ABBREVIATIONS

SYMBOLS AND ABBREVIATIONS

CMP - Corrugated Metal Pipe

msl - mean sea level

cfs - cubic feet per second

USGS - United States Geological Survey

HEC - The Hydrologic Engineering Center

DWOPER - Dynamic Wave Operational Model

LS - Lump Sum

Ac. - Acres

SF - Square Feet

CY - Cubic Yards

SWC - State Water Commission

BIBLIOGRAPHY

1. U.S. Army Corps of Engineers, HEC-2 Water Surface Profiles, September 1982.

2. North Dakota State Water Commission, Lower Mauvais Coulee Water Surface Profile Study, December 1980.

3. North Dakota State Water Commission, Chain Lakes Improvement, September 1991.

4. Olson-Kaufman, Inc., Hydraulic Analysis and Structure, Selection - Bridge No. 102.18.1.

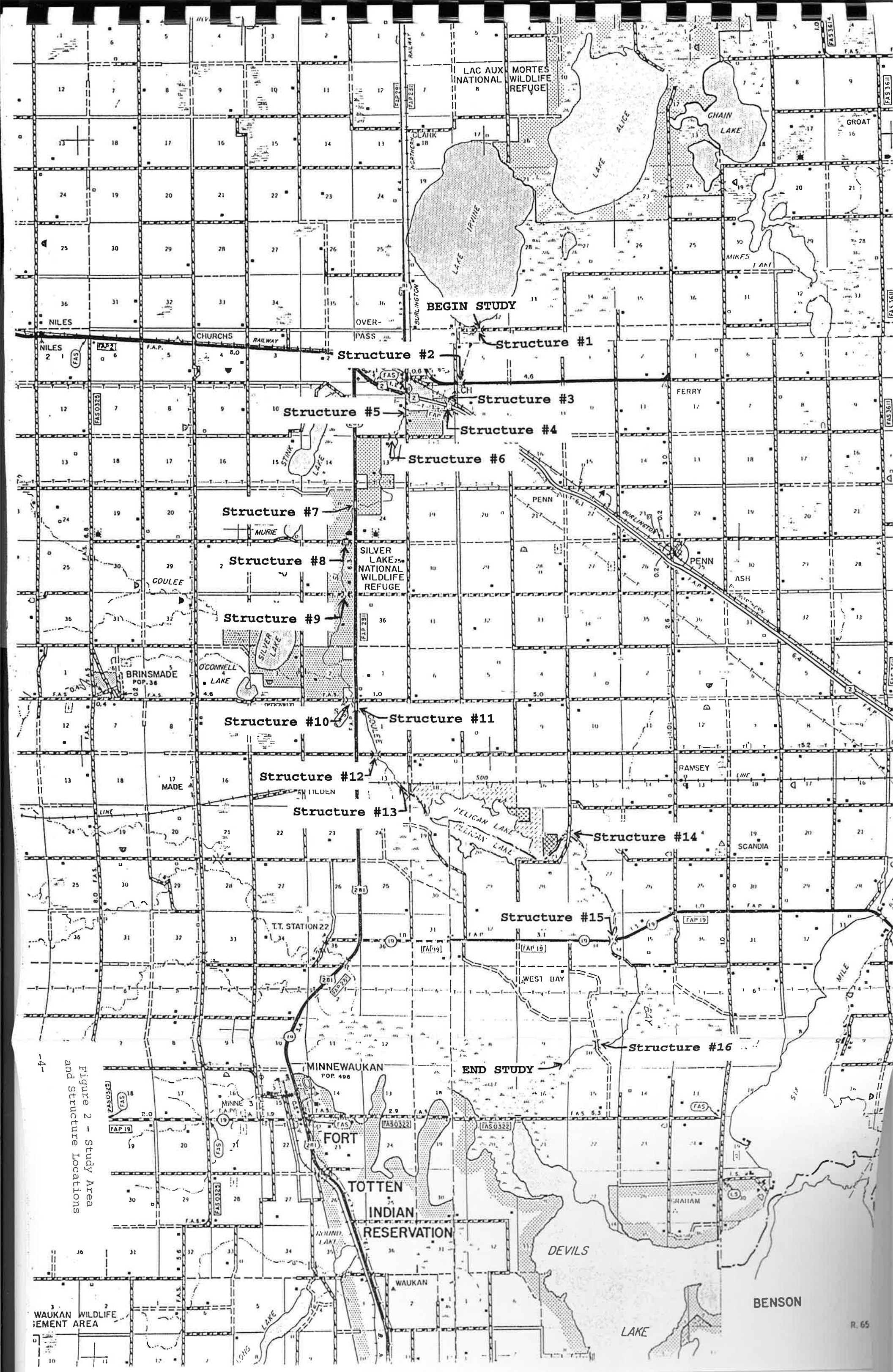


Figure 2 - Study Area and Structure Locations