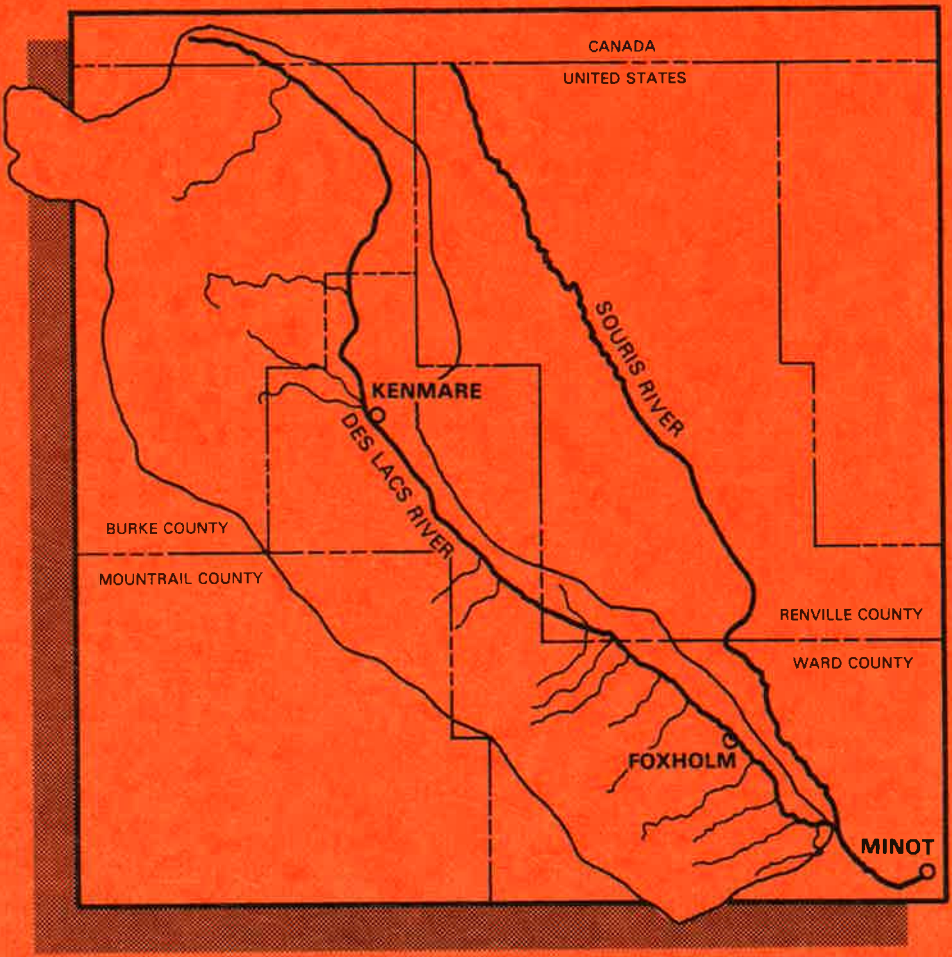
DES LACS RIVER FLOOD CONTROL STUDY

BURKE, WARD, MOUNTRAIL, RENVILLE COUNTIES
NORTH DAKOTA



PRELIMINARY ENGINEERING REPORT
SWC PROJECT NO. 1772
NORTH DAKOTA STATE WATER COMMISSION
APRIL, 1984

PRELIMINARY ENGINEERING REPORT

DES LACS RIVER BASIN STUDY

SWC PROJECT #1772

APRIL, 1984

NORTH DAKOTA STATE WATER COMMISSION
900 EAST BOULEVARD
BISMARCK, NORTH DAKOTA 58505

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SUMMARY

In May, 1983 the North Dakota State Water Commission entered into an agreement with the Ward County Water Resource District to develop a hydrologic model and evaluate flooding problems in the Des Lacs River Basin. A hydrologic computer model was used to estimate discharges on the tributaries and at selected points on the river.

Eight potential dam sites were investigated for their potential to reduce flooding in the basin. It should be pointed out that this report is not proposing that these dams be constructed at this time. If the Water Resource District desires to pursue any particular dam or type of dam, a more detailed investigation would be required.

The dams studied both individually and collectively do not provide a large degree of flood protection. The study shows that several dams would be required to reduce the flood peaks significantly. The following results pertain to the placement of dam sites.

1. Dams placed north of the Des Lacs Refuge would have little downstream effect due to the combined capacity of the refuge reservoirs.
2. Dams placed in the middle portion of the basin provide the greatest flood reduction. This is due to timing of flow from the tributaries being fairly close to the timing of the Des Lacs River.
3. In the lower portion of the basin, the peak flows from Tasker, Lloyds, and Larson Coulees were slightly ahead of the main stem peak. This would lessen the flood reduction benefit of dam sites.

In addition, it appears that dams constructed in the upper areas of the tributaries may be more cost effective than the larger dams located on the downstream end of the tributaries. For example, upstream and downstream dams were studied on Flaten Coulee, in the Carpio area. A dam site on the upstream end of the coulee reduced the 100-year flood peak at Foxholm by 7%, with a cost of approximately $305,000. The downstream dam reduced the peak by 12%, but the cost increased to $1.3 million. Overall, the results of the study provide an estimate of the costs and benefits that could be expected from dams of various sizes and locations.

A review was made of the impact of drainage in the basin. Although, the study showed that drainage could result in an increase in peak flows, it is unlikely that significant increases have occurred as a result of drainage.

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I. INTRODUCTION

The Des Lacs River has a history of flood problems. The lower Des Lacs River has several steep coulees that enter the river from the west and cause extensive agricultural flooding. In addition, minor urban flooding is experienced. There has been considerable speculation as to the measures that can be taken to decrease the flooding in the basin.

On May 6, 1983, the North Dakota State Water Commission entered into an agreement with the Ward County Water Resource Board. The purpose of this agreement was to develop a hydrologic computer model of the Des Lacs River Basin. This model would be capable of analyzing the general flooding problems in the basin as well as evaluating potential water projects. A copy of the agreement is included in Appendix A.

The dams evaluated in this study were selected to provide a general analysis of different projects in terms of size, type, and location. The basin has the potential for the construction of several other dams in addition to those included in this report.

II. DESCRIPTION OF THE BASIN

A. Location and Size

The Des Lacs River, a tributary of the Souris River, has a total drainage area of 1,042 square miles. The headwaters of the river are in southern Saskatchewan. The Basin includes portions of Burke, Renville, Mountrail and Ward Counties in North Dakota. Figure 1 is a general location map of the Des Lacs River Basin.

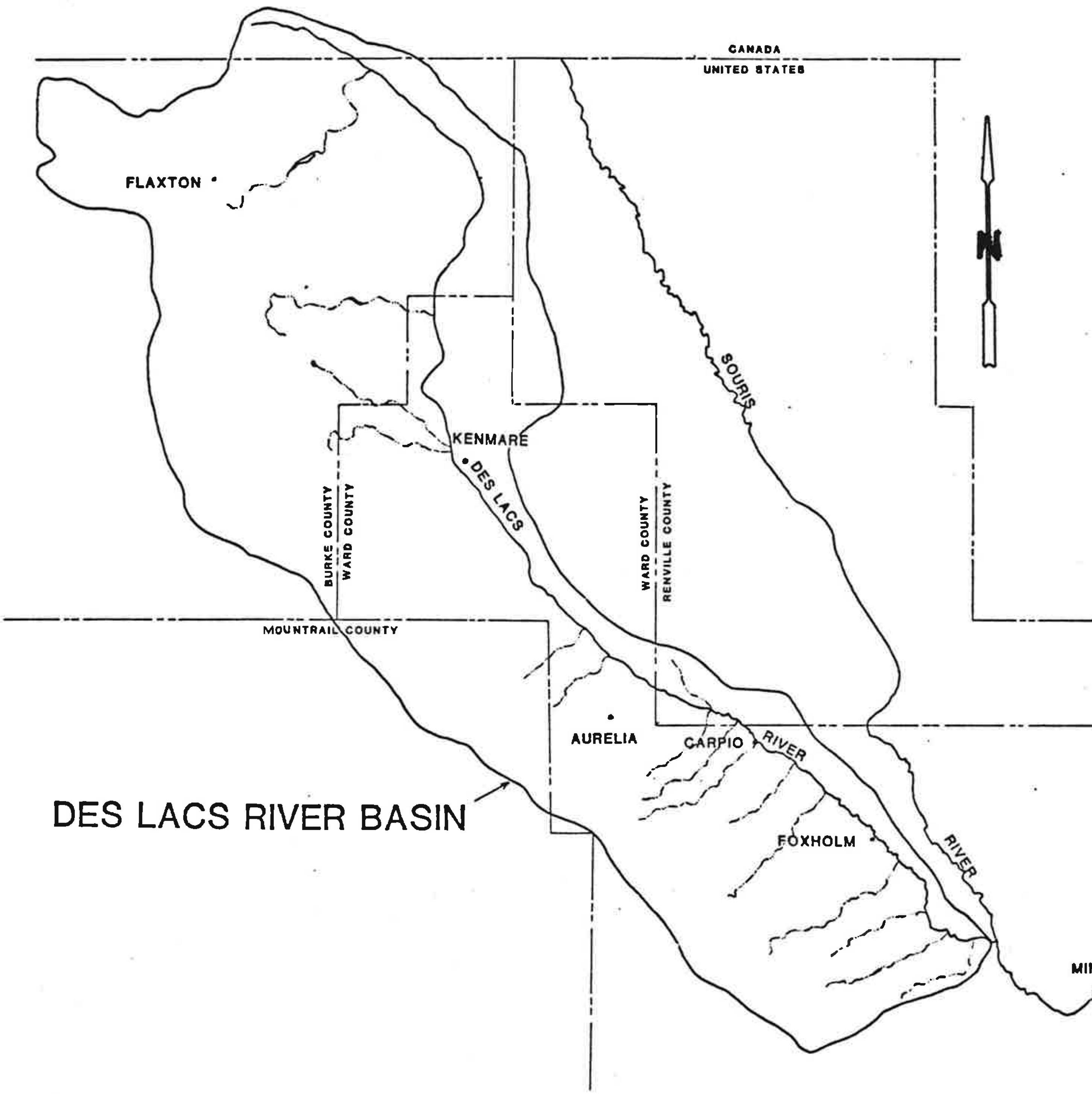
B. Geology and Topography

Ground moraine "pothole areas" and the broad river valley is characteristic of the Des Lacs River Basin. The soil consists mainly of well-drained loams and clay loams which are gently undulating. The southwest drainage divide follows a band of dead-ice moraines, with the basin having surficial glacial deposits which contain a broad pattern of meltwater channels.

Generally, the upper reaches of the tributary streams have the major concentration of potholes. Many pothole areas are considered as non-contributing due to their lack of an outlet. The downstream segments of the tributaries have steep, well defined channels. This causes flooding to occur extremely fast from both rapid snowmelt and summer thunderstorms.

C. Climate

The Des Lacs River Basin climate is characterized by extreme variations in temperature, variable rainfall and moderate snowfall. Records of the National Weather Service show that temperatures have varied from



General Location Map
Figure 1

the lows in -50°F to highs in 110°F range. Annual mean temperature is 39°F. Annual precipitation averages 15.5 inches. The mean precipitation ranges from a minimum of 0.4 in February to a maximum of 3.4 in June. The average annual snowfall is 33 inches.[1/]

D. Flooding Problems

Almost every year the Des Lacs River overflows its banks to some extent. Most floods are small and short in duration.[2/] Severe floods have occurred in spring of 1949, 1969, 1970, 1975, 1976, and 1979. Flooding can also occur in the area of blocked culverts or storm drains during periods of severe rainfall because of steep valley walls.[3/]

Only a few studies have been completed on flood problems in the basin. The Federal Emergency Management Agency has completed Flood Insurance Studies for the Cities of Burlington, Donnybrook, Carpio, and the unincorporated areas of Ward County. The U.S. Army Corps of Engineers have studied the lower Des Lacs River from Foxholm to the mouth in conjunction with Burlington Dam investigations.

1/ U.S. Army Corps of Engineers, Flood Control Lake Darling, Design Memorandum No. 3.

2/ North Dakota State Water Commission, 1983 State Water Plan.

3/ Federal Emergency Management Agency, Flood Insurance Study of Ward County.

III. EXISTING WATER PROJECTS

Several water projects have been constructed in the Des Lacs River Basin. Figure 2 shows the location of the larger projects. Below is a brief description of these projects:

A. Northgate Dam

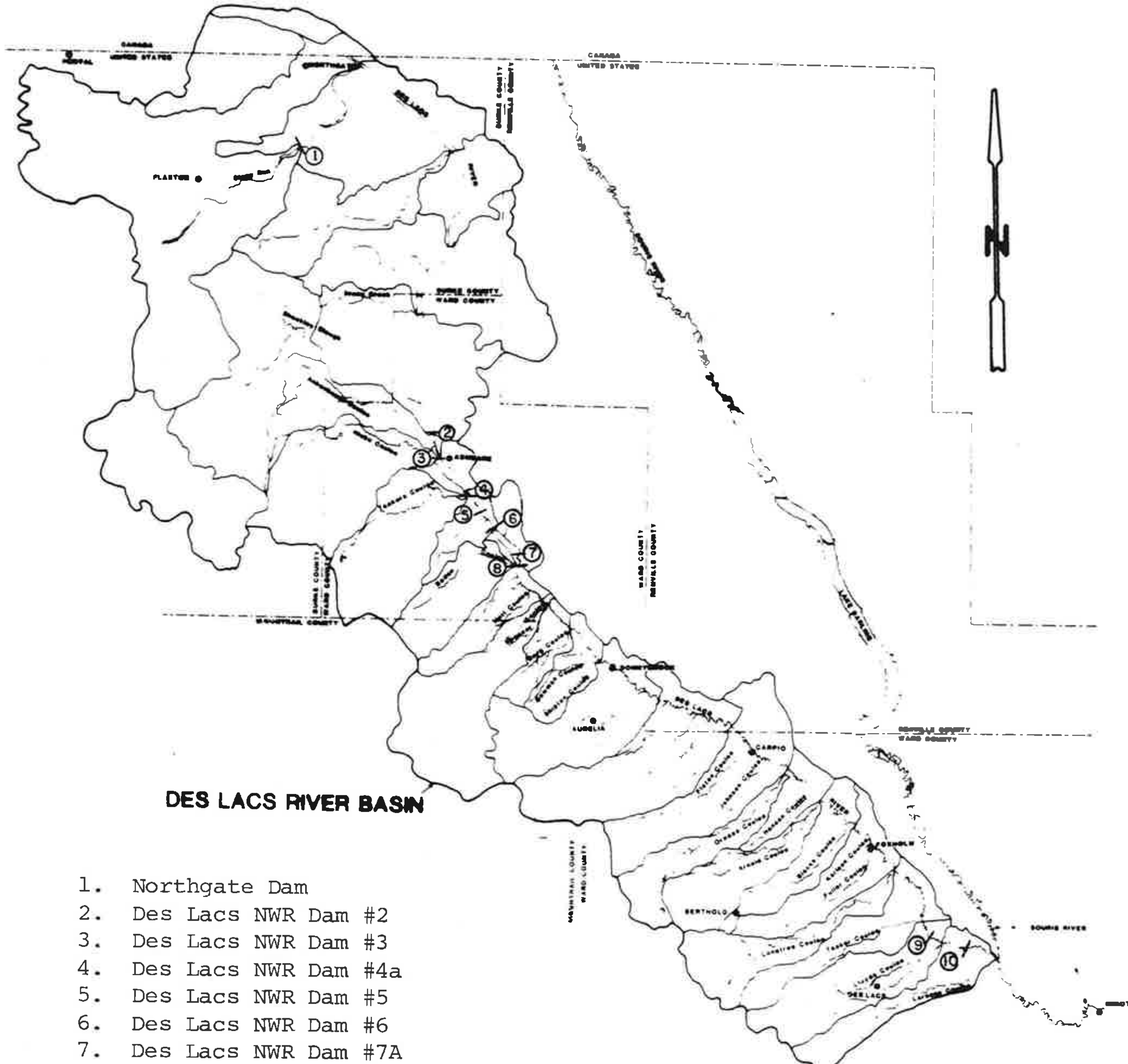
Northgate Dam is located in Section 19, Township 163 North, Range 89 West, on Stony Run Creek in northeastern Burke County. The City of Northgate is located approximately four miles north of the dam site. The dam was built in 1968 exclusively for recreation. The dam is 38 feet high with a storage capacity of 1,480 acre-feet at the control elevation.

B. Des Lacs National Wildlife Refuge Dams

The refuge is located in Ward and Burke Counties along the Des Lacs River. In 1935, the refuge was established for the restoration, development, and preservation of migratory waterfowl habitat. The dams are identified by number as 2, 3, 4A, 5, 6, 7A, and 8, with #2 the farthest north and #8 the most downstream. General characteristics of the dams are a earthfill embankment, uncontrolled weir spillway, and stop log structures to regulate approximately the top 2 feet of each reservoir. The average height of the dams above the flood plain is 4 feet, with the exception of #2, which is higher.[1/] The mean water depths range from 1.1 to 8.1 feet. The reservoirs have a combined capacity of 47,000 acre-feet and, as a result, have a strong influence on the Des Lacs River from the upper watersheds.[2/]

1/ North Dakota State Water Commission, Dam Safety Report, Northgate Dam.

2/ U.S. Army Corps of Engineers, Burlington Dam.



1. Northgate Dam
2. Des Lacs NWR Dam #2
3. Des Lacs NWR Dam #3
4. Des Lacs NWR Dam #4a
5. Des Lacs NWR Dam #5
6. Des Lacs NWR Dam #6
7. Des Lacs NWR Dam #7A
8. Des Lacs NWR Dam #8
9. Burlington Dam #2
10. Burlington Dam #1

Existing Water Projects
Figure 2

C. Burlington Dam No. 1

Burlington Dam No. 1 is located on the Des Lacs River about two miles northwest of Burlington, along the north side of U.S. Highway 2 and 52. The dam built in 1936 was initially constructed for irrigating lands in the Burlington Project area. The dam is 21 feet high and has maximum pool storage of 567 acre-feet.[1/]

D. Burlington Dam No. 2

Burlington Dam No. 2 is located on the Des Lacs River about 3.5 miles northwest of Burlington, along the north side of U.S. Highway 2 and 52. The dam built in 1938 was constructed to provide additional water for irrigation. This was to supplement Burlington Dam No. 1's water supply during a drought year. Today, irrigation is minimal with it being used for its recreational value. The dam is 24 feet above the streambed and has a maximum pool storage of 487 acre-feet.[2/]

1/ U.S. Army Corps of Engineers, Burlington Dam No. 1.
2/ U.S. Army Corps of Engineers, Burlington Dam No. 2.

IV. EXISTING STREAM GAGING DATA

Existing stream gaging data in the Des Lacs River Basin is currently collected at only one station - the Des Lacs River at Foxholm. This continuous gage has approximately 40 years of record (1905-06, 1946-present). Two crest stage stations were operated on tributaries from 1957-1973. The crest stage stations only provided peak flows for each year of record. The U.S. Fish and Wildlife Service records lake elevations on the refuge pools. These records are primarily collected during low flow periods. The staff gages are normally overtopped during flood periods.

Table 1 presents Log-Pearson Type III flow frequencies for the Des Lacs River at Foxholm and the two tributary gages. The highest recorded flood peak on the Des Lacs River at Foxholm was 4260 cubic feet per second on April 19, 1979. The 1979 flood was caused by a rapid snowmelt.

Figure 3 is a hydrograph plot of the three high floods on the Des Lacs River at Foxholm, 1969, 1970, and 1979. The day of peak was centered on the same day for each year. The three hydrographs all show a rather high initial peak discharge and a lower extended flow resulting from releases from the U.S. Fish and Wildlife Service Refuges.

Table 2 lists the annual peak discharge, the 30-day high volume and the annual volume of flow on the Des Lacs River at Foxholm. The highest volume year was 1976 with over 107,000 acre-feet flowing past Foxholm. A frequency analysis of the 30-day high volume flood for the Des Lacs River at Foxholm is shown in Table 3.

TABLE 1 - DES LACS RIVER BASIN
STREAM GAGE PEAK DISCHARGE FREQUENCIES

Stream Gage	Frequency 10-Year (cfs)	25-Year (cfs)	50-Year (cfs)	100-Year (cfs)
Des Lacs River at Foxholm (51 Years - Drainage area: 944 sq. mi.)	2,000	3,100	4,100	5,200
Des Lacs River Tributary near Donnybrook (Drainage Area: 3.8 sq. mi. Record: 18 years)	175	250	300	*_____
Fuller Coulee at Foxholm (Drainage Area: 12.8 sq. mi. Record: 19 Years)	250	400	500	*_____

*Insufficient record length to estimate.

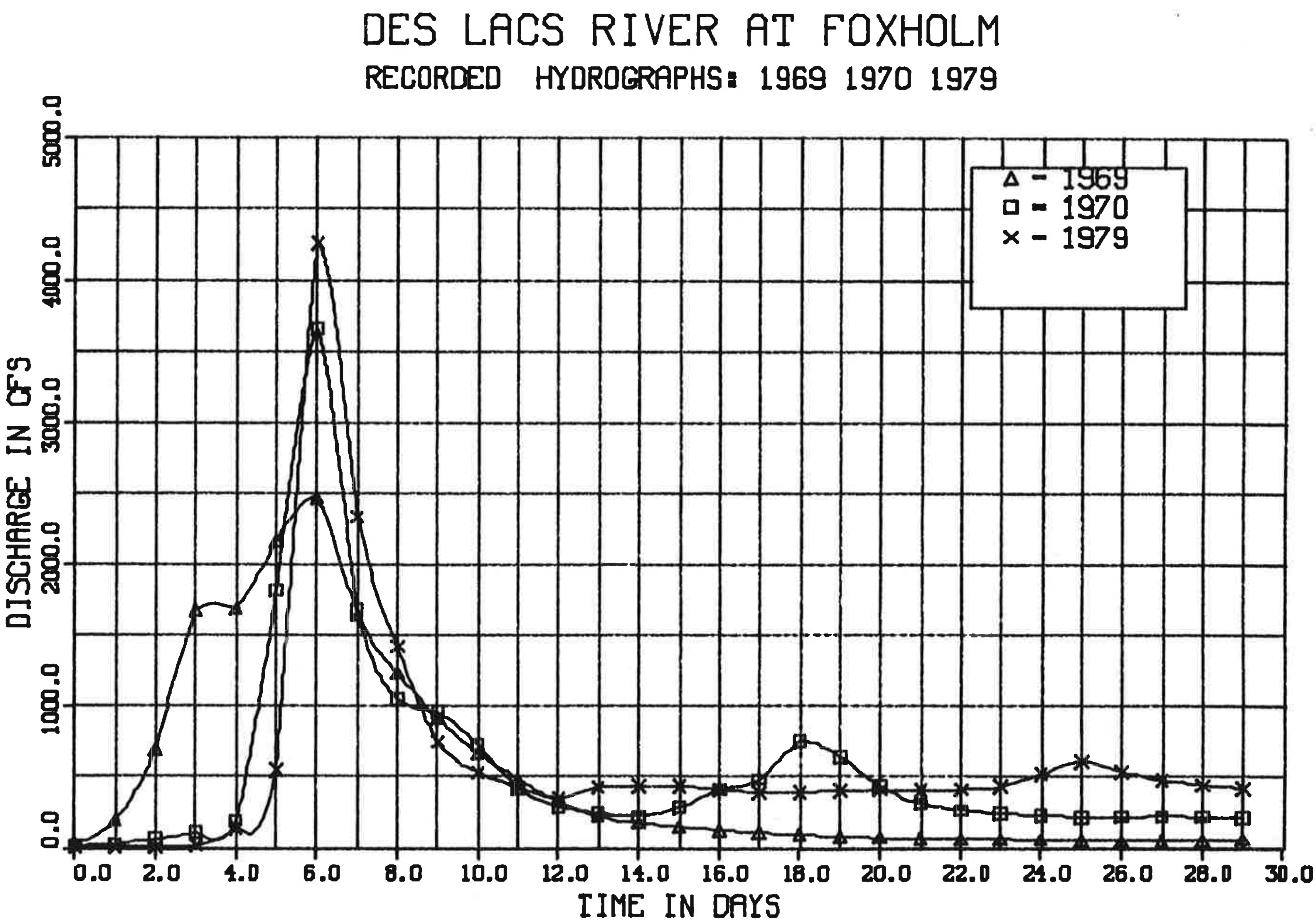

DES LACS RIVER AT FOXHOLM
RECORDED HYDROGRAPHS: 1969 1970 1979
DISCHARGE IN CFS
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
TIME IN DAYS
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
△ - 1969
□ - 1970
× - 1979

Figure 3

TABLE 2 - DES LACS RIVER AT FOXHOLM
STREAM GAGE DATA SUMMARY

Year	Peak Discharge (cfs)	30-Day High Volume (acre-feet)	1 Year Volume (acre-feet)
1905	100	1,200	3,300
1906	350	3,600	6,700
1939	1,220	-	-
1946	113	2,000	2,500
1947	640	8,700	11,600
1948	505	13,600	20,300
1949	2,000	21,500	29,000
1950	1,010	17,300	34,000
1951	1,800	26,400	45,600
1952	850	11,800	16,700
1953	775	8,800	15,900
1954	205	3,300	12,300
1955	900	11,500	29,700
1956	696	10,100	31,100
1957	150	1,700	3,900
1958	430	4,700	5,140
1959	105	1,000	1,700
1960	1,020	18,200	21,700
1961	25	400	600
1962	50	500	900
1963	934	6,100	8,700
1964	355	3,400	5,900
1965	406	5,400	12,300
1966	250	3,300	9,400
1967	530	4,300	5,700
1968	85	900	2,000
1969	2,460	30,800	52,800
1970	3,660	33,300	63,000
1971	193	3,200	8,000
1972	1,030	19,800	60,800
1973	529	3,700	14,500
1974	650	17,100	47,800
1975	2,670	44,600	89,000
1976	1,550	49,800	107,100
1977	42	700	2,100
1978	700	1,500	10,100
1979	4,260	38,000	60,800
1980	230	2,400	9,400
1981	580	4,600	6,400
1982	100	11,800	19,500
1983	350	10,500	23,900

TABLE 3 - DES LACS RIVER AT FOXHOLM
Volume of Frequencies

Frequency	30-Day Volume (acre-feet)
5 year	18,300
10 year	29,600
25 year	48,000
50 year	64,400
100 year	83,000

V. STUDY APPROACH

A. General

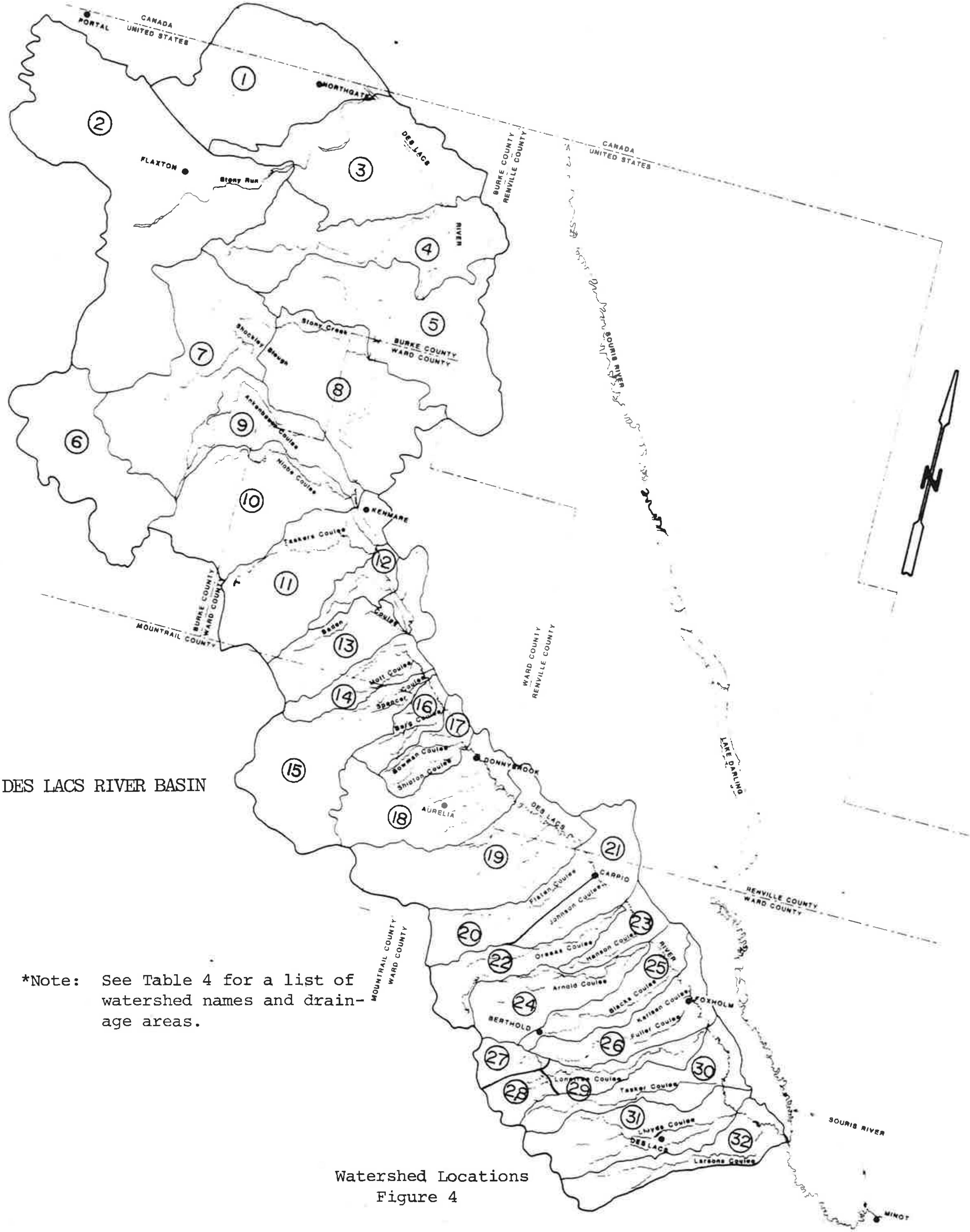
A numerical model using the Corps of Engineers Computer Program HEC-1, Flood Hydrograph Package was used to develop flow hydrographs in the Des Lacs River Basin. A hydrograph is a representation of the distribution of flow with respect to time. The HEC-1 model has several options available for hydrograph development, loss rate computation and routing procedures. This study utilized the Synder Unit hydrograph, the SCS Curve Number Loss Rate and the Muskingum routing methods.

B. Model Development for Existing Conditions

The Des Lacs River Basin was divided into over 30 separate subbasins. Figure 4 shows the subbasins included in the model. Table 4 lists the subbasins and the drainage area of each subbasin and the Des Lacs River at selected locations. Hydrographs were developed for each of the subbasins and at several points along the Des Lacs River.

The Muskingum routing method was used to simulate flood-flow movements from one river reach to the next. Reach travel times were estimated based on information provided by the National Weather Service on flow movements. Table 5 shows the time of the peak discharge at locations along the Des Lacs and Souris River. This information, during the 1979 spring flood also correlates to information available on the 1969 Des Lacs River flood.

DES LACS RIVER BASIN



*Note: See Table 4 for a list of watershed names and drainage areas.

Watershed Locations
Figure 4

TABLE 4 - DRAINAGE AREAS
OF TRIBUTARIES AND DES LACS RIVER

No.	Watershed	Drainage Area Sq. Mi.	Drainage Area Des Lacs River Sq. Mi.
1.	Northgate & Canada	57.7	57.8
2.	Northgate Dam	123.8	181.6
3.	Stony Run	54.3	235.9
4.	Unnamed Watershed 21, 22-162-88	50.5	286.4
5.	Nine Mile Corner	60.3	346.7
6.	Thompson Lake	42.6	
7.	Shockley Slough	57.1	
8.	Stony Creek	55.4	501.8
	Dam #2		501.8
9.	Ankenbauer Coulee	23.3	525.1
10.	Niobe Coulee	43.9	569.0
	Dam #3 Kenmare		569.0
11.	Taskers Coulee	42.3	611.3
	Dam #4A		611.3
12.	Dam #6	16.4	627.7
	Dam #7A		
13.	Baden Coulee	21.7	649.4
	Dam #8		649.4
14.	Mott Coulee	14.1	663.5
15.	Spencer Coulee	42.0	705.5
16.	Berg Coulee	9.8	715.3
17.	Bowman-Shipton Coulee	12.0	727.3
	Donneybrook		727.3
18.	Aurelia	38.0	765.3
19.	Carl Feldner	48.2	813.5
20.	Flaten Coulee	20.3	833.8
	Carpio		833.8
21.	Johnson Coulee	18.7	852.5
22.	Oleaas Coulee	18.4	870.9
23.	Hanson Coulee	9.6	880.5
24.	Arnold Coulee	22.6	903.1
25.	Blacks Coulee	18.0	921.1
26.	Karlsen-Fuller Coulee	22.7	943.8
	Foxholm		943.8
27.	Lonetree Trib. Dam	6.9	
28.	Lonetree Trib.	7.7	
29.	Lower Lonetree Coulee	10.7	969.1
30.	Tasker Coulee	23.0	992.1
31.	Lloyds & Kandolph Coulees	30.0	1022.1
32.	Larsons Coulee	20.4	1042.5
	Confluence with Souris River		1042.5

TABLE 5 - 1979 PEAK DISCHARGE TIMES

Location	Time of Peak
Des Lacs River at Donnybrook	April 18, 1979 - 8:00 P.M. (±2 hrs.)
Des Lacs River at Carpio	April 19, 1979 - 1:00 A.M. (±2 hrs.)
Des Lacs River at Foxholm	April 19, 1979 - 8:00 A.M.
Des Lacs River Peak at Minot	April 20, 1979 (Early A.M.)

The Des Lacs River at Foxholm stream gage was the primary station used to calibrate the computer model. A log-Pearson Type III statistical analysis of the stream gage data provided flows for the 10, 25, 50 and 100-year flood peak discharges (See Table 1). The model results were compared with the gage data and small adjustments to model inputs were made to reproduce log-Pearson peak discharges.

Once the hydrologic model was calibrated, there were 55 reference points in the Des Lacs River Basin at which specific information was available. The available information at each point includes contributing drainage area, peak discharge, volume of runoff and the discharge flood hydrograph.

C. Model Development For Tributary Dam Analysis

After the model was developed for existing conditions, several potential dam projects were added to the model. This provided flow hydrographs with and without the dams at locations below each dam site.

The dam sites were selected to provide an areal distribution of the projects as well as a variety of sizes. This provided for a comparison of costs and flood benefits for different types of dams. It was not the intent to include enough dams to control a particular size flood. The different types of dams studied provided an indication of the more feasible dam locations, and the flood reductions that could be anticipated with various projects.

All dams were considered as dry dams for flood control purposes. The dams would contain water only during flood periods.

The dams included in this analysis were located on tributaries to the Des Lacs River and not on the main stem. Main stem dams would require detailed design and were considered beyond the scope of this study. The general criteria for locating the dams were:

1) No farmsteads could be inundated by the reservoir pool area.
2) No county or farm to market road could be closed.
3) A dam 30 feet or higher must have the capability to contain a 100-year snowmelt flood without passing water through the emergency spillway. Dams less than 30 feet high must contain the 50-year flood.

For dam safety purposes, dams located above a city or farmsteads were designed more conservatively. These dams were designed with flatter side slopes and rock riprap was included for the entire upstream face of the dam. These dams would also be required to pass a probable maximum precipitation flood without overtopping. A grassed emergency spillway was used to pass the large floods. Detailed design studies would be required before a high hazard dam could be constructed.

For dams less than 30 feet high, minimal riprap was included in the cost estimate. In addition, corrugated metal pipes and side slopes of 3:1 upstream and 2:1 downstream were used.

Land costs were considered separately. The land for the dam, emergency spillway, and sediment pool areas were assumed to be purchased at a cost of $500 per acre. Flood easements were assumed to be suitable for an area of 1.5 times the flooded area at the emergency spillway pool elevation. Flood easements were estimated at $300 per acre.

VI. STUDY RESULTS

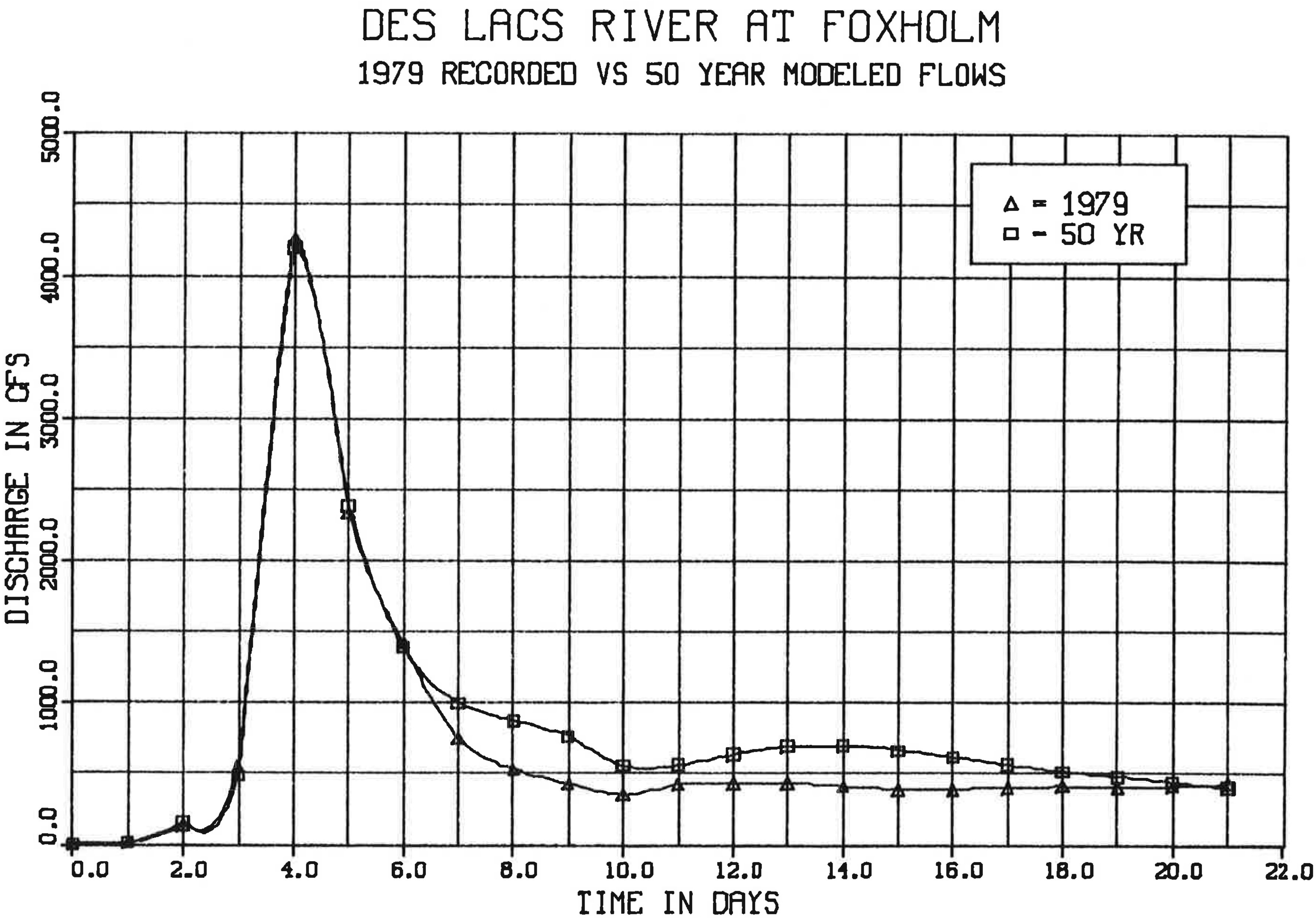
A. Model Results For Existing Conditions

The initial step in the model development was to calibrate the HEC-1 model. The 1979 flood was the most recent and largest recorded flood and, therefore was used as the base flood for calibration. A statistical analysis of records on the Des Lacs River at Foxholm determined that the 1979 flood was a 50-year event. Figure 5 compares the 1979 recorded flood with the 50-year modeled flood. The second step in the existing conditions model was to modify the precipitation volumes to correspond with the 10, 25, 50 and 100-year peak flows for the Des Lacs River at Foxholm.

After the model was calibrated to the Foxholm stream gage, peak discharges were determined for other points along the Des Lacs River. Table 6 shows different frequency discharges for the Des Lacs River at the United States/Canadian border, at Donnybrook, Carpio, Foxholm and at the confluence with the Souris River.

TABLE 6 - DES LACS RIVER FREQUENCIES

Des Lacs River	Peak Discharge Frequency			
Location	10-Year (cfs)	25-Year (cfs)	50-Year (cfs)	100-Year (cfs)
Near Canadian Border	200	300	400	500
Donnybrook	680	1,080	1,480	1,850
Carpio	1,320	2,050	2,760	3,420
Foxholm	2,000	3,100	4,200	5,200
Souris River Confluence	2,500	3,900	5,250	6,500



DES LACS RIVER AT FOXHOLM
1979 RECORDED VS 50 YEAR MODELED FLOWS
Δ = 1979
□ - 50 YR
DISCHARGE IN CFS
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
TIME IN DAYS

Figure 5

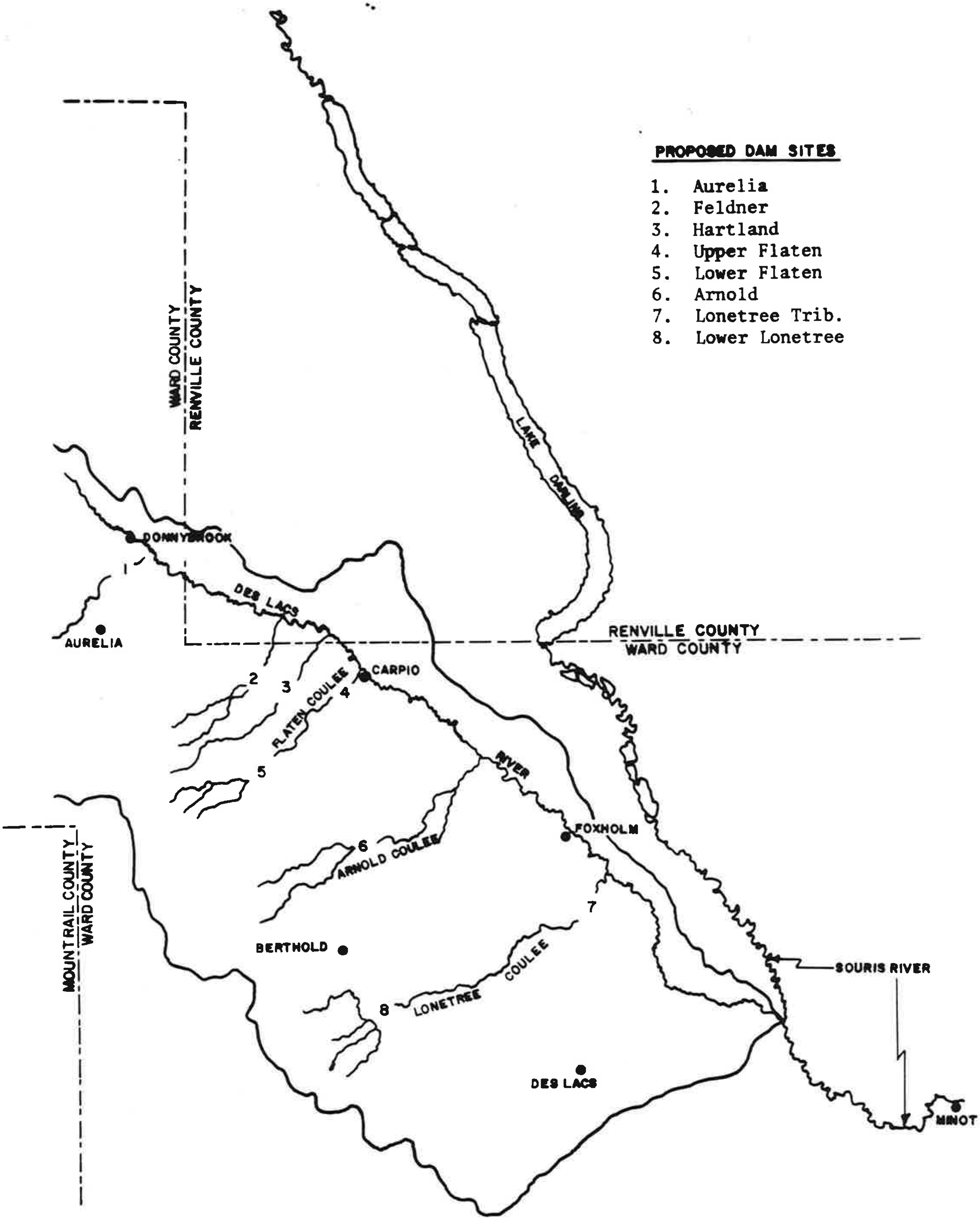
The refuge pools, although not constructed or operated for flood control, do provide flood benefits to the lower Des Lacs River. The upstream coulees in the Des Lacs River are not as steep as the lower basin coulees and, therefore, a double peak (the 2nd being smaller than the first) would naturally occur. The combined refuge pools have a large storage capacity and this results in a greater separation of the peaks and a significant decrease in the magnitude of the second peak.

B. Model Results For Tributary Dams

Eight dams were included in the final analysis. The locations of these dams are shown on Figure 6. Several other dams were studied but were not included due to a variety of reasons. Since the lower Des Lacs River peak results from the coulees below the Fish and Wildlife Refuges, dams north of the refuges had little downstream benefit. In addition, the tributaries in the lower Des Lacs River basin (namely Tasker, Lloyds and Larson Coulees) were slightly ahead of the main-stem peak. Therefore, less reduction in flood flows from these areas was noted than from tributaries in the middle watershed areas. The eight dams shown in this study are all located on coulees and tributaries between Donnybrook and the Lonetree-Berthold area.

Summary statistics on each site are shown in Table 7. Area-capacity curves, individual site location maps and cost estimates for each dam are shown in Appendices A, B, and C, respectively.

The impact on peak discharges on the Des Lacs River at Foxholm and at the Souris River confluence is shown in Tables 8 and 9, respectively. These tables show that Lower Flaten Dam has the largest flood-flow reduction. However, the cost of this project is also very high.



Potential Dam Site Locations
Figure 6

TABLE 7 - STATISTICS SUMMARY OF
POTENTIAL DAM SITES

Name	Location S-T-R Ward Co.	Drainage Area (sq. mi.)	Dam Height (feet)	Top of Dam Elev. (feet)	Emergency Spillway Elev. (feet)	Pipe Size & Type (inches)	Storage at Emergency Spillway (acre-feet)	Acreage at Emergency Spillway (acres)		Cost
Aurelia	NW23-158-87	3.5	34	1,832.0	1,827.0	24" RCP	190	13.2	Dam Land	$ 124,400 6,700 $ 131,100
Feldner	SW 4-157-86	4.7	42	1,922.0	1,917.0	24" RCP	280	19.8	Dam Land	$ 129,500 9,500 $ 139,000
Hartland	NE16-157-86	6.9	44	1,962.0	1,957.0	24" RCP	580	57	Dam Land	$ 284,765 26,900 $ 311,665
Upper Flaten	SE15-157-86	13.5	55	1,935.0	1,929.0	24" RCP	930	58.2	Dam Land	$ 291,000 27,200 $ 318,200
Lower Flaten	SW12-157-86	20.3	83	1,816.0	1,810.0	24" RCP	1,775	61.0	Dam Land	$1,327,898 28,700 $1,356,598
Arnold	NW 1-156-86	18.1	65	1,915.0	1,910.0	30" RCP	1,310	71.5	Dam Land	$ 270,200 34,000 $ 304,200
Lonetree Trib.	SW34-156-86	6.9	15	2,076.0	2,072.0	30" CMP	460	111.6	Dam Land	$ 32,100 50,500 $ 82,600
Lower Lonetree	SW12-156-84	25.3	70	1,722.0	1,716.0	30" RCP	2,050	85	Dam Land	$ 796,800 92,500 $ 889,300

TABLE 8 - PEAK DISCHARGES ON DES LACS RIVER AT FOXHOLM
WITH INDIVIDUAL TRIBUTARY DAMS

	PEAK DISCHARGE (cfs)								
		PROJECT NAME							
Frequency	Existing Conditions (no dams)	Aurelia Dam	Feldner Dam	Hartland Dam	Upper Flaten Dam	Lower Flaten Dam	Arnold Dam	Lonetree Trib. Dam	Lower Lonetree Dam
10 Year	1,980	1,960	1,965	1,940	1,875	1,800	1,910	1,980	1,980
25 Year	3,100	3,060	3,060	3,020	2,900	2,790	2,945	NA	NA
50 Year	4,180	4,130	4,130	4,070	3,910	3,750	3,960	4,180	4,180
100 Year	5,200	5,130	5,105	5,035	4,850	4,640	4,890	5,200	5,200

TABLE 9 - PEAK DISCHARGES ON DES LACS RIVER AT SOURIS RIVER CONFLUENCE WITH INDIVIDUAL TRIBUTARY DAMS

	PEAK DISCHARGE (cfs)								
		PROJECT NAME							
Frequency	Existing Conditions (no dams)	Aurelia Dam	Feldner Dam	Hartland Dam	Upper Flaten Dam	Lower Flaten Dam	Arnold Dam	Lonetree Trib. Dam	Lower Lonetree Dam
10 Year	2,505	2,490	2,490	2,465	2,410	2,340	2,415	2,480	2,405
25 Year	3,880	3,855	3,840	3,805	3,725	3,610	3,705	3,830	3,695
50 Year	5,235	5,195	5,175	5,125	5,020	4,870	4,960	5,165	4,950
100 Year	6,480	6,430	6,395	6,335	6,215	6,030	6,125	6,385	6,100

In order to relate the cost of each project with flow reduction, a comparison was developed between the cost of each project and the flow reduction achieved by each individual project (Table 10). Based on this comparison, Upper Flaten and Arnold Dams have the lowest cost per unit of flow reduction on the Des Lacs River. This technique does not replace the need of a more detailed benefit-cost analysis. If it is desired to pursue any one of the projects, a detailed analysis should be made to determine the benefits on the Des Lacs and Souris Rivers.

Three plans were analyzed to determine the cumulative effect of multiple projects. Plan 1 consisted of Arnold and Upper Flaten Dams. Plan 2 added the Lonetree Tributary dam to Plan 1, and Plan 3 added Feldner Dam to Plan 2. The cumulative impact of these plans are in Table 11. Figure 7 is a comparison of the 50-year hydrograph for the Des Lacs River at Foxholm with and without the Plan 3 dams.

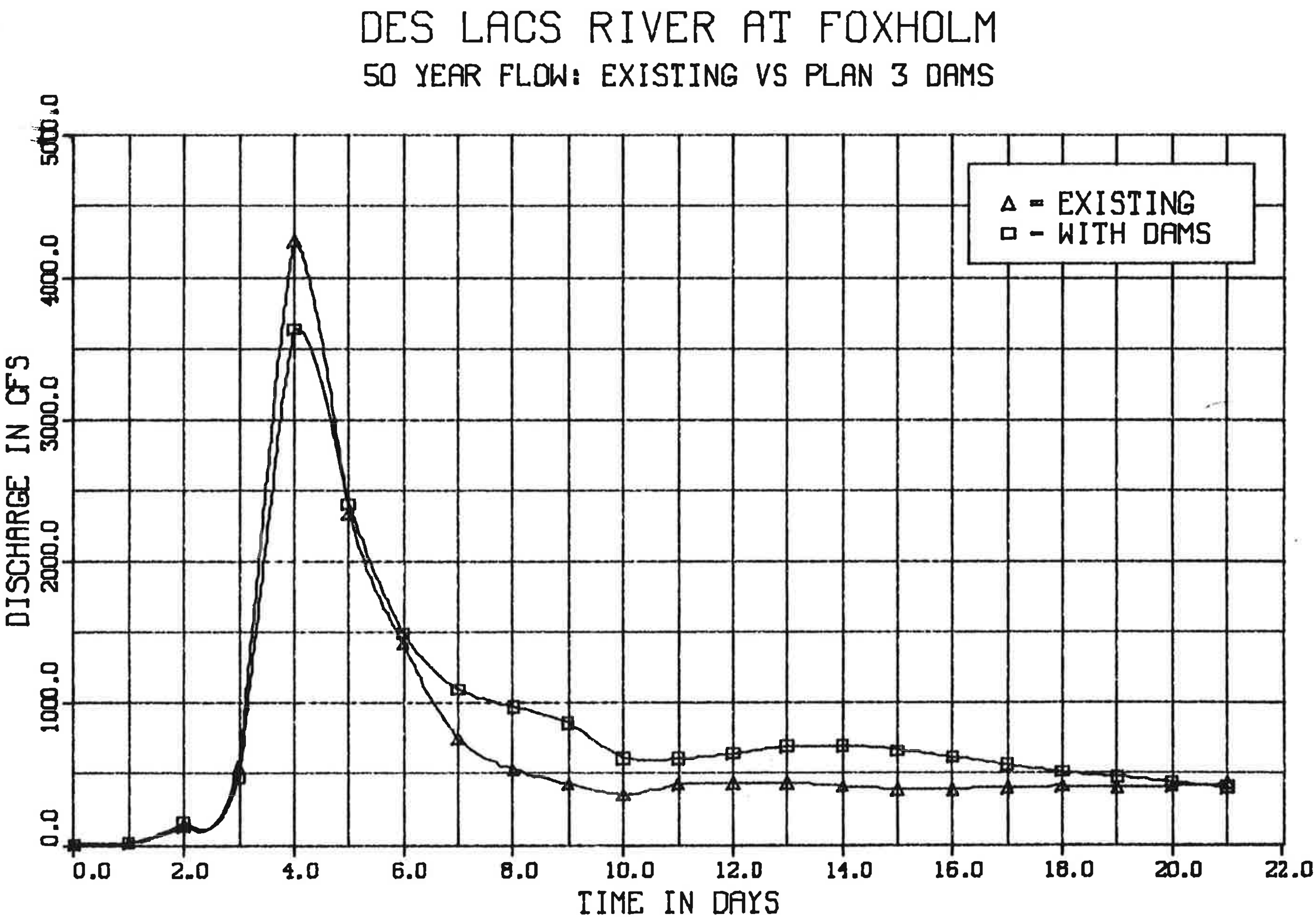
The results show a rather low reduction in overall flooding on the Des Lacs River due to one to four dams. The reason is due to the large number of small coulees that influence the flooding on the Des Lacs River. At the Souris River confluence, the Des lacs River has a contributing drainage area of 900 square miles. Plan 3 with four dams, only controls 43.2 square miles, or 4.8% of the total watershed. The decrease in peak discharge for Plan 3 ranges from 9% for the 10-year to 13% for the 100-year flood. While this indicates that certain coulees have a greater influence on flooding than others, the results also show that several dams would be required to decrease flooding by 25-50%.

TABLE 10 - COST VS FLOW REDUCTION
TRIBUTARY DAMS
50-YEAR FLOOD

Project Name	Project Cost $	Project Cost ($1,000) For 1 cfs Flow Reduction	
		Des Lacs River At Foxholm	Des Lacs River At Souris River Mouth
Aurelia Dam	$ 131,000	2.6	3.3
Feldner Dam	139,000	2.6	2.3
Hartland Dam	312,000	2.8	2.8
Upper Flaten Dam	318,000	1.2	1.5
Lower Flaten Dam	1,356,600	3.1	3.7
Arnold Dam	304,000	1.4	1.1
Lonetree Tributary Dam	83,000	-	1.2
Lower Lonetree Dam	889,000	-	3.1

TABLE 11 - PEAK FLOW BY FREQUENCIES WITH MULTIPLE DAM PROJECTS

	DES LACS RIVER AT FOXHOLM (cfs)				DES LACS RIVER AT SOURIS RIVER CONFLUENCE (cfs)			
Plan Number	10 Year	25 Year	50 Year	100 Year	10 Year	25 Year	50 Year	100 Year
Existing	1,982	3,094	4,182	5,193	2,504	3,879	5,234	6,478
Plan 1 (Arnold & Flaten Dam)	1,808	2,755	3,688	4,544	2,324	3,541	4,736	5,836
Plan 2 (Plan 1 plus Lonetree Trib. Dam)	1,808	2,755	3,688	4,544	2,302	3,501	4,666	5,741
Plan 3 (Plan 2 plus Feldner Dam)	1,803	2,730	3,633	4,567	2,287	3,467	4,607	5,658


DES LACS RIVER AT FOXHOLM
50 YEAR FLOW: EXISTING VS PLAN 3 DAMS
△ = EXISTING
□ - WITH DAMS
DISCHARGE IN CFS
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
TIME IN DAYS
Figure 7

C. Impacts of Drainage

The Des Lacs River is characterized by a main peak flow from the steep coulee areas and a rather long sustained recession flow from the upper watershed areas. The lower portions of these coulees have very few natural wetlands or potholes and, therefore, drainage is not a factor. However, the upper portions of these coulees are relatively flat cropland areas with a large concentration of potholes. Agricultural drainage has been active in these areas. In recent years there has been increased concern regarding downstream flooding impacts as a result of the agricultural drainage. Drainage can influence peak discharges and flood volumes by changing velocity, decreasing the channel lengths, increasing the contributing drainage area, and by reducing the upstream storage.

To test the impacts of drainage, several changes were made to the input parameters of the calibrated hydrology model. One or more of the following changes were made:

1) Reduce the time of concentrations;
 (Due to higher stream flow velocities)

2) Increase the drainage areas;

3) Decreased the number of depressions.

The results showed increase in the peak flows and volumes from the individual watersheds. However, the impact on flows in the Des Lacs River was dependent on the timing of the tributary and main stem peaks. For example, a 10 to 15% increase in peak discharges on a tributary resulted in only a 1-2% increase in the Des River peak discharges. Collectively, a 7 to 15% increase on all the tributaries resulted in a 7% increase at Foxholm and 4-6% increase at the Des Lacs River confluence with the Souris River.

Therefore, it appears that a substantial amount of drainage would have to occur in the upper tributaries to significantly increase the peak discharges on the Des Lacs River. The volume of flow can be increased more significantly than the peak discharge.

D. Souris River Flooding Impacts

A brief review was made on the impact of Des Lacs River tributary dams on Souris River flows at Minot. The Souris River at Minot usually has two peaks that occur one to three weeks apart. The first peak results from the Des Lacs River and Souris River coulees upstream from Minot. The second and largest peak results from releases from Lake Darling Dam. The tributary dams in the Des Lacs River basin would decrease Souris River flooding during the first peak. Although unlikely, the dams could decrease flooding during the second peak if the peaks were only a few days apart. It is more likely that the Des Lacs River tributary dams would slightly increase Souris River flooding during the second peak. Without the dams, the Des Lacs River water would be past Minot before the second peak. With the dams, however, discharges may still be occurring as the second peak reached Minot.

There have been two primary proposals for controlling Souris River flooding. The Burlington Dam project would include a large dam on the Souris River and a Des Lacs River diversion tunnel and control structure. Therefore, both Souris and Des Lacs River flows would be controlled. The tributary dams studied in this report would be above the Des Lacs River diversion bypass and would not affect the Souris River flows. The Burlington Dam project has considerable opposition and it is not likely to be constructed in the near future.

Efforts are currently being directed at an enlargement of the flood storage capacity in Lake Darling Dam. This project would control about a 35-year flood on the Souris River but would not control the Des Lacs River. Tributary dams in the Des Lacs River Basin would provide limited benefits to the Souris River with the raising of Lake Darling Dam. The timing of the Des Lacs and Souris River flows would be an important consideration.

VII. CONCLUSIONS

The model developed for the Des Lacs River basin does represent the existing conditions and can be used as an effective tool to analyze flooding in the basin. Based on results of this model, the following general conclusions can be drawn.

1. The peak discharges along the lower Des Lacs River are the result of flows from the steep coulee areas located primarily between the towns of Donnybrook and Des Lacs. Dam projects constructed in these areas would be the most effective in controlling flooding.
2. The Des Lacs River above the Fish and Wildlife Refuges normally peaks later and at a lower discharge than the lower coulee flows.
3. Several tributary dams would be necessary to control flooding on the Des Lacs River.
4. Dams constructed in the upper areas of the tributaries may be more cost effective than dams constructed in the downstream areas. As one example, upstream and downstream dams were studied on Flaten Coulee in the Carpio area. The dam site located approximately four miles upstream of the confluence reduced the 100-year flood peak on the Des Lacs River at Foxholm by 7%, with an estimated cost of $305,000. The downstream dam, located near the confluence of Flaten Coulee, reduced the Foxholm peak by 12% but the cost increased to $1.3 million.
5. It is unlikely that drainage has significantly increased peak discharges in the lower Des Lacs River.

APPENDIX A

Investigation Agreement

May 6, 1983
SWC Project #1772

A G R E E M E N T

Investigation of the Des Lacs River Watershed

I. PARTIES

THIS AGREEMENT is between the North Dakota State Water Commission, hereinafter referred to as the Commission, acting through the State Engineer, Vernon Fahy; and the Ward County Water Resource Board, hereinafter referred to as the Board, acting through its Chairman, Arden Haner.

II. PROJECT, LOCATION AND PURPOSE

The Board wishes to evaluate the flooding potential along the Des Lac River and develop a hydrologic model of the watershed. The model will be a water management tool that can be used to evaluate the effects of future projects in the Des Lacs River Basin.

Approximately three potential dam sites will be located and evaluated according to their flow reduction capacity. A very preliminary design will be done for these sites based on a field measured profile and information from topographic maps. This design will not result in a set of plans for construction but rather is intended to provide general cost and hydrology information.

The project area will consist of the watershed of the Des Lacs River above its confluence with the Souris River.

Field surveys will be done to gather information necessary for the development of the hydrologic model. Flow rates will be determined at the mouth of the Des Lacs River and at other selected points on the main stem.

III. PRELIMINARY INVESTIGATION

The Parties agree that further information is necessary in order to evaluate the flooding problems in the project area and develop a hydrologic model. Therefore, the Commission shall conduct an investigation consisting of the following:

1. Do necessary field work to set up the model. This will consist of cross-sections at hydrologically important locations and the measurement of structures that will affect the hydrology of the project area.
2. Select approximately three potential dam sites that would temporarily retain flood waters. A profile along the potential alignment of the sites will be taken in the field.
3. Do a preliminary design of the proposed dams based on the measured profile and information from topographic maps.
4. Develop and calibrate a hydrologic model of the project area.
5. Determine the flow rates for the 10, 25, 50 and 100-year events at the mouth of the Des Lacs River and at selected points of importance along the main stem. These flow rates will reflect present conditions.
6. Develop preliminary cost estimates of any proposed retention dams based on the preliminary design.
7. Prepare a Preliminary Engineering Report that would describe the present hydrologic conditions, evaluate potential projects, present preliminary project designs and their estimated costs.

If the Board decided to proceed further with any potential project identified in this preliminary investigation, more detailed information and a more detailed study would be needed to develop plans for construction

This is beyond the scope of this investigation and would have to do done under a separate agreement.

IV. DEPOSIT - REFUND

The Board shall deposit a total of $2,200 with the Commission to partially defray the costs of the investigation. Upon receipt of a request from the Board to terminate proceeding further with the preliminary investigation or upon a breach of this agreement by any of the parties, the Commission shall provide the Board with a statement of all expenses incurred in the investigation and shall refund to the Board any unexpended funds.

V. RIGHTS OF ENTRY

The Board agrees to obtain written permission from any affected landowners for field investigations by the Commission which are required for the preliminary investigation. The Commission shall inform the Board of the locations where surveys are needed.

VI. INDEMNIFICATION

The Board hereby accepts responsibility for and holds the Commission harmless from all claims for damages to public or private property, rights or persons arising out of the project and the travel to and from the project area by the Board or any of its subcontractors, agents, or employees. In the event such a suit is initiated or judgement entered against the Commission, the Board will indemnify the Commission for any settlement arrived at or judgement satisfied. No indemnification will be required of the Board for claims resulting from negligent acts of the Commission.

VII. CHANGES TO THE AGREEMENT

Changes to any contractual provisions herein will not be effective or binding unless such changes are made in writing, signed by both parties, and attached hereto.

Arden Haner
ARDEN HANER
Chairman

June 13, 1983
DATE:

Marie L Rasmussen
WITNESS:

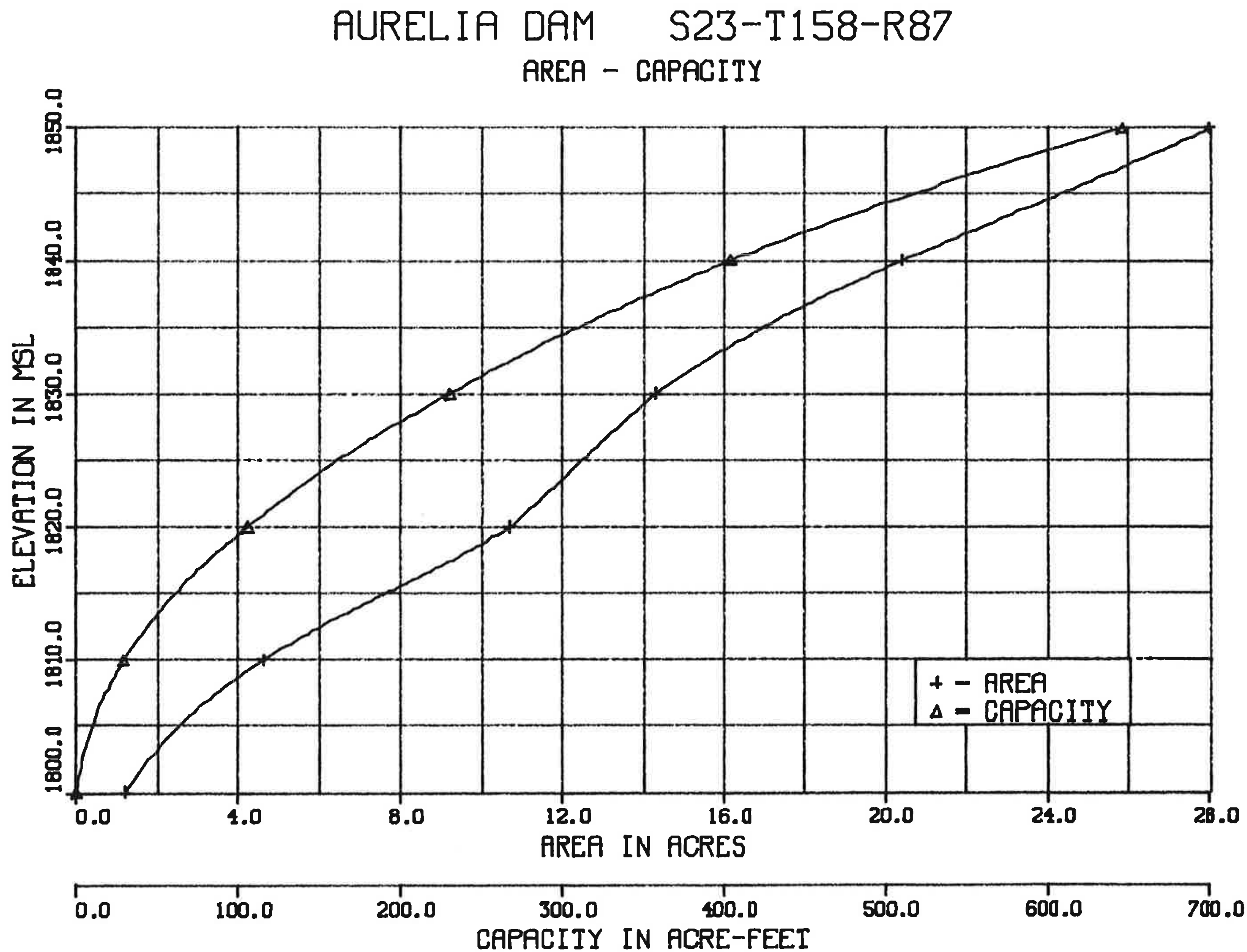
Vernon Fahy
VERNON FAHY
State Engineer

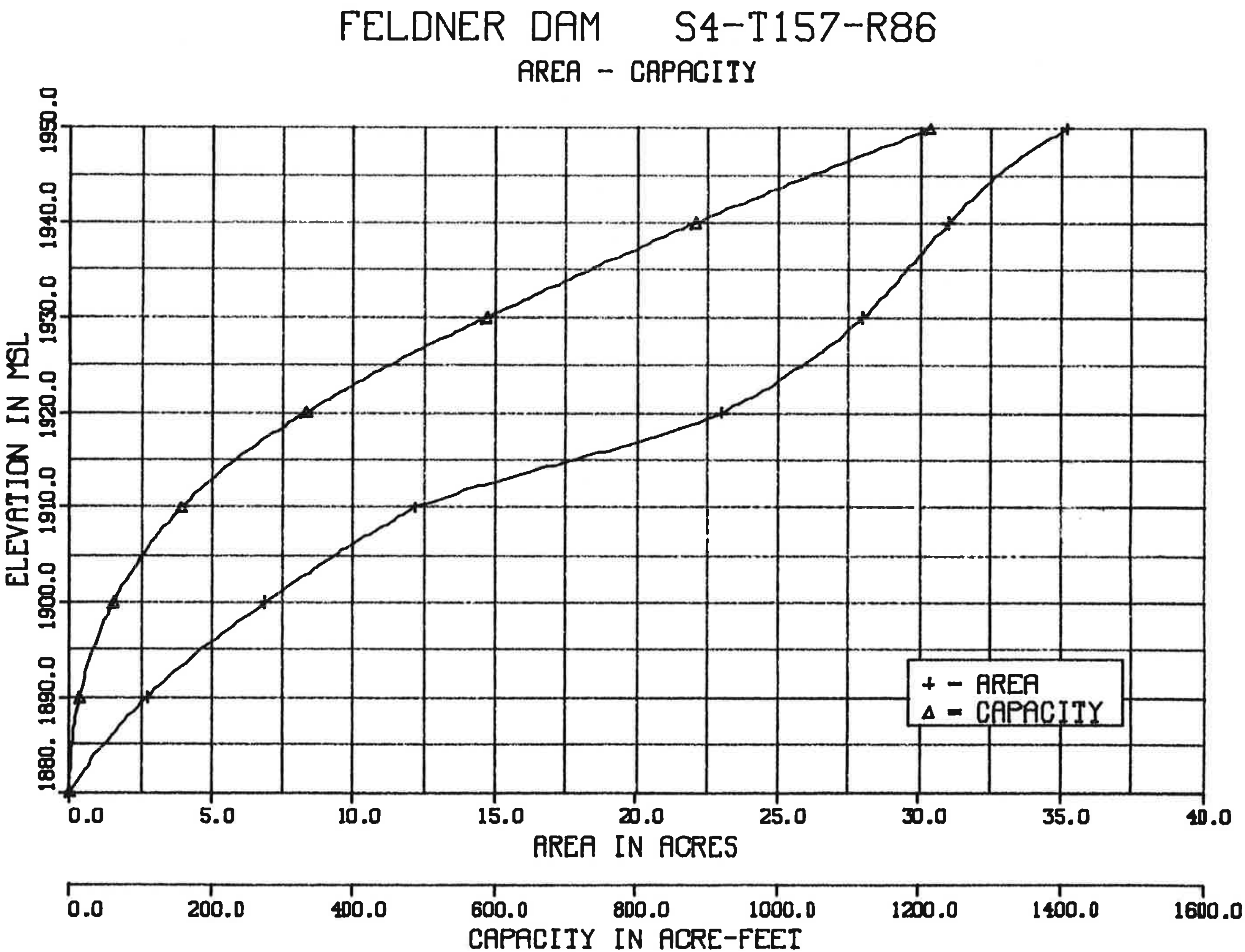
5-13-83
DATE:

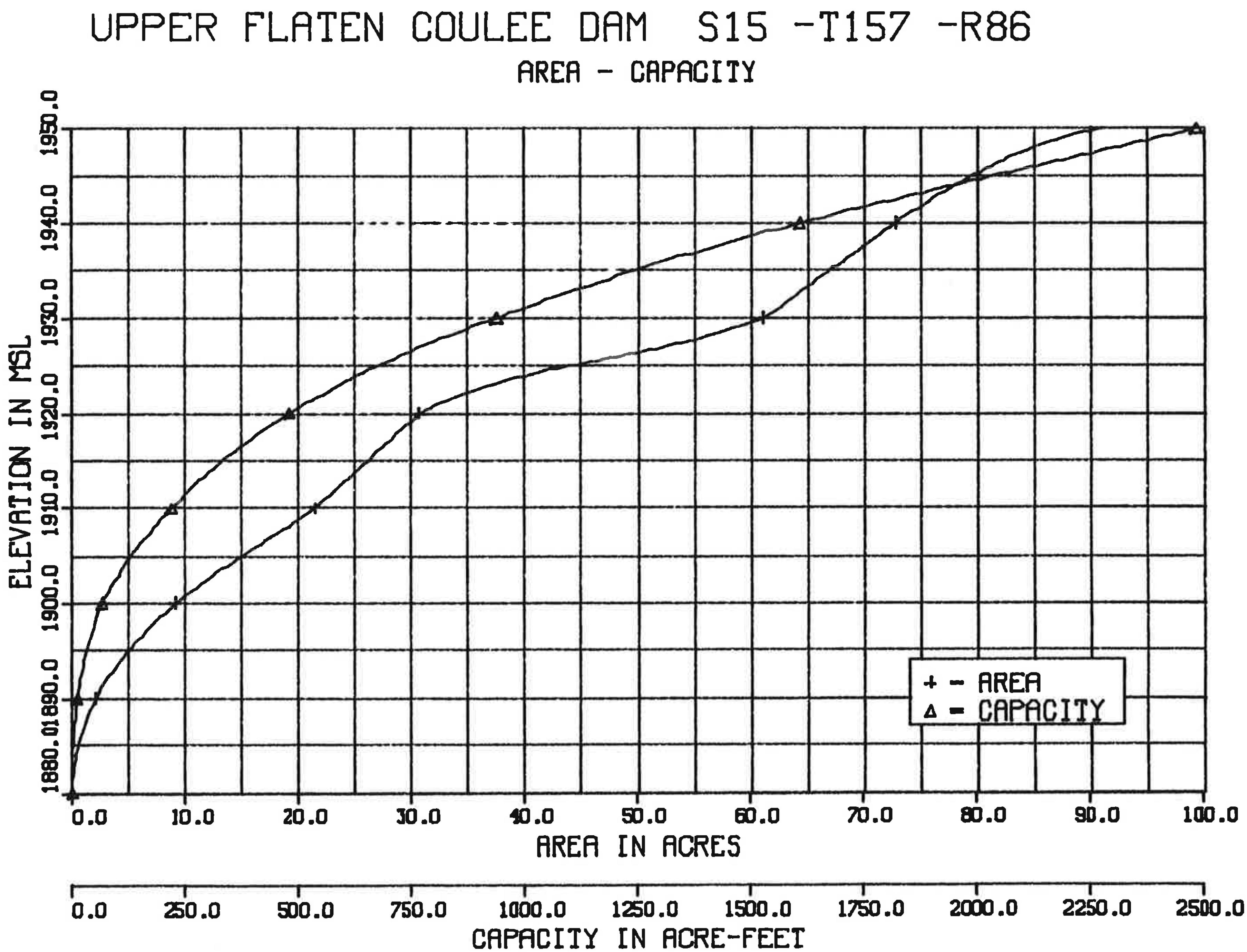
[signature]
WITNESS

APPENDIX B

Area-Capacity Curves For
Potential Dam Sites


AURELIA DAM S23-T158-R87
AREA - CAPACITY
ELEVATION IN MSL
1800.0
1810.0
1820.0
1830.0
1840.0
1850.0
+ - AREA
Δ - CAPACITY
0.0
4.0
8.0
12.0
16.0
20.0
24.0
28.0
AREA IN ACRES
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
CAPACITY IN ACRE-FEET

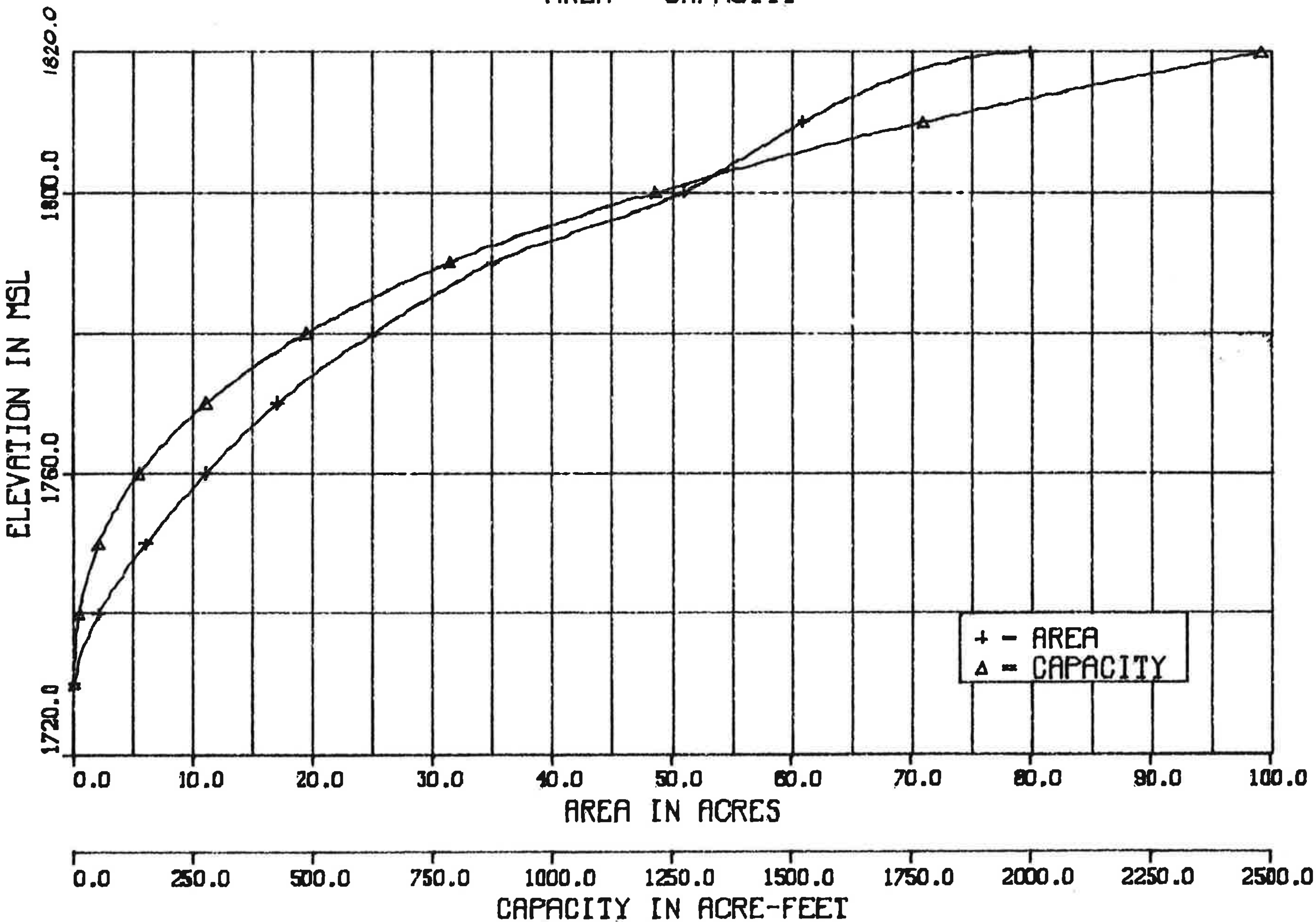

FELDNER DAM S4-T157-R86
AREA - CAPACITY
ELEVATION IN MSL
1880.
1890.0
1900.0
1910.0
1920.0
1930.0
1940.0
1950.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
AREA IN ACRES
0.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0
1600.0
CAPACITY IN ACRE-FEET
+ - AREA
Δ = CAPACITY



UPPER FLATEN COULEE DAM S15 -T157 -R86
AREA - CAPACITY
ELEVATION IN MSL
1880.0
1890.0
1900.0
1910.0
1920.0
1930.0
1940.0
1950.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
AREA IN ACRES
0.0
250.0
500.0
750.0
1000.0
1250.0
1500.0
1750.0
2000.0
2250.0
2500.0
CAPACITY IN ACRE-FEET
+ - AREA
Δ = CAPACITY

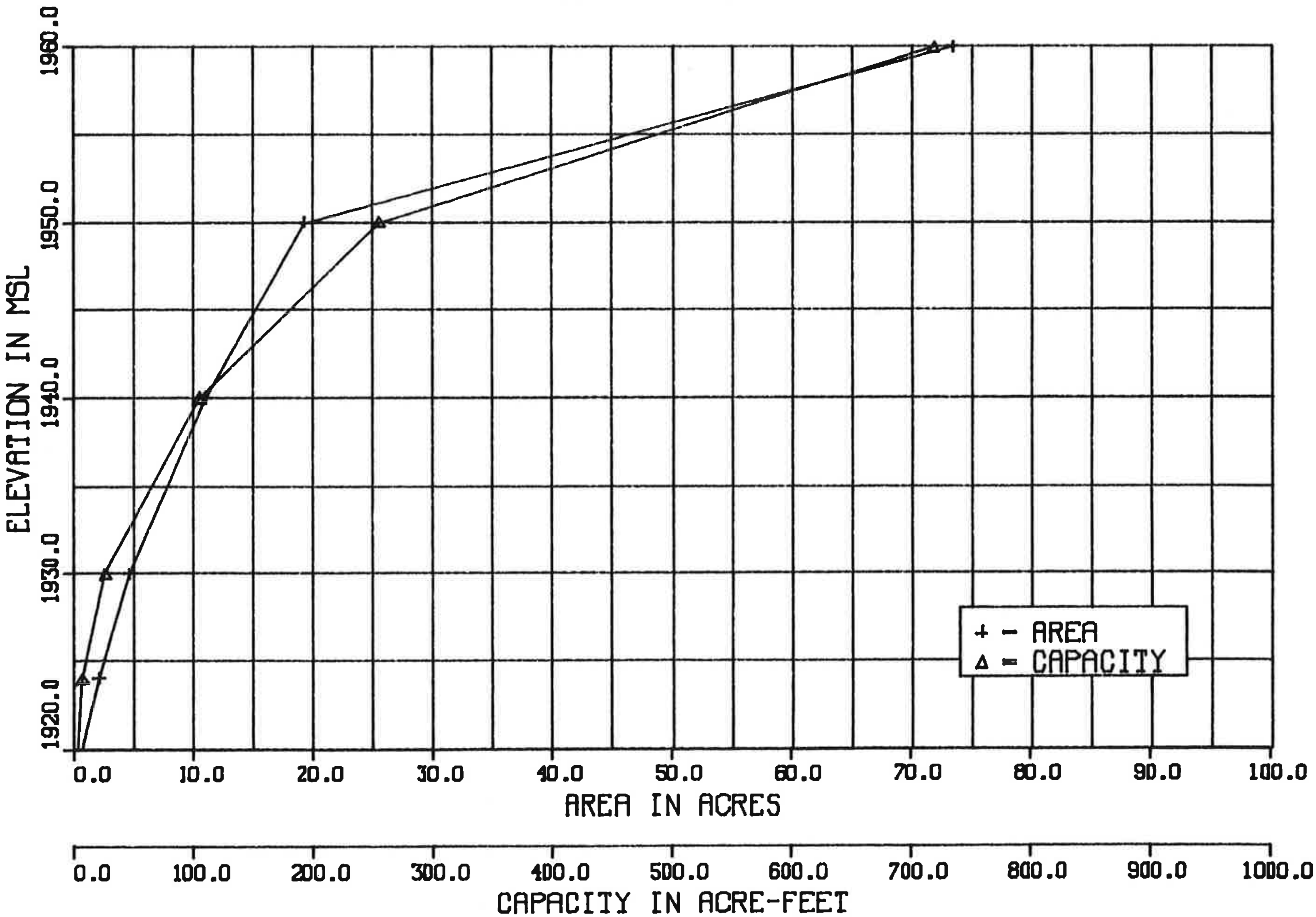
LOWER FLATEN COULEE DAM S12-T157-R86

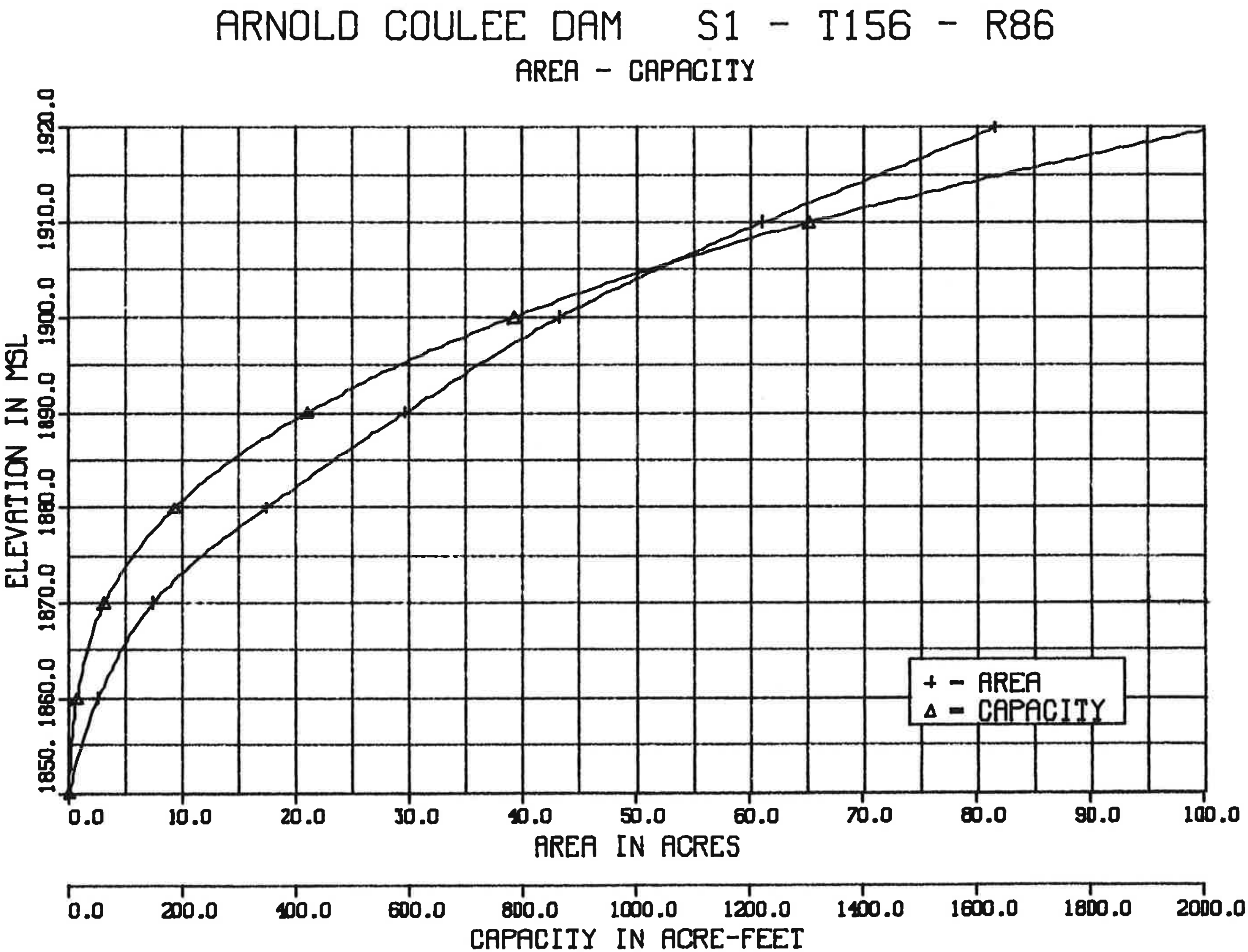
AREA - CAPACITY



HARTLAND DAM S16 - T157 - R86

AREA - CAPACITY

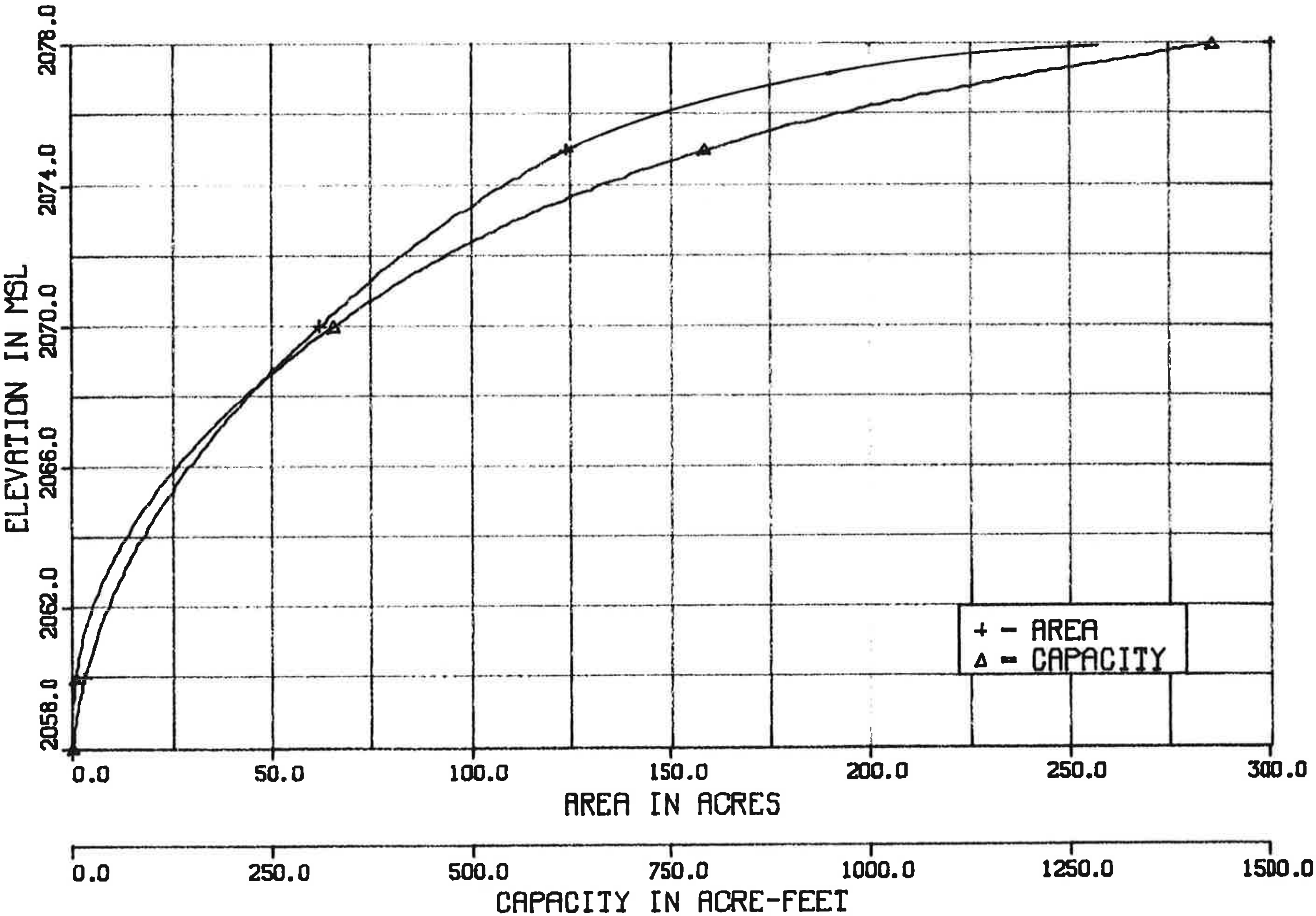




ARNOLD COULEE DAM S1 - T156 - R86
AREA - CAPACITY
ELEVATION IN MSL
1850.
1860.0
1870.0
1880.0
1890.0
1900.0
1910.0
1920.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
AREA IN ACRES
0.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0
1600.0
1800.0
2000.0
CAPACITY IN ACRE-FEET
+ - AREA
Δ - CAPACITY

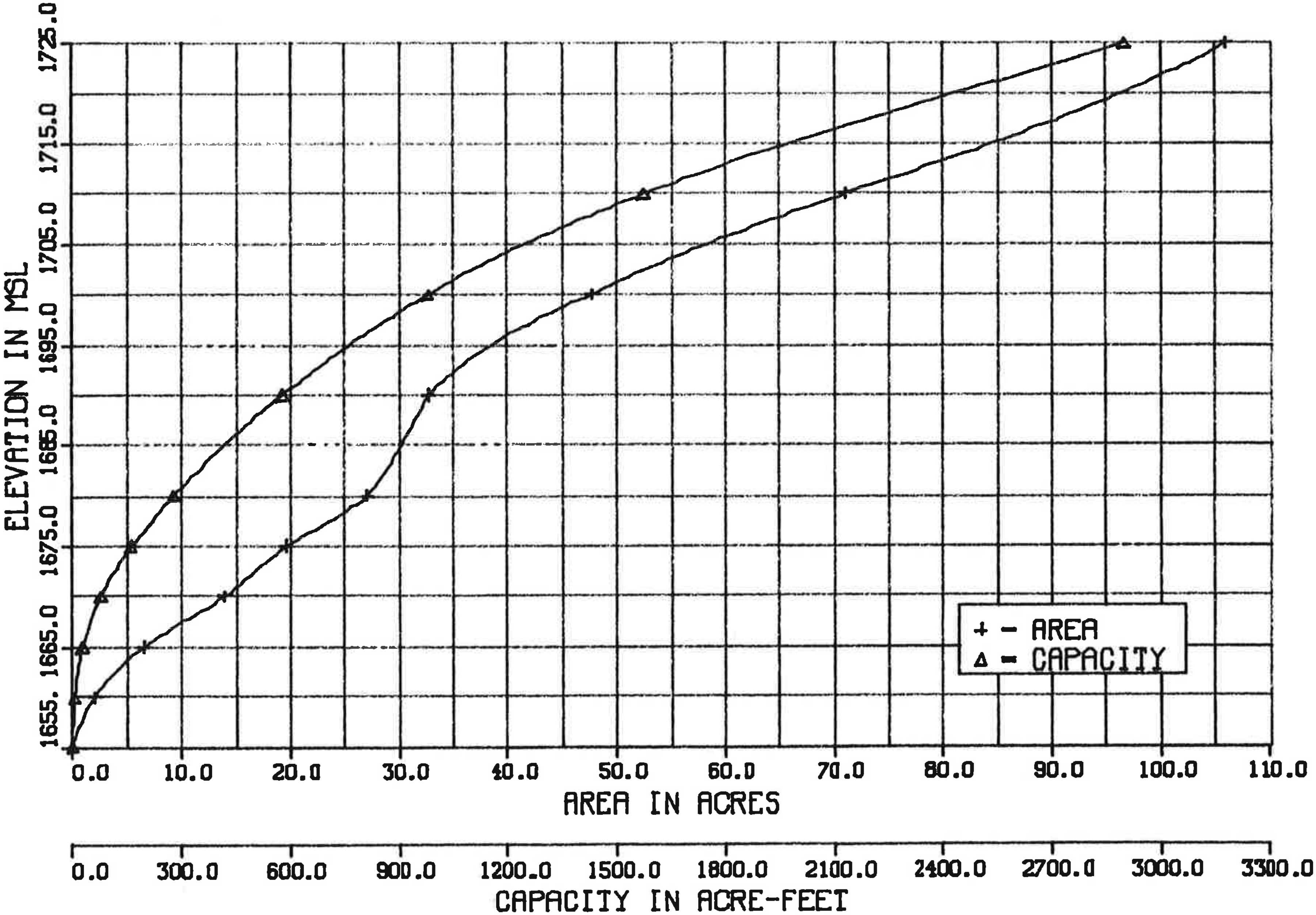
LONETREE TRIBUTARY DAM S24-T156-R86

AREA - CAPACITY



LOWER LONETREE COULEE DAM S12-T156-R85

AREA - CAPACITY



APPENDIX C

Preliminary Cost Estimate
For Potential Dams

TABLE 12 - PRELIMINARY COST ESTIMATE

Item/Unit Cost	Aurelia Quantity/Cost	Feldner Quantity/Cost	Upper Flaten Quantity/Cost	Lower Flaten Quantity/Cost
Clearing & Grubbing 2,710/Acre	2/$ 5,420	2.5/$ 6,775	3/$ 8,130	3/$ 8,130
Stripping & Spreading Topsoil $0.26/CY	2,444/$ 635	2,300/$ 598	4,060/$ 1,056	17,419/$ 4,529
Excavation $1.87/CY	5,600/$ 10,472	3,680/$ 6,882	5,600/$ 10,472	16,320/$ 30,518
Embankment $1.00/CY	44,920/$ 44,920	43,316/$ 43,316	100,060/$100,060	646,990/$646,990
Water for Compaction $4.72/M Gal.	764/$ 3,606	740/$ 3,493	1,700/$ 8,024	10,999/$ 51,873
Pipe *24" RCP 75/LF **30" RCP 95/LF *** 24" CMP 40.60/LF	*200/$ 15,000	*250/$ 18,750	*330/$ 24,750	*515/$ 38,625
Concrete 285/CY	34.5/$ 9,833	47/$ 13,395	73/$ 20,805	106/$ 30,210
Reinforcing Steel $.50/LB	3,450/$ 1,725	4,700/$ 2,350	7,300/$ 3,650	10,600/$ 5,300
Rock Riprap 25/CY	60/$ 1,500	60/$ 1,500	1,340/$ 33,500	6,200/$155,000
Rock Riprap Filter Bedding 12/CY	20/$ 240	20/$ 240	670/$ 8,040	3,100/$ 37,200
Seeding 259.77/Acre	5/$ 1,299	5/$ 1,299	15/$ 3,897	20/$ 5,195
Drawdown 16" DIP 52.60/LF	20/$ 1,052	20/$ 1,052	25/$ 1,315	150/$ 7,890
Subtotal	$ 95,702	$ 99,650	$223,699	$1,021,460
30% Contingency, Administration & Engineering	$ 28,698	$ 29,850	$ 67,301	$ 306,438
Total	124,400	129,500	291,000	1,327,898
Land	6,700	9,500	27,200	28,700
TOTAL COST	$131,100	$139,000	$318,200	$1,356,598

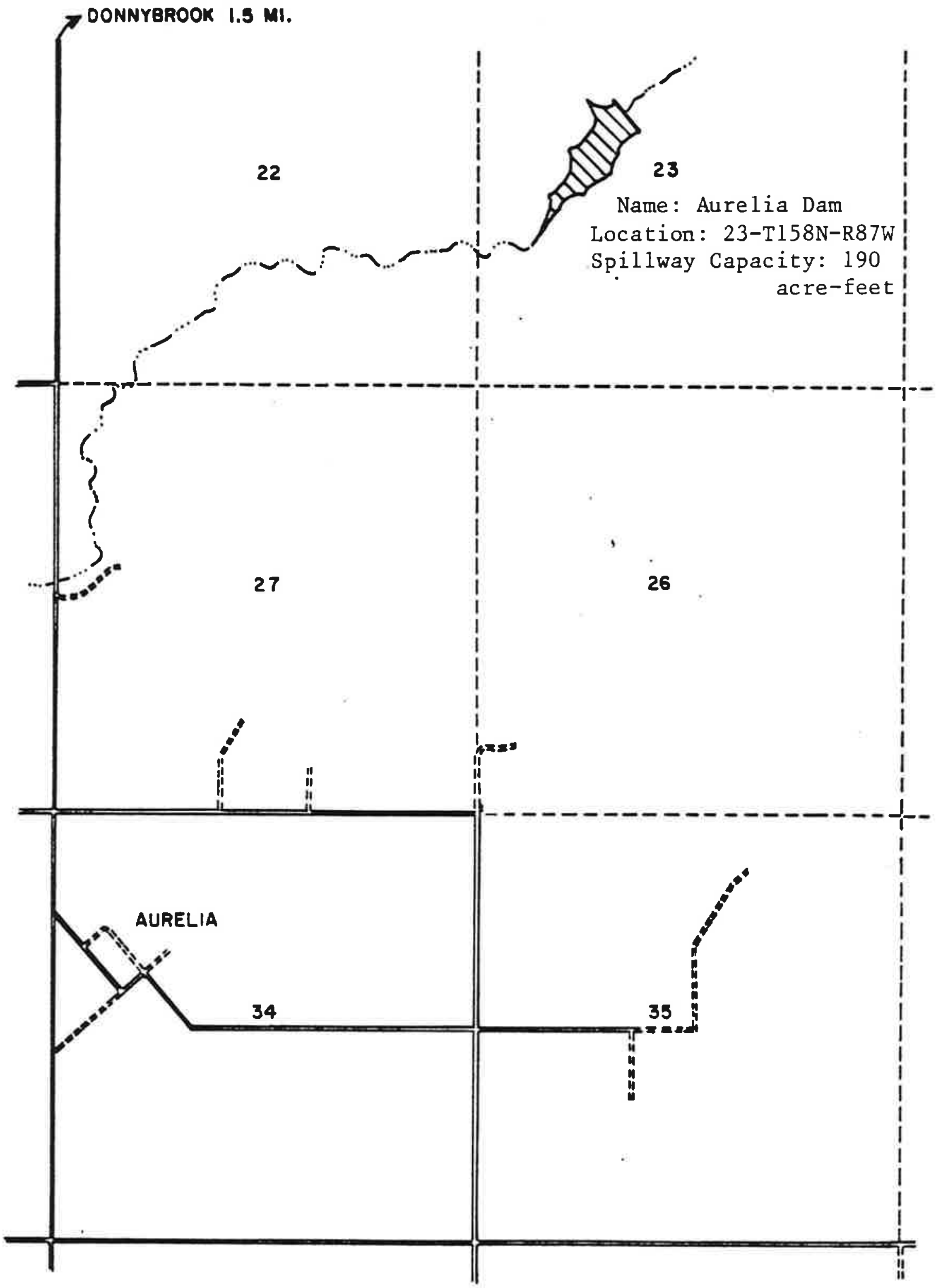
TABLE 12 - PRELIMINARY COST ESTIMATE (CONT.)

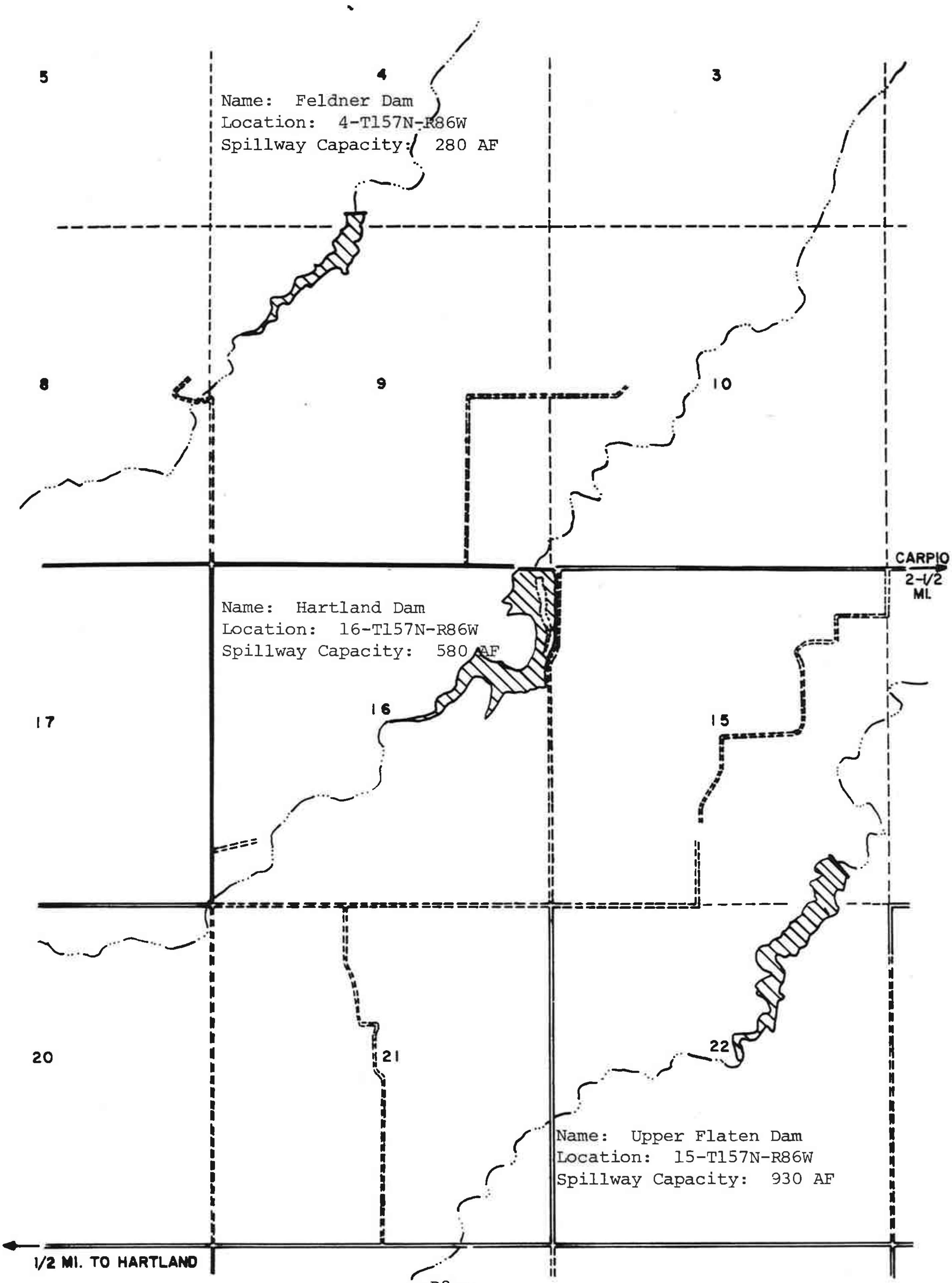
Item/Unit Cost	Hartland Quantity/Cost	Arnold Quantity/Cost	Lonetree Trib. Quantity/Cost	Lower Lonetree Quantity/Cost
Clearing & Grubbing 2,710/Acre	1/$ 2,710	1/$ 2,710		6/$ 16,260
Stripping & Spreading Topsoil $0.26/CY	6,047/$ 1,572	6,940/$ 1,840	1,142/$ 297	14,641/$ 3,807
Excavation $1.87/CY	9,280/$ 17,354	5,040/$ 9,425	2,270/$ 4,245	13,600/$ 25,432
Embankment $1.00/CY	97,068/$ 97,068	117,270/$117,270	10,309/$10,309	377,130/$377,130
Water for Compaction $4.72/M Gal.	1,650/$ 7,788	1,994/$ 9,412	175/$ 826	6,411/$ 30,260
Pipe *24" RCP 75/LF **30" RCP 95/LF *** 24" CMP 40.60/LF	* 245/$ 18,375	** 360/$ 34,200	***85/$ 5,451	**425/$ 40,375
Concrete 285/CY	58/$ 16,530	77.5/$ 22,088		90/$ 25,650
Reinforcing Steel $.50/LB	5,800/$ 2,900	7,750/$ 3,875		9,000/$ 4,500
Rock Riprap 25/CY	1,640/$ 41,000	80/$ 2,000	40/$ 1,000	2,660/$ 66,500
Rock Riprap Filter Bedding 12/CY	820/$ 9,840	30/$ 360	15/$ 180	1,330/$ 15,960
Seeding 259.77/Acre	10/$ 2,598	10/$ 2,598	5/$ 1,299	20/$ 5,195
Drawdown 16" DIP 52.60/LF	25/$ 1,315	40/$ 2,104	20/$ 1,052	35/$ 1,841
Subtotal	$219,050	$207,882	$24,659	$612,910
30% Contingency, Administration & Engineering	65,715	62,318	7,441	183,890
Total	284,765	270,200	32,100	796,800
Land	26,900	34,000	50,500	92,500
TOTAL COST	$311,665	$304,200	$82,600	$889,300

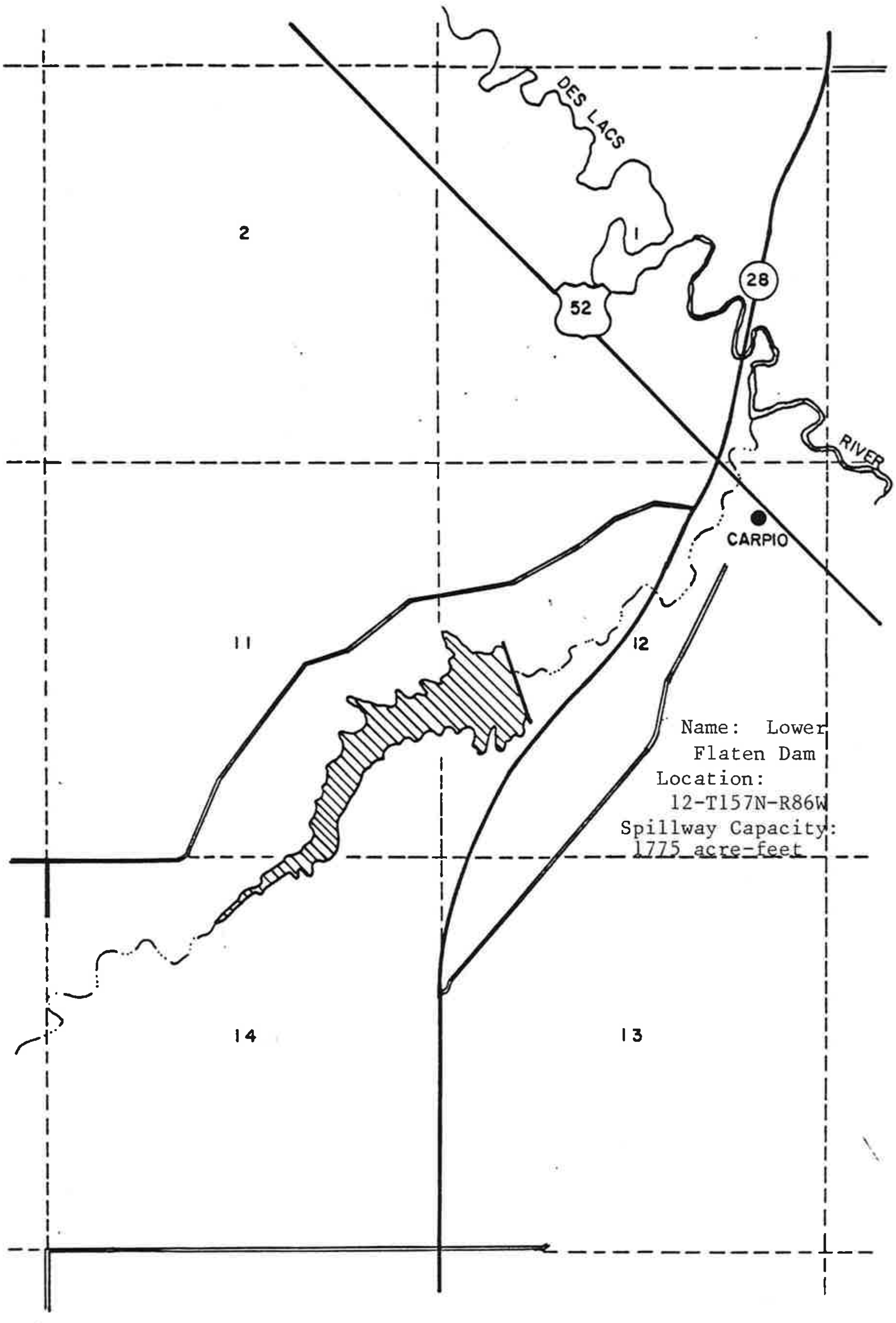
*** Includes cost for 24" CMP and $2,000 for an inlet structure.

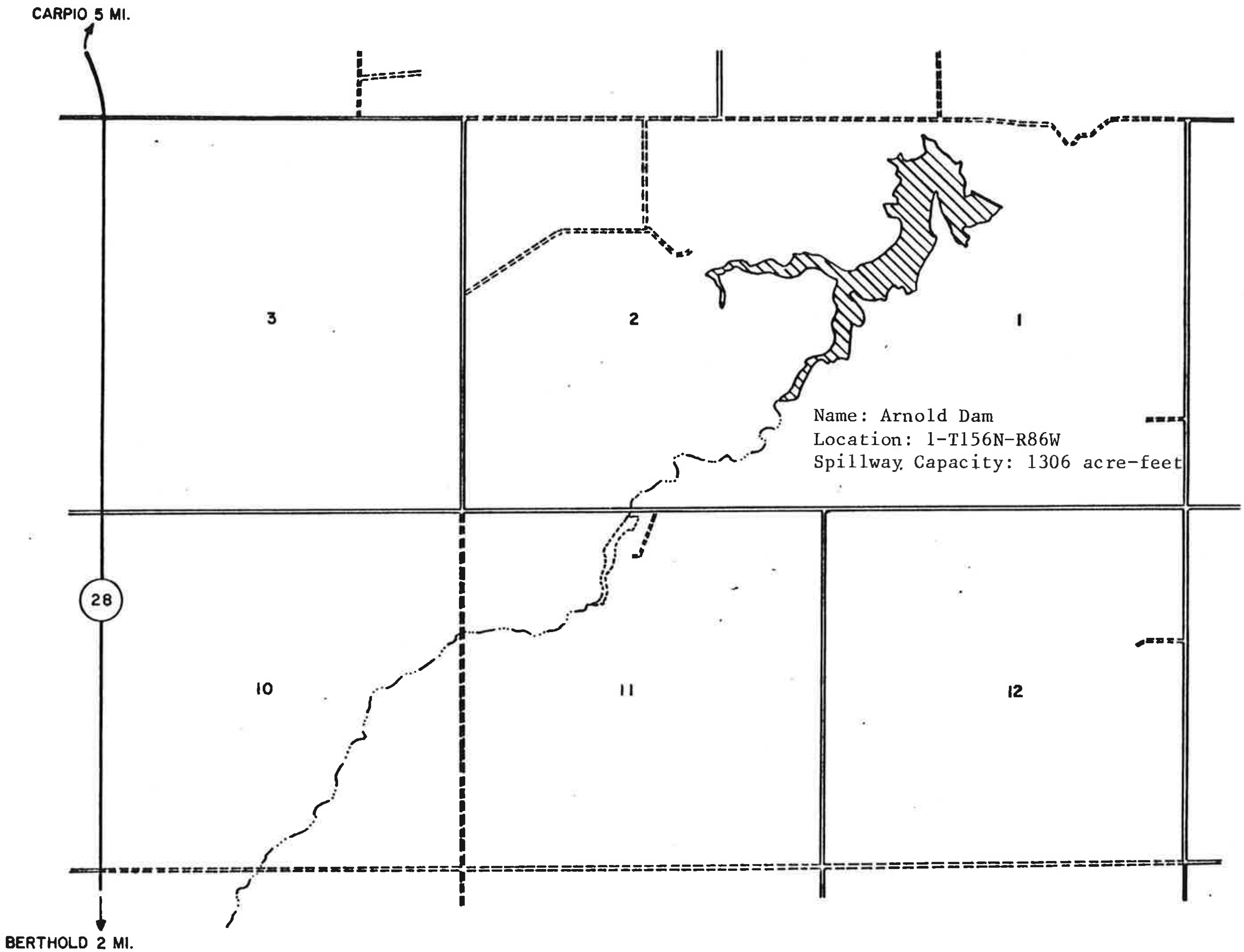
APPENDIX D

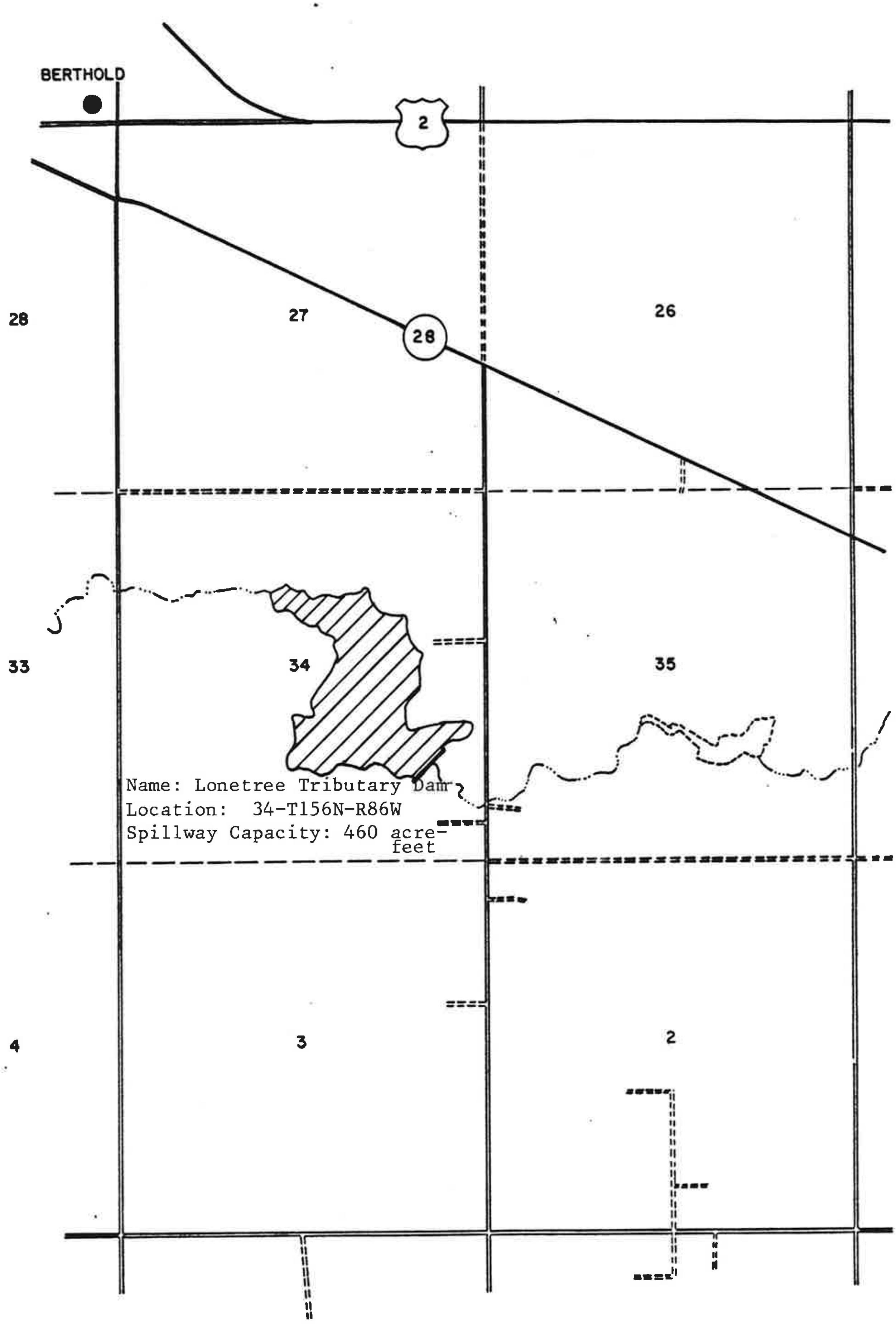
Individual Dam Location Maps

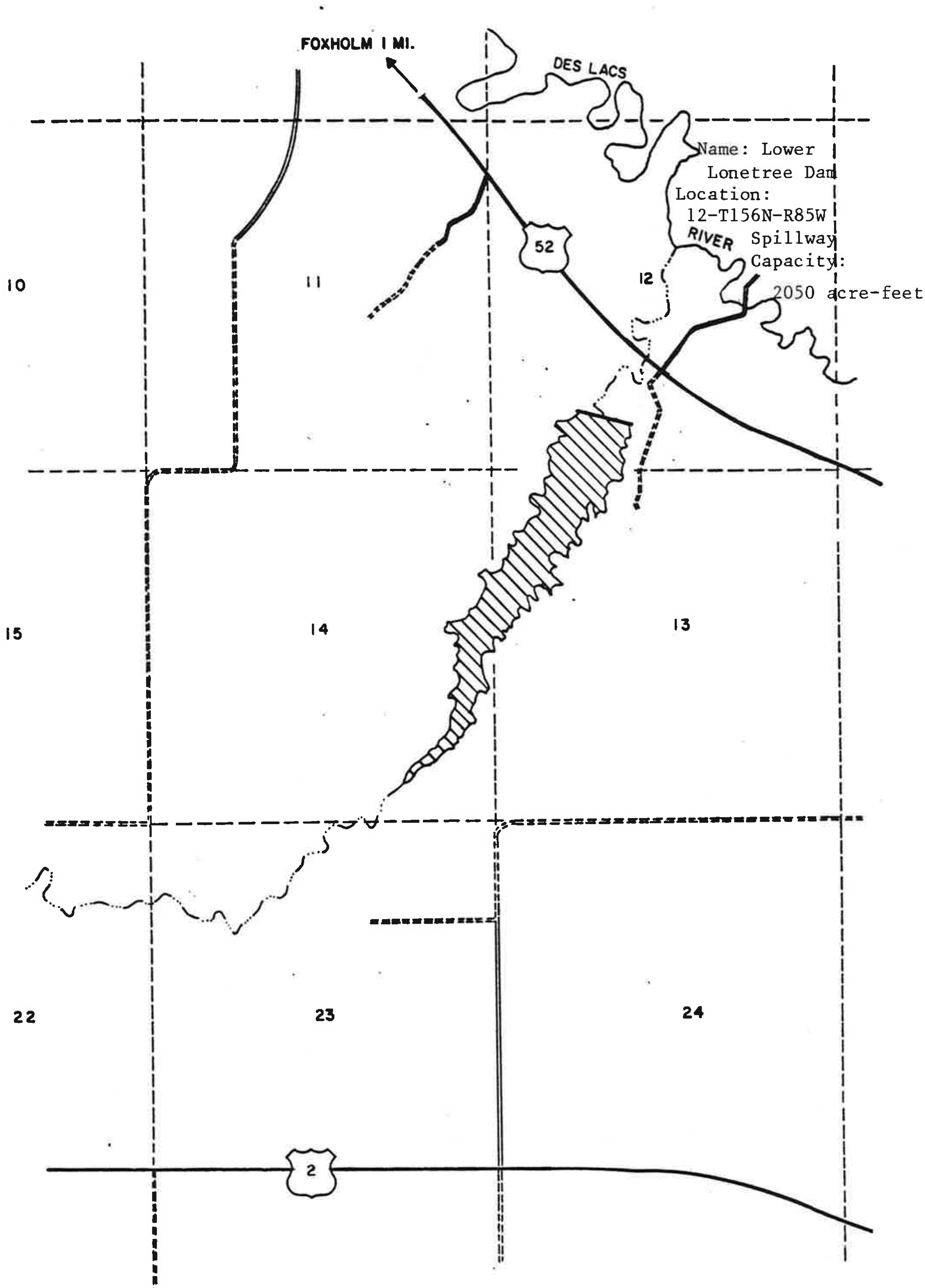

DONNYBROOK 1.5 MI.
22
23
Name: Aurelia Dam
Location: 23-T158N-R87W
Spillway Capacity: 190
acre-feet
27
26
AURELIA
34
35


5
4
3
Name: Feldner Dam
Location: 4-T157N-R86W
Spillway Capacity: 280 AF
8
9
10
CARPIO
2-1/2
MI.
Name: Hartland Dam
Location: 16-T157N-R86W
Spillway Capacity: 580 AF
17
16
15
20
21
22
Name: Upper Flaten Dam
Location: 15-T157N-R86W
Spillway Capacity: 930 AF
1/2 MI. TO HARTLAND


DES LACS
RIVER
52
28
CARPIO
2
1
11
12
14
13
Name: Lower
Flaten Dam
Location:
12-T157N-R86W
Spillway Capacity:
1775 acre-feet


CARPIO 5 MI.
3
2
1
Name: Arnold Dam
Location: 1-T156N-R86W
Spillway Capacity: 1306 acre-feet
28
10
11
12
BERTHOLD 2 MI.


BERTHOLD
2
28
28
27
26
33
34
35
4
3
2
Name: Lonetree Tributary Dam
Location: 34-T156N-R86W
Spillway Capacity: 460 acre-feet


FOXHOLM 1 MI.
DES LACS
RIVER
52
Name: Lower Lonetree Dam
Location: 12-T156N-R85W
Spillway Capacity: 2050 acre-feet
10
11
12
15
14
13
22
23
24
2