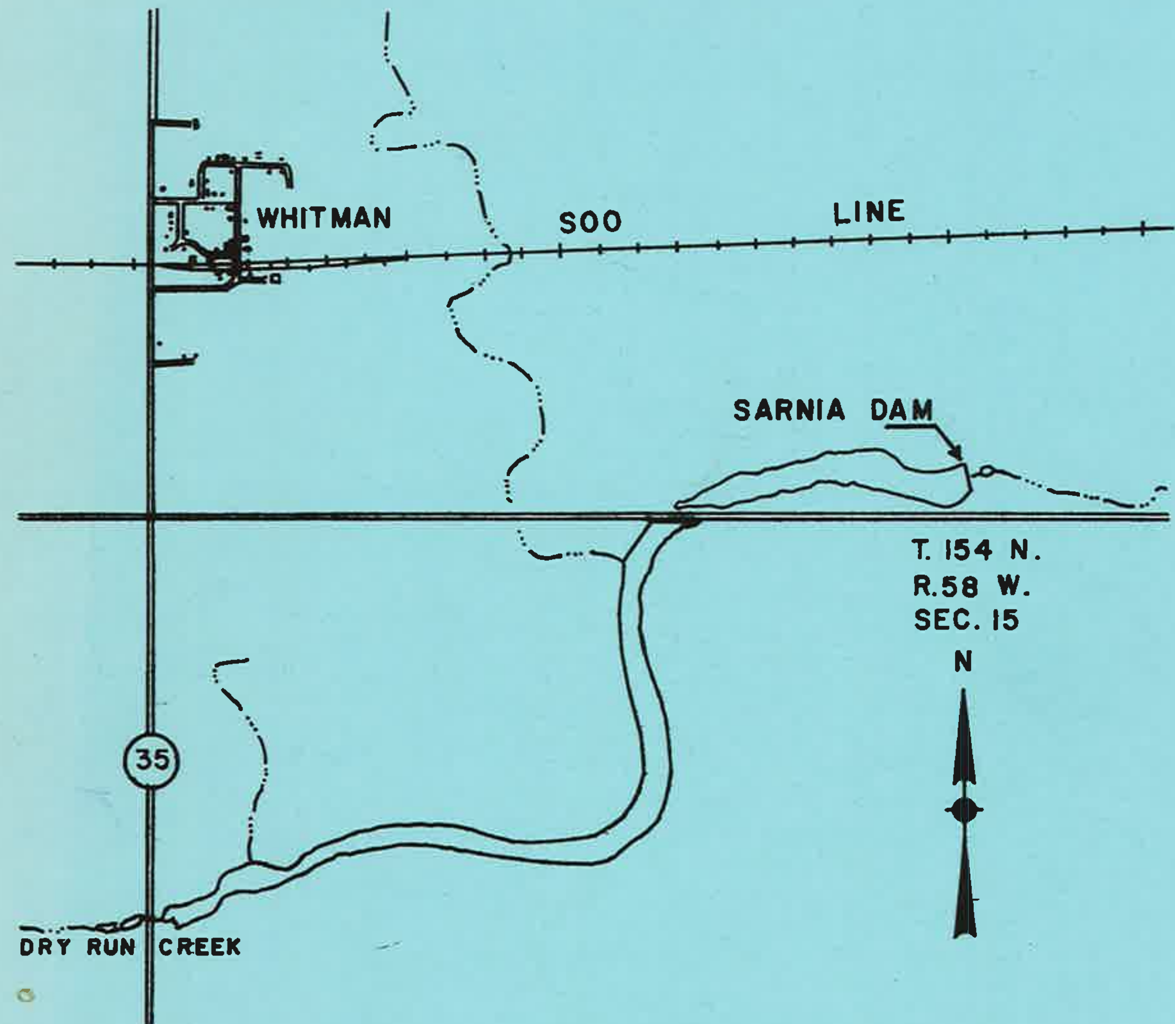
PRELIMINARY ENGINEERING REPORT

FEASIBILITY STUDY
FOR THE
REPAIR OF SARNIA DAM



NORTH DAKOTA
STATE WATER COMMISSION
MAY 1979

SWC PROJECT 291

FEASIBILITY STUDY

FOR THE

REPAIR OF SARNIA DAM

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

SWC Project #291

SARNIA DAM - SWC #291
COST ESTIMATE
April 9, 1981

ITEM	UNIT	COST
Salvage and Spread Topsoil	20,000 S.Y. @ $0.20	$ 4,000
Salvage and Spread R.R.R.	300 C.Y. @ $15	4,500
Excavate Cutoff Trench	1,694 C.Y. @ $2	3,388
Excavate Outlet Channel	1,112 C.Y. @ $1	1,112
Borrow Excavation	16,000 C.Y. @ $1.10	17,600
Rock Riprap	400 C.Y. @ $20	8,000
Rock Riprap Filter Material	250 C.Y. @ $8	2,000
42" Ø CMP	110 L.F. @ $70	7,700
Seeding	4 Acres @ $250	1,000
	Subtotal	$49,300
	Contingencies	4,700
	Engineering & Admin.	6,000
	TOTAL	$60,000

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This document paid for with State funds.

I. INTRODUCTION

A. PURPOSE AND SCOPE

This report on Sarnia Dam in Nelson County contains the results of a study conducted by the State Water Commission to develop plans for the reconstruction of Sarnia Dam as a dry dam. The intention of the Nelson County Water Management Board is to provide flood protection for agricultural land downstream of Sarnia Dam and to reduce the effect of upstream agricultural drainage on downstream landowners. Therefore the Board requested the State Water Commission to investigate the feasibility of repairing Sarnia Dam.

Preceding the engineering analysis is a section on the historical background of Sarnia Dam, a physical description of the area, and a description of the soil exploration studies. The engineering analysis includes a description of the hydrologic and hydraulic analysis of the drainage basin, a construction cost estimate, a description of project benefits, and a summary of the report.

The engineering analysis utilizes the best practical technology to investigate the reconstruction of Sarnia Dam. The design of Sarnia Dam complies with criteria established by the State Water Commission.

II. HISTORICAL BACKGROUND

As far as can be determined, Sarnia Dam was built on Dry Run Creek about 1936 by the WPA or the Federal Emergency Relief Administration for livestock watering and recreational use. The easements for the land to be flooded were given by William G. Lamb and J. S. Lamb (S$\frac{1}{2}$ of Section 15, NW$\frac{1}{4}$ Section 22, NE$\frac{1}{4}$ Section 21 all located in Township 154, Range 58) and E. G. Sommerfield (SE$\frac{1}{4}$ of Section 21, Township 154, Range 58).

In 1941 E. G. Sommerfield requested that the dam be lowered because it was flooding lands of his on which no easements were granted. Nothing became of Mr. Sommerfield's complaint in 1941 but this problem came up once again in 1947. From information on file, it seems that nothing was ever done to alleviate this problem.

Over the years, erosion of the spillway has been a continual problem. In the spring of 1949 a section of the masonry spillway face was undermined at the junction with the south training wall. This was repaired with the costs shared by the North Dakota State Water Conservation Commission, the North Dakota State Game and Fish Department and Local Aid. In 1964 the masonry spillway was badly eroded again. The Nelson County Water Management District decided to make minor repairs to the structure in an effort to retain the project until the District had sufficient funds to cooperate with state and federal agencies to reconstruct the dam. In 1966, an inspection revealed that water was seeping between the weir and the spillway chute. This water eroded a large cavity beneath the chute. There was some speculation as to whether the dam was worth fixing because of its close proximity to Whitman Dam, lack of depth, and lack of interest on the part of the Game and Fish Department. By 1968 the rock and mortar spillway had completely failed and the only portion remaining was the upstream cutoff wall. During 1969 the emergency spillway was raised 18 inches and a reinforced concrete cutoff wall was placed across the emergency spillway. Also a control structure was installed consisting of a concrete drop inlet with an anti-vortex device, a trash rack and a 36 inch diameter corrugated metal pipe (CMP). In 1974 the Soil Conservation Service did some minor repair of the emergency spillway. Once again in the spring of 1976, high flows caused damage to the spillway. The Water Management Board then repaired the dam.

CURRENT CONDITIONS

During the 1978 spring runoff, the spillway of Sarnia Dam completely washed out. The Nelson County Water Management Board requested the State Water Commission to check with the Disaster Emergency Services to see if Sarnia Dam could be funded by the Federal Disaster Assistance Administration. However, the Corps of Engineers inspectors decided that the failure occurred from other than disaster related causes, since neither the dam nor the emergency spillway was overtopped. Therefore, disaster assistance funds were not made available for repair.

Since that time the Nelson County Water Management Board has requested the State Water Commission to proceed with the investigation of repairing Sarnia Dam. (See Appendix C for Agreement)

It should also be noted that the recently constructed Enterprise Drain discharges into the drainage area of Sarnia Dam. Therefore, the dam acts as a final control for Enterprise Drain and should be maintained.

III. PHYSICAL DESCRIPTION

A. GEOLOGY AND PHYSIOGRAPHY

Sarnia Dam is located in the S½ Section 15, Township 154 North, Range 58 West, in the north central portion of Nelson County, in northeastern North Dakota (see Figure 1). The axis of the dam lies almost straight north and south. The reservoir backs from the face of the dam west, then south, and then west for approximately 2 to 3 miles.

Topographically, the dam site occupies a narrow, moderately entrenched channel on a gently rolling glacial drift plain. The surficial geology is primarily of glacial origin being situated in the Western Lake Section of the Central Lowland Province, a physiographic province of North Dakota. The dam site area is part of the Drift Prairie, a region characterized by land forms resulting from various glacial processes.

The area around Sarnia Dam is mainly productive farmland producing small grains and row crops. The immediate beneficiaries of the rebuilt Sarnia Dam would be the farmers downstream from the dam. They would receive flood protection from snowmelt in the spring and from runoff from large summer rains.

Sarnia Dam is located in the Red River Basin which is classified as a subhumid to humid continental climate with moderately warm summers and cold winters. Rapid changes in daily weather patterns are characteristic of this area. Frequent passage of weather fronts and high and low pressure systems result in a wide variety of weather. The annual mean temperature is 39°F with the warmest month being July and the coldest month being January. The annual mean precipitation is 17 inches with 82 percent of the precipitation occurring in the months of April through September. The average mean annual snowfall is 30 inches with 120 days with a snow depth of 1 inch or more.

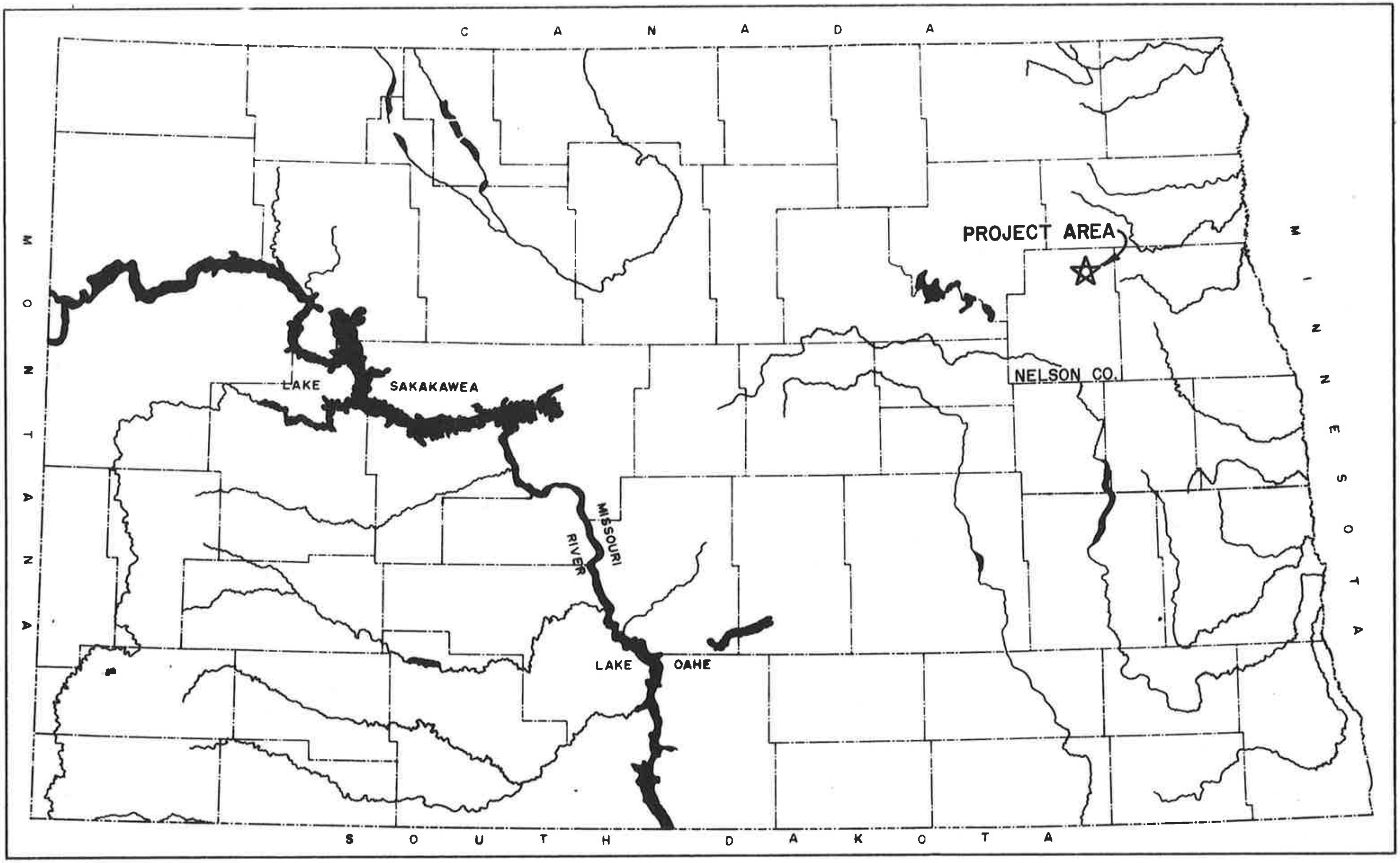


FIGURE I

Project Area Location

IV. SUBSURFACE EXPLORATION

A. INTRODUCTION

A subsurface exploration was initiated by the State Water Commission to determine the subsurface deposits and the feasibility of constructing a grassed, emergency spillway near the south abutment of Sarnia Dam. The principal spillway pipe located near the north abutment has washed out numerous times due to high discharges during spring runoff.

Six auger borings were drilled by Metzger's Prospecting Service, Mandan, North Dakota on December 28, 1978. The auger borings were drilled with a Texoma earth drill on or about centerline of the proposed emergency spillway. Representative bulk samples were collected from five of the six borings. A Water Commission engineer supervised and reviewed the drilling and sampling operations.

B. SOIL CONDITIONS

The surficial deposits in the proposed emergency spillway (upstream to downstream) consist predominantly of shaley till and shale-silt-clay mixtures. The shaley till (silt-clay mixtures) was logged as ML and CL, where as the shale-silt-clay mixtures were logged MH, being composed predominantly of shale fragments of varying sizes and proportions in a silty matrix (See Tables 1 and 2).

The silt-clay mixtures are moderately plastic to plastic, slightly sandy with a trace of gravel. Coloration is generally tan to olive brown. Moisture content based on visual examination varies from dry to slightly moist with depth. Maximum dry densities ranged from 86 pcf for the ML sample to 105 pcf for a CL with moderately plastic fines. Optimum moisture contents were 29% and 17%, respectively, for the two extremes.

The shale-silt-clay mixtures of the MH soil group are plastic, occassionally sandy and contain ½ to 2 inch angular fragments of moderately soft to moderately hard shale in a matrix of medium dense silt. The shale fragments are iron-stained and weathered. The shale-silt-clay samples are quite heterogeneous. They were all classified as CH's that have liquid limits of 66 and 68 and PI's from 19 to 23. The compacted densities obtained on the MH samples were all less than 75 pcf. This low density is due to light-weight shale fragments that make up the sand-size fraction and also due to the skip grading and poor gradation of these samples. Also the specific gravity of the minus No. 4 fraction is considerably lower than the ML and CL samples.

C. DISCUSSION AND RECOMMENDATIONS

It has been proposed to reconstruct a portion of the embankment that failed in the area of the principal spillway pipe. It is also proposed to relocate the service spillway and raise the embankment crest five feet.

In order to raise the embankment to the proposed design elevation of 1512.0 msl, additional borrow areas must be explored for embankment construction.

Based on visual examination of soils encountered in the proposed emergency spillway and subsequent laboratory tests, we recommend the following:

1. Perform additional borings or subsurface explorations in the immediate dam site area. Due to the presence of both shaley till, alluvium and slope wash (undifferentiated) in the upstream and downstream end of the emergency spillway respectively, borrow exploration should be confined to the higher upland surfaces, preferably the area north of the left abutment.

2. Exploratory borings along the existing centerline of the dam indicate the embankment was probably constructed without an impervious cutoff trench. Therefore, cleanout and excavation of the washed out spillway structure should be conducted under full drawdown of the reservoir. This should facilitate excavation of unsuitable material from a partial cutoff trench and further excavation of the embankment at backslopes of 3 horizontal to 1 vertical.

3. The placing and compacting of fill material within the cutoff trench in the washed out area should be select material from proposed borrow excavation as specified in paragraph 1 above. In the event that select glacial drift is available from the upland surface north of the left abutment, both Standard and Modified Proctor compaction tests should be made on representative samples. The primary reason for conducting both compaction tests is to determine the response to the heavier compactive efforts on the shaley drift material.

4. In the event that CL glacial drift is available in the aforementioned borrow area, the material should be placed wet of optimum in the cutoff trench in the washed out area, and compacted to a minimum density of 95 percent of Standard Proctor density (ASTM D-698, Method A) or 90 percent of Modified Proctor density (ASTM D-1557, Method A).

5. The proposed relocation of the principal spillway pipe will cross the existing dam somewheres near the center of the embankment. The consolidation potential of the foundation deposits is unknown. Since compacted backfill will be required in this area, it is recommended that a cutoff trench be excavated through undesirable deposits and into firm shale in order to obtain a uniform foundation.

6. Glacial drift (preferably CL material) should be used as backfill and placed wet of optimum in the cutoff trench of the new location of the principal spillway pipe. The material should be compacted to a minimum density of 95 to 98 percent of Standard Proctor or 90 percent of Modified Proctor.

7. Materials represented by the samples submitted, may be used in the raising of the embankment. Although MH material is not desirable in rolled-fill construction; sand clays and lean clays of the SC and CL soil group respectively may be scarce or non-available in the glacial drift deposits.

8. Material excavated from the proposed emergency spillway should be utilized in embankment construction. The emergency spillway should be over-excavated a minimum of 1½ feet along its bottom from inlet to outlet end. Select CL glacial drift material should be used as backfill. The material should be placed at or near optimum and at 95 percent of standard density. Six inches of topsoil should be placed over the rolled compacted fill and seeded in accordance with project specifications.

NORTH DAKOTA STATE WATER COMMISSION SOILS LABORATORY

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation: D 2487

Project Name Sarnia Dam

Project No. 291

REPORT OF TESTS OF SOIL SAMPLES

ASTM Designation D 421
ASTM Designation D 422

Test Pit or Auger Hole No. 1, 3 & 5

County Nelson

Borrow Area & Location: Proposed Emergency Spillway

Sample No.	AH#1 1-1		AH#3 3-1		AH#5 5-1
Depth, Feet	1.0-4.5		1.0-7.0		1.0-4.5
(1) Gravel, Pass 3" & Retained on #4	42		15		10
(a) % Coarse Gravel (-3" + 3/4")	3		2		7
(b) % Fine Gravel (-3/4" + #4)	39		13		3
(2) Sand, Pass #4 & Retained on #200	31		33		41
(a) % Coarse Sand (-#4 + #10)	13		5		3
(b) % Medium Sand (-#10 + #40)	9		10		9
(c) % Fine Sand (-#40 + #200)	9		18		29
(3) % Silt Size (0.074-0.005 mm)	16		31		34
(4) % Clay Size (Smaller than 0.005 mm)	11		21		15
(5) % Shale & Soft Rock					
Moisture Content %					
Liquid Limit %	45		37		29
Plasticity Index	16		17		9
Shrinkage Limit %	22		16		22
Shrinkage Ratio	1.66		1.84		1.67
Specific Gravity	2.65		2.64		2.65
Color	Tan		Tan		Tan
Textural Class					
Soil Group (U.S.C.S.)	ML		CL		CL
Optimum Moisture *	29		19		17
Maximum Dry Density *	86		102		105

* By ASTM Designation D 698

The gravel and sand fraction of the above samples contains a high percentage of shale fragments.

Table 1

SWC Form #179B

NORTH DAKOTA STATE WATER COMMISSION SOILS LABORATORY

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation: D 2487

Project Name Sarnia Dam

Project No. 291

REPORT OF TESTS OF SOIL SAMPLES

ASTM Designation D 421
ASTM Designation D 422

Test Pit or Auger Hole No. 6 & 7

County Nelson

Borrow Area & Location

Sample No.	AH#6 6-1		AH#7 7-1		AH#7 7-2
Depth, Feet	1.0 - 5.0		1.0 - 3.5		3.5 - 5.5
(1) Gravel, Pass 3" & Retained on #4	49		35		41
(a) % Coarse Gravel (-3" + 3/4")	12		3		11
(b) % Fine Gravel (-3/4" + #4)	37		32		30
(2) Sand, Pass #4 & Retained on #200	28		37		30
(a) % Coarse Sand (-#4 + #10)	11		21		14
(b) % Medium Sand (-#10 + #40)	12		11		11
(c) % Fine Sand (-#40 + #200)	5		5		5
(3) % Silt Size (0.074-0.005 mm)	14		19		20
(4) % Clay Size (Smaller than 0.005 mm)	9		9		9
(5) % Shale & Soft Rock					
Moisture Content %					
Liquid Limit %	66		66		68
Plasticity Index	23		19		21
Shrinkage Limit %	35		41		37
Shrinkage Ratio	1.33		1.23		1.27
Specific Gravity	2.50		2.52		2.42
Color	Tan		Tan		Tan
Textural Class					
Soil Group (U.S.C.S.)	MH		MH		MH
Optimum Moisture *	38		43		43
Maximum Dry Density *	74		71		69

* By ASTM Designation D 698

The gravel and sand fraction of the above samples contains a very high percentage of shale fragments

Table 2

SWC Form #179B

V. ENGINEERING ANALYSIS

A. HYDROLOGIC INVESTIGATION

The TR-20 computer program developed by the U.S. Soil Conservation Service was used to determine the peak discharge and corresponding flow volumes for various frequency storms. The program formulates a mathematical model of the watershed based on the following input data: rainfall distribution, type of soil, soil moisture condition, land use, time of concentration, hydraulic characteristics of the channels and the size of the drainage area. The hydrologist must make accurate estimates of the data to formulate an accurate model of the watershed. The program was used to generate an inflow hydrograph for Sarnia Dam to determine the size of the principal spillway pipe and emergency spillway channel. Explanation of the more important input data are given in the following paragraphs.

Cover complex numbers (CN) are used in estimating direct runoff from rainfall and snowmelt. To determine cover complex numbers, the soil type needs to be determined from county soil maps. There are four major soil groups used for the primary classifications of soils. They are as follows:

Group A - Soils having high infiltration rates even when throughly wetted, consisting chiefly of deep, well to excessively drained sands and/or gravel. These soils have a high rate of water transmission and would result in a low runoff potential.

Group B - Soils having moderate infiltration rates when thoroughly wetted, consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately coarse textures. These soils have a moderate rate of water transmission.

Group C - Soils having slow infiltration rates when thoroughly wetted, consisting chiefly of (1) soils with a layer that impedes the downward movement of water, or (2) soils with moderately fine to fine texture and a slow infiltration rate. These soils have a slow rate of water transmission.

Group D - Soils having very slow infiltration rates when thoroughly wetted, consisting chiefly of (1) clay soils with a high swelling potential, (2) soils with a high permanent water table, (3) soils with claypan or clay layer near the surface, and (4) shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission.

The soils are grouped without considering slope as a variable and without considering the benefit of vegetative cover. The cover complex numbers are further adjusted for each drainage basin in the watershed by determining the characteristics of the land use. The soil encountered in the analysis of Sarnia Dam consisted of about 78% type B and 22% type C. The land use is given below:

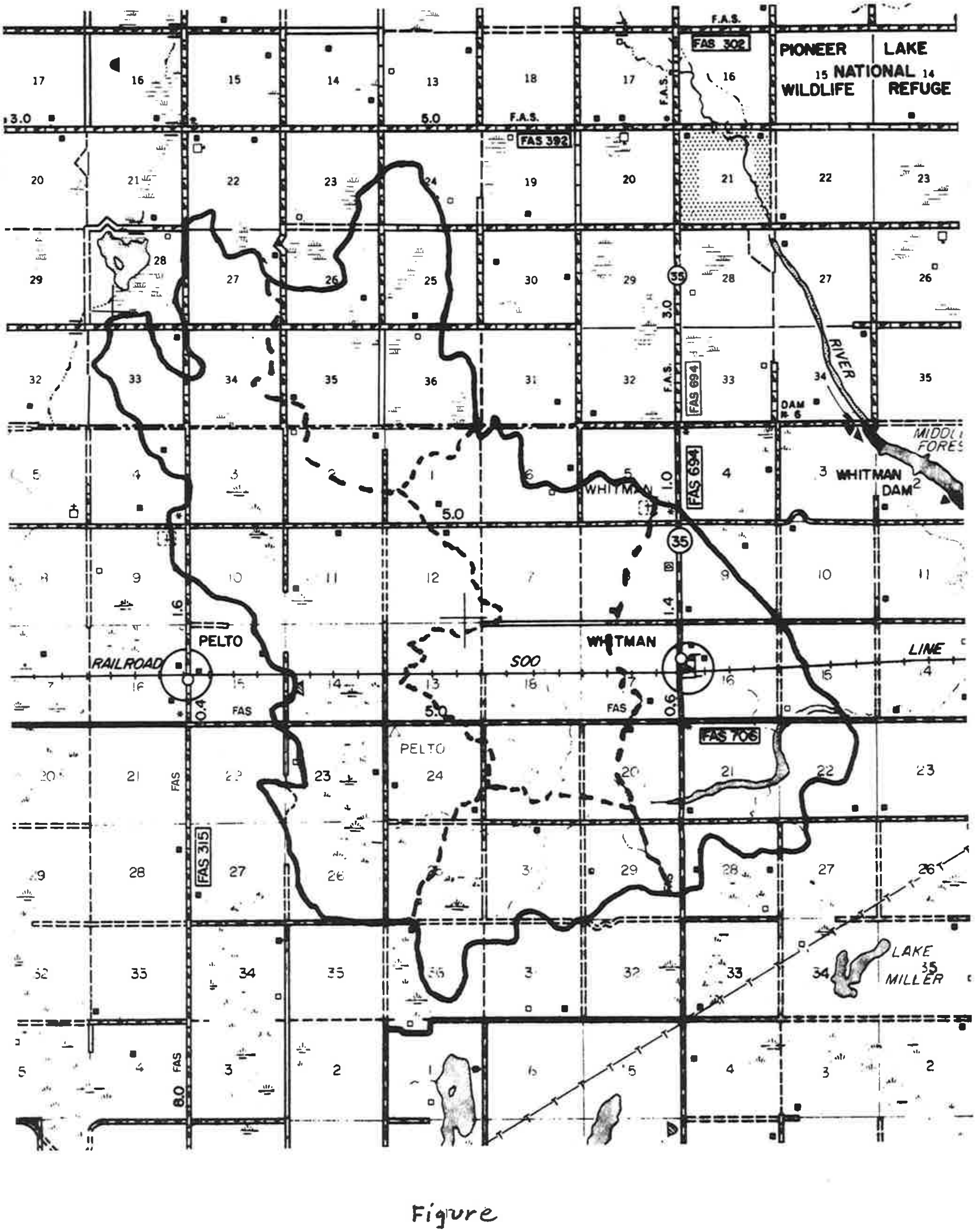
Land Use

75%	Small grain crops
10%	Pasture
10%	Ponds and Sloughs
4%	Farmsteads
1%	Roads
100%	Total

The time of concentration (Tc) denotes that amount of time required for water to travel from the furthermost point of the drainage area to its outlet. The method most commonly used by the State Water Commission is called the "Upland Method". This method involves separating the different flow conditions for each drainage area and determining the length, drop and slope of the drainage area. Charts based on Mannings equation are used to obtain the velocity for the various flow conditions using the slope of the area. When a velocity has been obtained, the time of concentration is determined by dividing the length of flow reach by the velocity. The time of concentration will determine the time of the peak flow from an area.

The amount of precipitation for a certain frequency rainstorm or snowfall is determined by using maps available from the National Weather Service, which show the precipitation amount in inches for North Dakota. After the amount of precipitation is determined for the storm frequencies to be analyzed, the amount of precipitation is adjusted to reflect the amount of ponding areas within the drainage area. Generally, the more ponding areas in a drainage area, the less the runoff will be. To reflect this decrease in runoff, the amount of precipitation is reduced accordingly.

The total contributing drainage area is 26 square miles as shown on Figure 2. The system was analyzed for runoff from rainfall as well as from snowmelt. The rainfall is given as the number of inches that would occur over a 24 hour period and the snowmelt is specified as inches of runoff that would occur over a 10 day period. It was found that the snowmelt produced the larger runoff, therefore, it was used for the design hydrograph.



F.A.S.
FAS 302
PIONEER LAKE NATIONAL WILDLIFE REFUGE
F.A.S.
FAS 392
5.0
RIVER
DAM #6
MIDDLE FOREST
WHITMAN DAM
WHITMAN
FAS 694
5.0
PELTO
RAILROAD
SOO
WHITMAN
LINE
FAS
FAS
FAS 706
PELTO
FAS 315
LAKE MILLER

Figure

15

The 100 year frequency rainfall on the watershed is approximated by 4.91 inches falling in a 24 hour period. Likewise, a snowmelt of 100 year frequency on the watershed in approximated by 4.51 inches of runoff that would occur over a 10 day period.

The discharges and elevations for the various frequency storms that could occur in the natural channel are shown in Table 3. These elevations are the elevations that the flood waters would reach in the natural channel for the respective discharges and frequency storms.

Table 3

Rainfall

Natural Channel

Frequency (years)	Discharge (cubic ft. per sec.)	Elevation (MSL)
5	296	1506.4
10	416	1506.6
25	582	1506.9
50	756	1507.2
100	957	1507.5

Snowmelt

Natural Channel

Frequency (years)	Discharge (cubic ft. per sec.)	Elevation (MSL)
10	357	1506.5
25	526	1506.8
50	697	1507.1
100	864	1507.3

B. HYDRAULIC INVESTIGATION

Sarnia Dam is to be reconstructed as a dry dam for the purpose of providing flood protection for agricultural land downstream of the dam, and to reduce the effects of upstream agricultural drainage on downstream landowners. In the design of the principal spillway, the main objective was to maximize the reduction of the flows out of the spillway during the more frequent runoff such as the 5, 10 and 25 year frequency. This was done since generally the impact of agricultural drainage on downstream flows is greatest during these lesser flows compared to its impact on the 50 year or 100 year frequency runoff. Even though the objective was to maximize reduction of flows on the more frequent runoff periods, the effect on the larger runoff periods, such as the 50 year and 100 year, was determined.

The computer program, TR-20, was used to flood route various rainfall and snowmelt conditions through the reservoir. Alternative sized principal spillways were compared in order to maximize flow reductions. Appendix A contains the summary of the various pipe size alternatives.

C. PRINCIPAL SPILLWAY WORKS

As stated above, in sizing and designing the principal spillway works, the criteria, which had to be met, was to provide the greatest percent reduction between the inflow and outflow flood waters. This criteria was met by using a 24 inch diameter CMP low level drain, a 54 inch diameter CMP riser, and a 42 inch diameter CMP spillway pipe. The invert of the 24 inch diameter CMP is to be established at elevation 1497.0 msl. The crest of the 54 inch diameter CMP riser is to be established at 1503 msl and the invert at the outlet of the 42 inch diameter CMP is to be established at elevation 1496 msl (See Figure 3). The emergency spillway elevation is set at 1508 msl. The various rainfall and snowmelt conditions that were flood routed through the reservoir by the TR-20 for the principal spillway are shown in Table 4.

Table 4 Reservoir Operational Data

Rainfall

Frequency (years)	Natural Channel Discharge (cfs)	Natural Channel Elevation (msl)	With Dam Discharge (cfs)	With Dam Elevation (msl)	% Reduction	Time of Flow Over Emergency Spillway
5	296	1506.4	86	1504.2	71	
10	416	1506.6	100	1505.4	76	
25	582	1506.9	112	1506.9	81	
50	756	1507.2	170	1508.2	78	13 hours
100	957	1507.5	353	1508.9	63	25 hours

Snowmelt

Frequency (years)	Natural Channel Discharge (cfs)	Natural Channel Elevation (msl)	With Dam Discharge (cfs)	With Dam Elevation (msl)	% Reduction	Time of Flow Over Emergency Spillway
10	357	1506.5	98	1505.2	72	
25	526	1506.8	114	1507.2	78	
50	697	1507.1	230	1508.5	67	31 hours
100	864	1507.3	395	1509.1	54	41 hours

As can be seen there is a 81% reduction in the 25 year rainfall runoff and a 63% reduction in the 100 year rainfall runoff. A graphical representation of the 100 year rainfall and snowmelt discharge hydrographs are illustrated in Figure 4 and 5 respectively. Figure 6 is the reservoir area-capacitycurve used in the flood routing.

Before Sarnia Dam washed out in the spring of 1978 the principal spillway consisted of a 6 foot by 6 foot concrete box inlet established at elevation 1502.6 msl and a 36 inch diameter CMP spillway pipe. The emergency spillway was 50 feet wide and established at elevation 1504.5 msl.

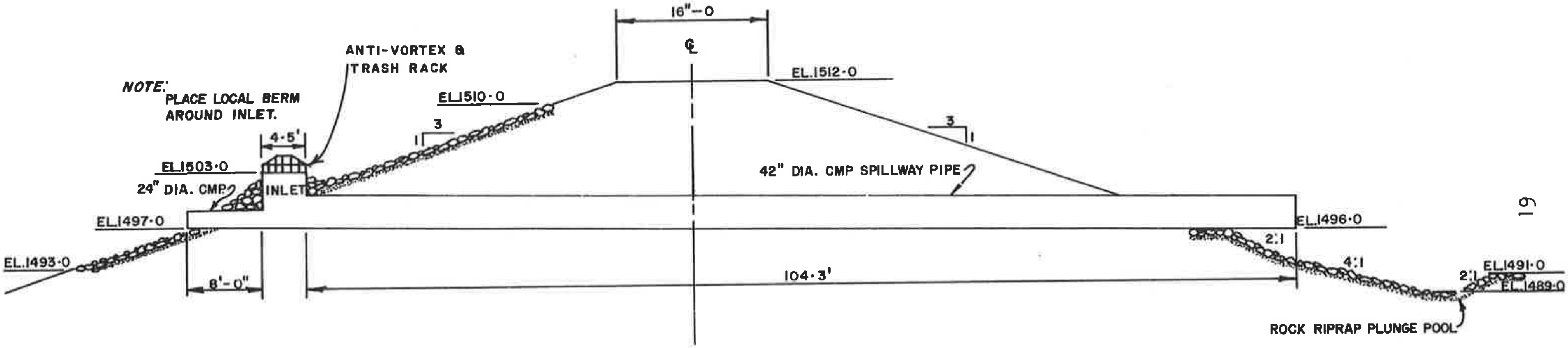


Figure 3

TYPICAL CROSS SECTION OF DAM AT MAIN SPILLWAY

NO SCALE

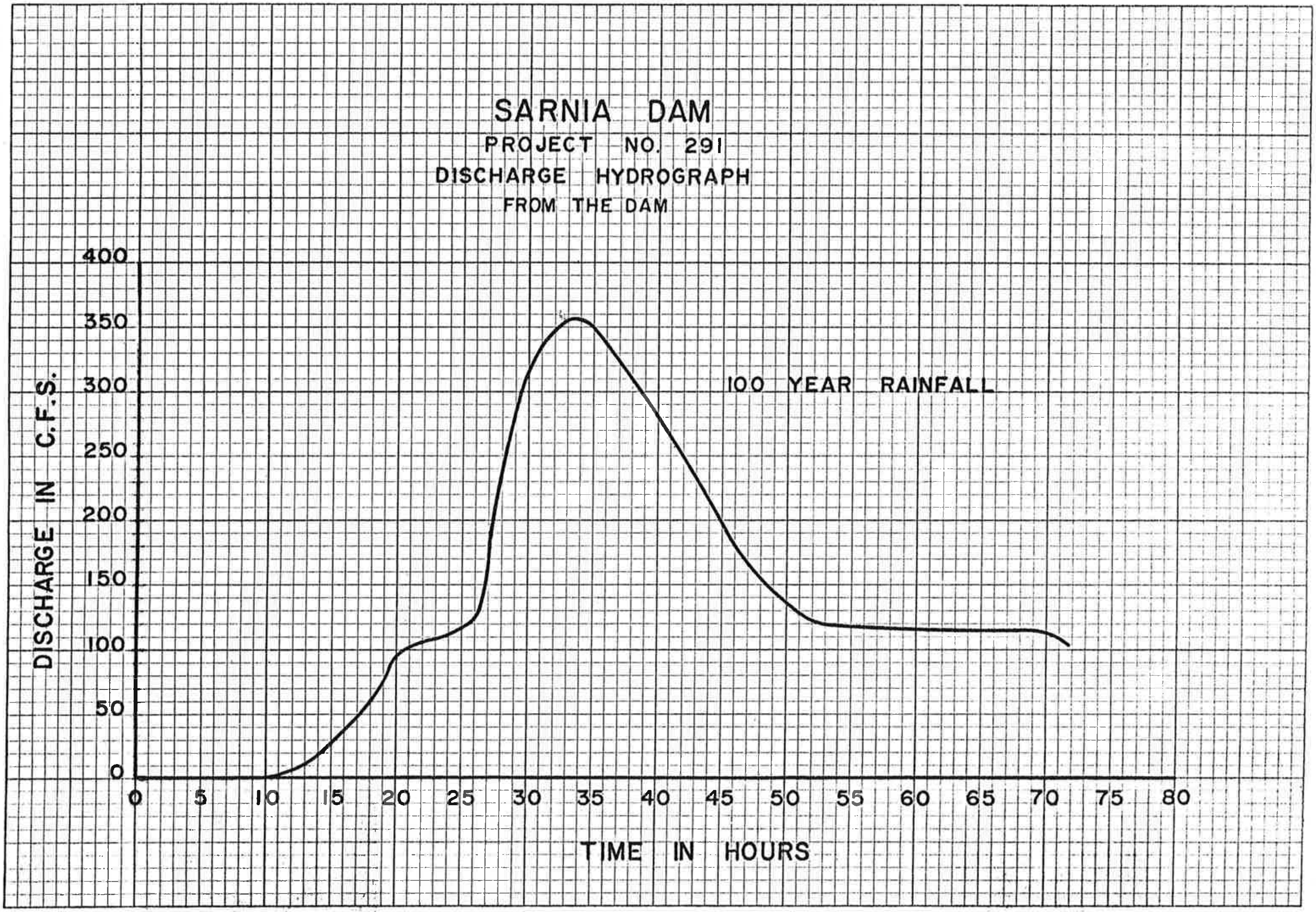

SARNIA DAM
PROJECT NO. 291
DISCHARGE HYDROGRAPH
FROM THE DAM
100 YEAR RAINFALL
DISCHARGE IN C.F.S.
0
50
100
150
200
250
300
350
400
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
TIME IN HOURS

Figure 4

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 0782

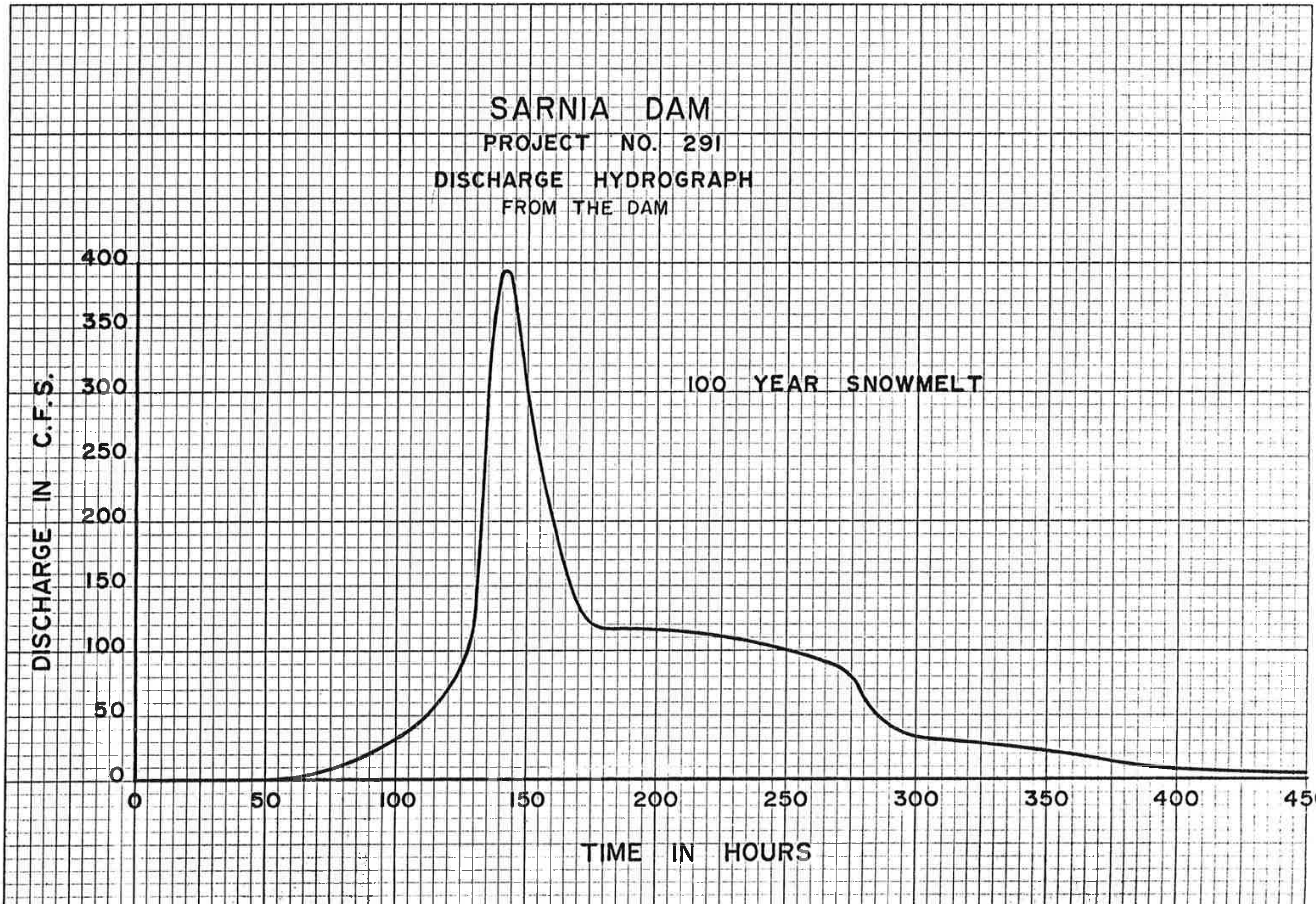


Figure 5

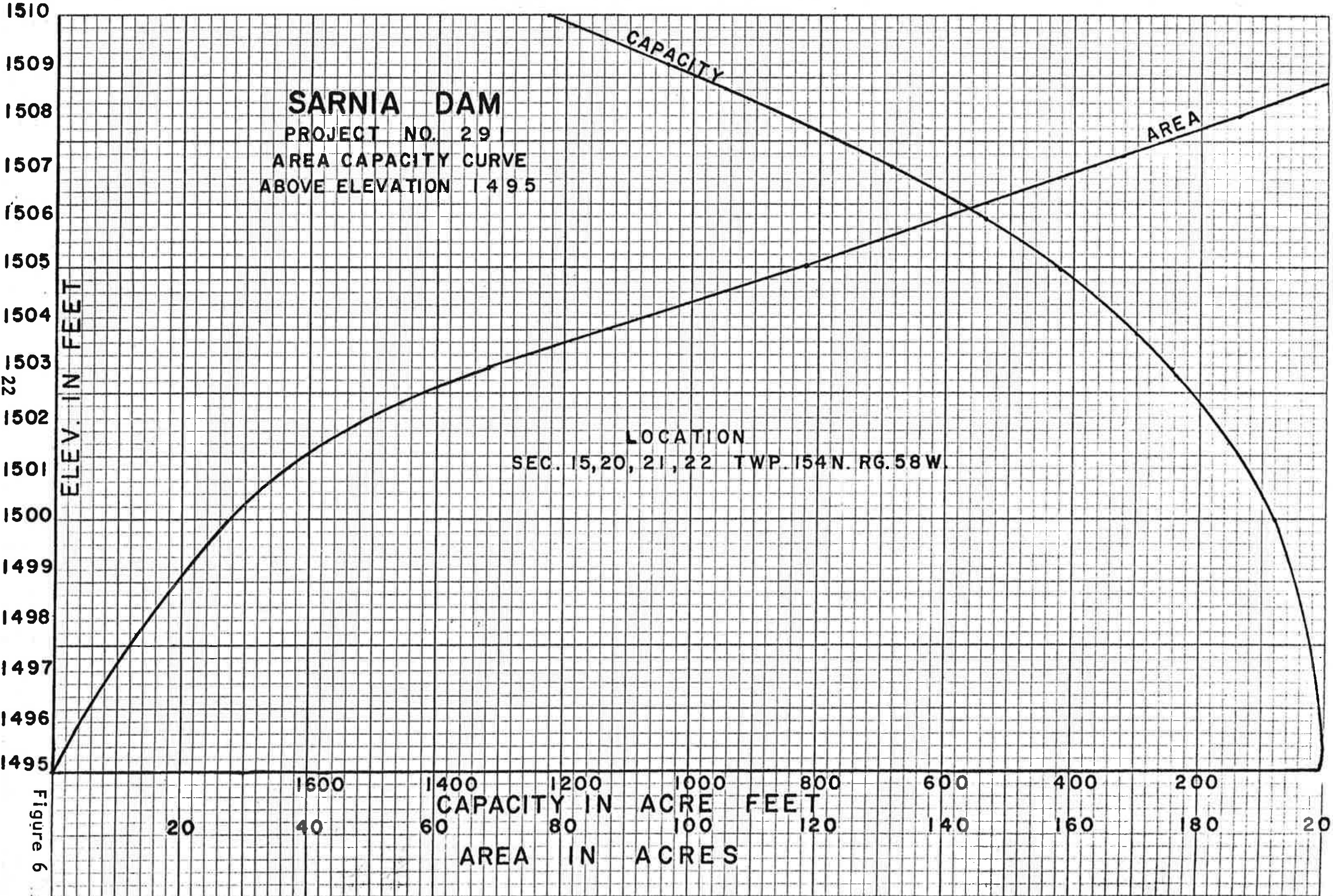

SARNIA DAM
PROJECT NO. 291
AREA CAPACITY CURVE
ABOVE ELEVATION 1495
LOCATION
SEC. 15, 20, 21, 22 TWP. 154 N. RG. 58 W.
CAPACITY
AREA
ELEV. IN FEET
1510
1509
1508
1507
1506
1505
1504
1503
1502
1501
1500
1499
1498
1497
1496
1495
1600
1400
1200
1000
800
600
400
200
CAPACITY IN ACRE FEET
20
40
60
80
100
120
140
160
180
200
AREA IN ACRES

Figure 6

Referring to table 5 it can be seen that there was a 26% reduction in the 25 year rainfall runoff and a 21% reduction in the 100 year rainfall runoff as compared to a 81% and 63% reduction in the 25 and 100 year rainfall runoff respectively of the proposed new Sarnia Dam spillway. As can be seen from these figures not only is the percent reduction of runoff in the more frequent storms (5, 10, and 25 year) greatly increased but also the percent reduction of runoff in the larger frequency storms (50 and 100 year) has been greatly increased.

The outlet structure of the spillway is a rock plunge pool. The design of the plunge pool is shown in appendix B. An outlet channel approximately 800 feet long, 15 feet wide and 2 feet deep with 4 on 1 side slopes, will be constructed to provide adequate discharge of flood waters.

D. EMERGENCY SPILLWAY

The emergency spillway would consist of a grassed waterway with a bottom width of 85 feet and side slopes of 4 horizontal to 1 vertical. The elevation of the control section will be set at 1508 msl. Referring back to Table 4 it can be seen that the flood waters from a 50 or a 100 year frequency snowmelt will reach an elevation of 1508.5 and 1509.1 msl respectively. Therefore there will be .5 feet of water flowing in the emergency spillway during the 50 year frequency snowmelt and 1.1 feet of water flowing in the emergency spillway during the 100 year frequency snowmelt. With the elevation of the top of the dam set at 1512 msl there will be 3.5 feet of freeboard during the 50 year frequency snowmelt and 2.9 feet of freeboard during the 100 year frequency snowmelt.

Table 5 Comparison of Discharges and Reservoir Elevations between Previous Structure and Proposed Structure

Freq. (yrs.)	Natural Channel Discharge (cfs)	Natural Channel Elev. (msl)	Flows With Previous Structure Discharge (cfs)	Flows With Previous Structure Elev. (msl)	% Reduction	Time of Flow Over Emergency Spillway	Flows With Proposed Structure Discharge (cfs)	Flows With Proposed Structure Elev. (msl)	% Reduction	Time of Flow Over Emergency Spillway
5	296	1506.4	171	1505.2	42	21 hrs. 5 min.	86	1504.2	71	
10	416	1506.6	285	1505.7	31	27 hrs. 45 min.	100	1505.4	76	
25	582	1506.9	432	1506.2	26	32 hrs. 15 min.	112	1506.9	81	
50	756	1507.2	584	1506.7	23	35 hrs. 20 min.	170	1508.2	78	13 hrs.
100	957	1507.5	755	1507.2	21	37 hrs. 55 min.	353	1508.9	63	25 hrs.

E. SUMMARY OF PROJECT FEATURES

1) Drainage Area - 26 square miles

2) Reservoir Capacity at Riser Inlet (1503 msl.) - 240 acre-feet

3) Reservoir Area at Riser Inlet (1503 msl) - 68 acres

4) Reservoir Capacity at Emergency Spillway (1508 msl) - 840 acre-feet

5) Reservoir Area at Emergency Spillway (1508 msl) - 186 acres

6) 100 year water surface elevation - 1509.1 msl

7) 100 year discharge - 395 cfs

8) Invert of 24 inch CMP lowlevel drain - 1497.0 msl

9) Crest elevation of 54 inch CMP riser - 1503.0 msl

10) Invert of outlet 42" CMP - 1496.0 msl

11) Emergency spillway crest elevation - 1508.0 msl

12) Embankment crest elevation - 1512.0 msl

13) Freeboard clearance at maximum elevation - 2.9 feet

F. PROJECT COSTS

Reconstruction of Sarnia Dam is estimated to cost approximately $52,225. The detailed cost estimate is shown in Table 6. It should be noted that this cost estimate does not include necessary land easements.

Table 6

Dam Cost Estimate

Item	Quantity	Unit Price	Cost
Salvaging & Spreading Top Soil	18,364 sq. yd.	$.20/sq. yd.	$ 3,673
Borrow Excavation	15,717 c.y.	$1.00/c.y.	15,717
Rock Riprap	472 c.y.	20.00/c.y.	9,440
Rock Riprap Filter Material	160 c.y.	8.00/c.y.	1,280
Seeding	3.8 acres	200.00/acre	760
Excavation of Outlet Channel	1,111 c.y.	1.00/c.y.	1,111
54" Diameter CMP Riser	7 feet	102.00/foot	714
24" Diameter CMP Low Level Drain	8 feet	56.00/foot	448
24" Water Tight Bands	1 Band	90.00/Band	90
42" Diameter CMP Spillway Pipe	105 feet	63.00/feet	6,615
42" Water Tight Bands	4 Bands	183.00/Band	732
Trash Rack & Anti Vortex Device	1	1,200	1,200
		Subtotal	$41,780
		Contingencies	4,178
		Engineering, Contract Administration and Construction Inspection	6,267
		Total	$52,225

VI. ENVIRONMENTAL SURVEY

The following environmental survey gives an overview of the positive and negative environmental impacts that would result from the implementation of this project. This is not intended to be a comprehensive environmental assessment, however, it will identify subjects that would be analysed in detail in an environmental assessment. In the following paragraphs several environmental categories are identified and discussed specifically for the watershed of Sarnia Dam.

LAND USE

The watershed at Sarnia Dam currently has the following land use breakdown:

Small Grain Crops	75%
Pasture	10%
Ponds and Sloughs	10%
Farmsteads	4%
Roads	1%
	100%

It should be noted that all easements for lands which will be inundated during flood periods will have to be obtained before construction can begin. Lands which will be inundated will mainly be pasture land. The land use of the remaining portions of the watershed will not be altered as a result of this project.

AESTHETICS

The embankment and the area that would be inundated by flood water will not conform to the natural environment. Silt deposition may occur within the water retention area. The rock riprap placed on the upstream side of the embankment will be exposed except during flood periods. Also the plunge pool outlet to the principal spillway will be covered with rock riprap. The specific items mentioned above will not create an aesthetically pleasing landscape within the vicinity of the dam.

It should be noted the embankment, emergency spillway, and the borrow area will be seeded with native grasses.

DOWNSTREAM FLOOD FLOWS

The purpose of this project is to provide flood protection for agricultural land downstream of Sarnia Dam. The proposed project will provide flood protection from the 100 year flood.

FISH AND WILDLIFE

The existing reservoir was not of sufficient depth to maintain fish life. Likewise, the proposed project, which is a dry dam, will not support fish life. No field data has been obtained on wildlife population within the watershed. The proposed project will not change the wildlife habitat significantly.

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

All materials, labor, and energy used in the construction of the project would be irretrievable.

VII. SUMMARY

The purpose of this report was to present plans for reconstruction of Sarnia Dam to act as a dry dam. In order to maximize the reduction of the impacts of upstream drainage, an attempt was made to maximize the reduction of the 10 year and 25 year frequency runoff. This was done by selecting a 42 inch CMP as the principal spillway pipe.

Rebuilding Sarnia Dam will cost approximately $52,225 and will provide a 78 percent reduction between the inflow and outflow flood waters of a 25 year snowmelt. It will also provide a 81 percent reduction between the inflow and outflow flood waters of a 25 year rainfall. This will provide valuable flood protection for agricultural lands downstream.

The studies show that both from a geological and hydrological standpoint, the dam can be reconstructed at the present site. Therefore, from a technical aspect, the project can be considered feasible.

The local sponsors must determine whether this project is feasible on a financial basis.

APPENDIX A

ALTERNATE PRINCIPAL SPILLWAYS

Alternate 1: 72" Pipe at Elevation 1495 and 85' Emergency Spillway at Elevation 1506

Storm (years)	Natural Channel Discharge (cfs)	Natural Channel Elevation (msl)	With Dam Discharge (cfs)	With Dam Elevation (msl)	% Reduction	Time of Flow Over Emergency Spillway
5	296	1506.4	187	1501.9	37	
10	416	1506.6	248	1503.1	40	
25	582	1506.9	303	1504.7	48	
50	756	1507.2	366	1506.1	52	5 hrs. 5 min.
100	957	1507.5	574	1506.9	40	15 hr. 40 min.

Alternate 2: 60" Riser at Elevation 1503, 24" Lowlevel Drain at Elevation 1495, 48" Outlet Pipe and 85' Emergency Spillway at Elevation 1506

Storm (years)	Natural Channel Discharge (cfs)	Natural Channel Elevation (msl)	With Dam Discharge (cfs)	With Dam Elevation (msl)	% Reduction	Time of Flow Over Emergency Spillway
5	296	1506.4	93	1504.1	69	
10	416	1506.6	143	1505.1	66	
25	582	1506.9	234	1506.3	60	13 hrs. 15 min.
50 Snow	697	1507.1	409	1507.0	41	30 hrs.
50 Rain	756	1507.2	398	1507.0	47	21 hrs. 35 min.
100 Snow	864	1507.3	572	1507.6	34	37 hrs.
100 Rain	957	1507.5	574	1507.6	40	26 hrs. 20 min.

Alternate 3: 54" Pipe at Elevation 1495 and 85' Emergency Spillway at Elevation 1506

Storm (years)	Natural Channel Discharge (cfs)	Natural Channel Elevation (msl)	With Dam Discharge (cfs)	With Dam Elevation (msl)	% Reduction	Time of Flow Over Emergency Spillway
5	296	1506.4	144	1502.5	51	
10	416	1506.6	171	1504.1	59	
25	582	1506.9	195	1505.8	67	
50	756	1507.2	373	1506.7	51	17 hrs.
100	957	1507.5	559	1507.4	42	22 hrs. 55 min.

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Alternate 4: 60" Riser at Elevation 1503, 24" Lowlevel Drain at Elevation 1495, 54" Outlet Pipe, and 85' Emergency Spillway at Elevation 1506

Storm	Natural Channel		With Dam		% Reduction	Time of Flow Over Emergency Spillway
	Discharge	Elevation	Discharge	Elevation		
(years)	(cfs)	(msl)	(cfs)	(msl)		
5	296	1506.4	95	1504.1	68	
10	416	1506.6	175	1504.9	58	
25	582	1506.9	241	1506.2	59	9 hrs. 30 min.
50 Snow	697	1507.1	418	1506.9	40	25 hrs.
50 Rain	756	1507.2	409	1506.9	46	18 hrs. 55 min.
100 Snow	864	1507.3	580	1507.5	33	32 hours
100 Rain	957	1507.5	585	1507.5	39	23 hrs. 55 min

Alternate 5: 60" Riser at Elevation 1503, 24" Lowlevel Drain at Elevation 1495, 42" Outlet Pipe, and 85' Emergency Spillway at Elevation 1507

Storm	Natural Channel		With Dam		% Reduction	Time of Flow Over Emergency Spillway
	Discharge	Elevation	Discharge	Elevation		
(years)	(cfs)	(msl)	(cfs)	(msl)		
5	296	1506.4	93	1504.1	69	
10	416	1506.6	143	1505.1	66	
25	582	1506.9	157	1506.5	73	
50 Snow	697	1507.1	318	1507.6	54	25 hrs.
50 Rain	756	1507.2	293	1507.5	61	16 hrs. 30 min.
100 Snow	864	1507.3	484	1508.3	44	33 hrs.
100 Rain	957	1507.5	473	1508.2	51	23 hrs. 50 min.

Alternate 6: 54" Riser at Elevation 1503, 24" Lowlevel Drain at Elevation 1495, 42" Outlet Pipe and 85' Emergency Spillway at Elevation 1506

Storm	Natural Channel		With Dam		% Reduction	Time of Flow Over Emergency Spillway
	Discharge	Elevation	Discharge	Elevation		
(years)	(cfs)	(msl)	(cfs)	(msl)		
5	296	1506.4	87	1504.1	71	
10	416	1506.6	109	1505.3	74	
25	582	1506.9	228	1506.5	61	17 hrs.
50 Snow	697	1507.1	403	1507.2	42	36 hrs.
50 Rain	756	1507.2	390	1507.1	48	24 hrs. 35 min.
100 Snow	863	1507.3	566	1507.7	34	45 hrs.
100 Rain	957	1507.5	565	1507.8	41	29 hrs. 15 min.

Alternate 7: 54" Riser at Elevation 1503, 24" Lowlevel Drain at Elevation 1495, 42" Outlet Pipe, and 85' Emergency Spillway at Elevation 1507

Storm (years)	Natural Channel Discharge (cfs)	Natural Channel Elevation (msl)	With Dam Discharge (cfs)	With Dam Elevation (msl)	% Reduction	Time of Flow Over Emergency Spillway
5	296	1506.4	87	1504.1	71	
10	416	1506.6	109	1505.3	74	
25 Snow	526	1506.8	119	1506.9	77	
25 Rain	582	1506.9	119	1506.8	80	
50 Snow	697	1507.1	314	1507.8	55	32 hrs.
50 Rain	756	1507.2	289	1507.7	62	20 hrs. 10 min.
100 Snow	864	1507.3	478	1508.4	45	42 hrs.
100 Rain	957	1507.5	464	1508.4	52	26 hrs. 50 min.

Alternate 8: 54" Riser at Elevation 1503, 24" Lowlevel Drain at Elevation 1495, 42" Outlet Pipe and 85' Emergency Spillway at Elevation 1508

Storm (years)	Natural Channel Discharge (cfs)	Natural Channel Elevation (msl)	With Dam Discharge (cfs)	With Dam Elevation (msl)	% Reduction	Time of Flow Over Emergency Spillway
5	296	1506.4	87	1504.1	71	
10 Snow	357	1506.5	105	1505.0	70	
10 Rain	416	1506.6	109	1505.3	74	
25 Snow	526	1506.8	119	1506.9	77	
25 Rain	582	1506.9	119	1506.8	79	
50 Snow	697	1507.1	210	1508.3	70	24 hrs.
50 Rain	756	1507.2	164	1508.2	78	11 hrs. 30 min.
100 Snow	864	1507.3	378	1509.0	56	39 hrs.
100 Rain	957	1507.5	350	1508.9	63	24 hrs. 10 min.

Alternate 9: 54" Riser at Elevation 1503, 24" Lowlevel Drain at Elevation 1497, 42" Outlet Pipe and 85' Emergency Spillway at Elevation 1508

Storm (years)	Natural Channel Discharge (cfs)	Natural Channel Elevation (msl)	With Dam Discharge (cfs)	With Dam Elevation (msl)	% Reduction	Time of Flow Over Emergency Spillway
5	296	1506.4	87	1504.2	71	
10 Snow	357	1506.5	98	1505.2	72	
10 Rain	416	1506.6	100	1505.4	76	
25 Snow	526	1506.8	114	1507.2	78	
25 Rain	582	1506.9	112	1506.9	81	
50 Snow	697	1507.1	230	1508.5	67	31 hrs.
50 Rain	756	1507.2	170	1508.2	78	12 hrs. 50 min.
100 Snow	864	1507.3	395	1509.1	54	41 hrs.
100 Rain	957	1507.5	353	1509.0	63	24 hrs. 45 min.

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The original Sarnia Dam box inlet and pipe that were washed out, 6'x6' box inlet at Elevation 1502.6, 36" Outlet Pipe with a 50' Emergency Spillway at Elevation 1504.5

Storm (years)	Natural Channel Discharge (cfs)	Natural Channel Elevation (msl)	With Dam Discharge (cfs)	With Dam Elevation (msl)	% Reduction	Time of Flow Over Emergency Spillway
5	296	1506.4	171	1505.2	42	21 hrs. 5 min.
10	416	1506.6	285	1505.7	31	27 hrs. 45 min.
25	582	1506.9	432	1506.2	26	32 hrs. 15 min.
50	756	1507.2	584	1506.7	23	35 hrs. 20 min.
100	957	1507.5	755	1507.2	21	37 hrs. 55 min.

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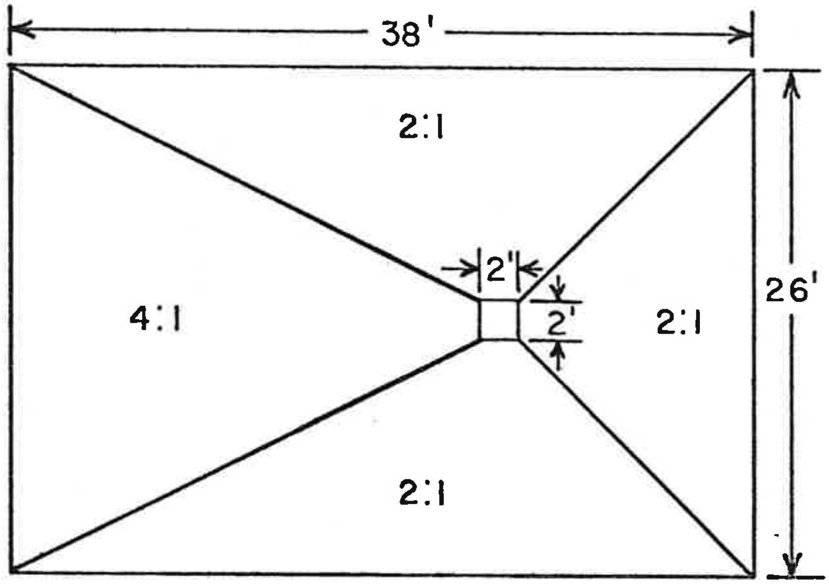
APPENDIX B

DESIGN OF OUTLET BASIN



<u>Volume ABCD</u>

$$\text{Volume} = \int_0^6 (2 + 6x)\ (2 + 4x)\ dx$$

$$= (4 + 20x + 24x^2)\ dx$$

$$= 4dx + 20x\ dx + 24x^2\ dx$$

$$= \Big/_0^6 4x + \Big/_0^6 \frac{20x^2}{2} + \Big/_0^6 \frac{24x^3}{3}$$

$$= 24 + 360 + 1728$$

$$= 2112 \text{ feet}^3$$

<u>Volume EFGH</u>

$$\text{Volume} = \int_0^4 (2 + 6x)\ (2 + 4x)\ dx$$

$$= \int_0^4 (4 + 20x + 24x^2)\ dx$$

$$= 4dx + 20x\ dx + 24x^2\ dx$$

$$= \Big/_0^4 4x + \Big/_0^4 \frac{20x^2}{2} + \Big/_0^4 \frac{24x^3}{3}$$

$$= 16 + 160 + 512$$

$$= 688 \text{ feet}^3$$

Volume of riprap & filter material = 2112 - 688 = 1424 ft^3

Volume of Filter Material

$$\text{Volume} = \int_0^6 (2 + 6x)\ (2 + 4x)\ dx$$

$$= \int_0^6 (4 + 20x + 24x^2) dx$$

$$= /_0^6 4x \ + /_0^6 \frac{20x^2}{2} \ + /_0^6 \frac{24x^3}{3}$$

$$= 2112 \text{ feet}^3$$

$$\text{Volume} = \int_0^{5\frac{1}{2}} (2 + 6x)\ (2 + 4x)\ dx$$

$$= \int_0^{5\frac{1}{2}} (4 + 20x + 24x^2)\ dx$$

$$= /_0^{5\frac{1}{2}} 4x \ + /_0^{5\frac{1}{2}} \frac{20x^2}{2} \ + /_0^{5\frac{1}{2}} \frac{24x^3}{3}$$

$$= 1655.5 \text{ feet}^3$$

Volume of Filter Material = 2112 ft^3 - 1655.5 ft^3 = 456.5 ft^3

Volume of Rock Riprap

$$\text{Volume} = \int_0^{5\frac{1}{2}} (2 + 6x)\ (2 + 4x)\ dx$$

$$= \int_0^{5\frac{1}{2}} (4 + 20x + 24x^2)\ dx$$

$$= /_0^{5\frac{1}{2}} 4x \ + /_0^{5\frac{1}{2}} \frac{20x^2}{2} \ + /_0^{5\frac{1}{2}} \frac{24x^3}{3}$$

$$= 1655.5 \text{ feet}^3$$

$$\text{Volume} = \int_0^4 (2 + 6x)\ (2 + 4x)\ dx$$

$$= \int_0^4 (4 + 20x + 24x^2)\ dx$$

$$= /_0^4 4x \ + /_0^4 \frac{20x^2}{2} \ + /_0^4 \frac{24x^3}{3}$$

$$= 688 \text{ feet}^3$$

Volume of Rock Riprap = 1655.5 ft^3 - 688 ft^3 = 967.5 ft^3

Volume JEI

$$\frac{Lbh}{2} = \frac{(26)(6)(3)}{2} = 234\ ft^3$$

Volume INM

$$\frac{Lbh}{2} = \frac{(26)(2)(1)}{2} = 26\ ft^3$$

Volume IKL

$$\frac{Lbh}{2} = \frac{26\ (3)(3)}{2} = 117\ ft^3$$

b = base
h = height
L = length

Volume of Riprap & Filter Material = $234\ ft^3 - 26\ ft^3 = 208\ ft^3$

Volume of Rock Riprap = $234\ ft^3 - 117\ ft^3 = 117\ ft^3$

Volume of Filter Material = $117\ ft^3 - 26\ ft^3 = 91\ ft^3$

Additional rock riprap needed for additional rock riprap placed approximately 4' beyond outer dimensions of plunge pool

Volume of BOP

$$\frac{2(4)(26)}{2} = 104\ ft^3$$

$$\frac{2(4)(26)}{2} = 104\ ft^3$$

$$\frac{2(4)(26)}{2} = 104\ ft^3$$

Volume of RJKS

$1.5(4)(26) = 156\ Ft^3$ Rock Riprap

$.5\ (4)(26) = 52\ ft^3$ Filter Material

Total Volume of Riprap Used for Outlet Basin

$$967.5\ ft^3 + 117\ ft^3 + 3(104\ ft^3) + 156\ ft^3 = 1552.5\ ft^3$$

$$1552.5\ ft^3 \frac{(1\ yd^3)}{(27\ ft^3)} = 57.5\ yd^3$$

Total Volume of Filter Material Used for Outlet Basin

$$456.5\ ft^3 + 91\ ft^3 + 52\ ft^3 = 599.5\ ft^3$$

$$599.5\ ft^3 \frac{(1\ yd^3)}{(27\ ft^3)} = 22.2\ yd^3$$

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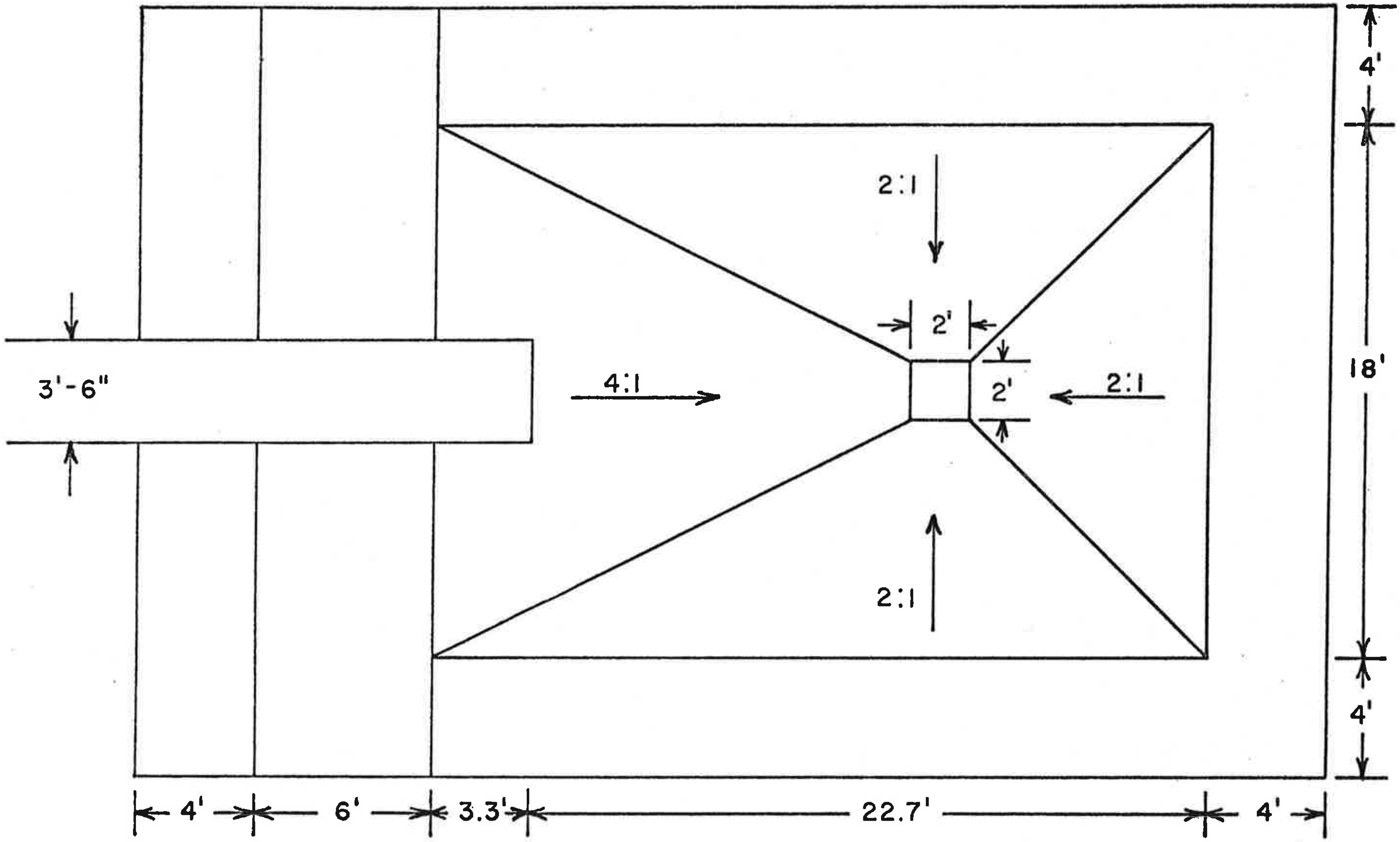

OUTLET BASIN

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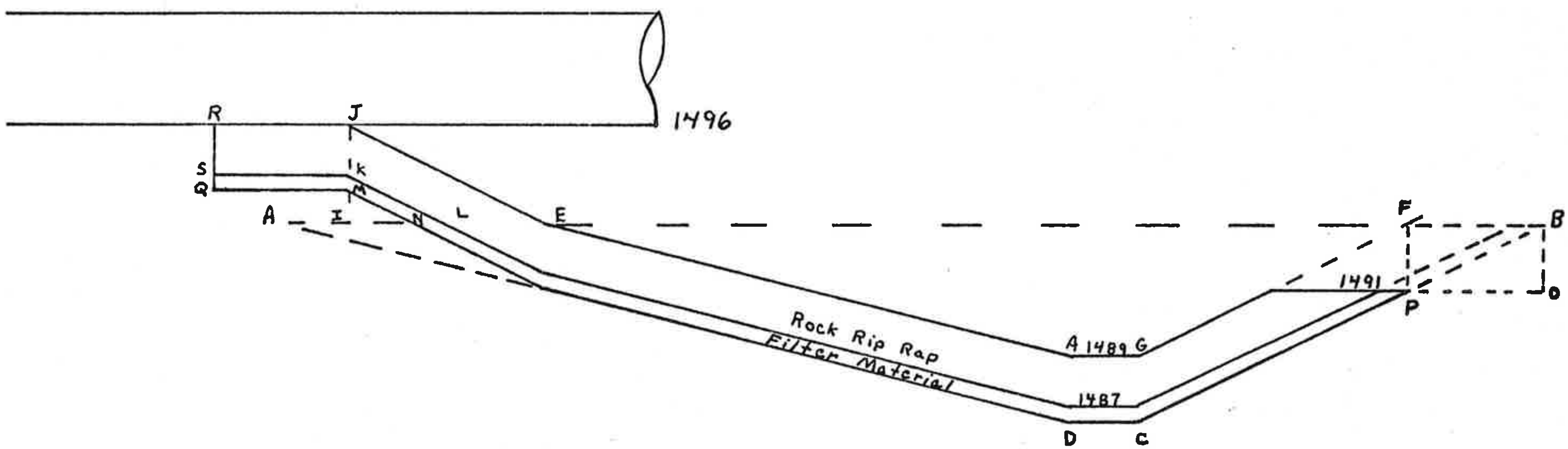

OUTLET BASIN

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APPENDIX C

AGREEMENT

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SARNIA DAM
SWC Project #291
June 29, 1978

File

AGREEMENT

Preliminary Investigation
by the
North Dakota State Water Commission

I. PARTIES

THIS AGREEMENT is between the North Dakota State Water Commission, hereinafter referred to as the Commission acting through the State Engineer, Vern Fahy and the Board of Commissioners, Nelson County Water Management District, hereinafter referred to as the Board, acting through its Chairman, Benhart Varnson.

II. PROJECT, LOCATION AND PURPOSE

The Board has requested the Commission to investigate and determine the feasibility of repairing the dam and modifying it to act as a dry dam for flood control purposes. Said dam is located in Section 15, Township 154 North, Range 58 West, in Nelson County. The reservoir has a minimum amount of recreational value, but is important for the retention of flood waters. The purpose of this investigation is to determine the feasibility of the project as described herein.

III. PRELIMINARY INVESTIGATION

The parties agree that further information is necessary concerning the proposed project. Therefore, the Commission shall conduct a preliminary investigation consisting of the following:

1. The acquiring of field survey data necessary for the investigation.
2. A hydrologic analysis of the watershed.
3. A preliminary design of the hydraulic and structural features of proposed improvements.
4. A detailed cost estimate of the proposed project.
5. A detailed preliminary engineering report.

The investigation outlined herein does not include a subsurface exploration program or a stability analysis. If the Commission determines that a subsurface exploration program or a stability analysis is necessary another investigation agreement will be drafted. Field surveys, subsurface exploration and design work for the final design and specification stage shall not be made under this agreement.

IV. DEPOSIT - REFUND

The Board shall depoist a total of $500.00 with the Commission. Upon completion of the investigation outlined herein, upon receipt of a request from the Board to terminate the 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 return any unexpended deposit funds.

V. RIGHTS OF ENTRY

The Board agrees to obtain written permission from any affected landowner for field surveys by the Commission which are required for the investigation.

VI. INDEMNIFICATION

The Board hereby accepts responsibility for and holds the Commission free from all claims and damages to public or private properties, rights, or persons arising out of this investigation. In the event a suit is initiated or judgment rendered against the Commission, the Board shall indemnify it for any judgment arrived at or judgment satisfied.

BOARD OF COMMISSIONERS
NELSON COUNTY WATER MANAGEMENT DISTRICT

Benhart Varnson
Chairman

7-3-78
Date

NORTH DAKOTA STATE WATER COMMISSION

Vernon Fahy
State Engineer

June 29, 1978
Date

Distribution:
- Board (1)
- SWC Project #291 (1)
- SWC Accountant (1)
- SWC Investigations Engineer (1)