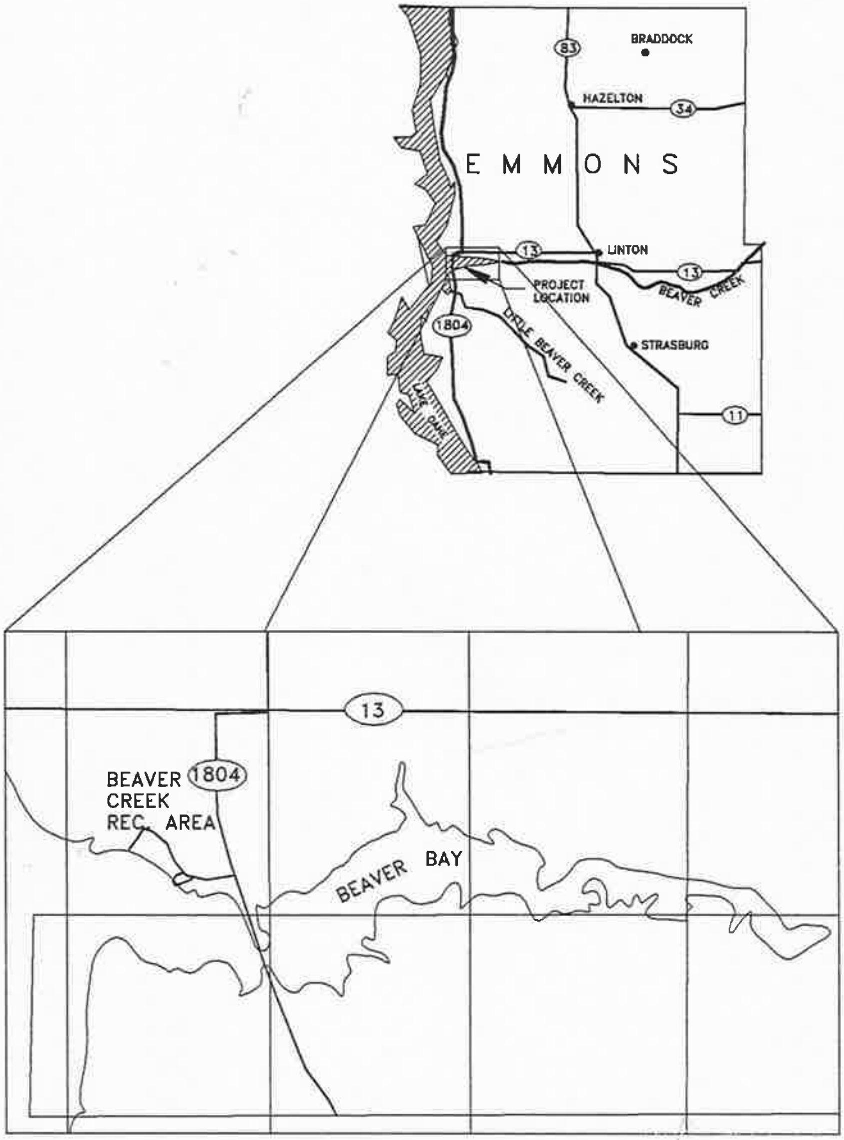
PRELIMINARY ENGINEERING REPORT

BEAVER BAY DAM

SWC NO. 1277
EMMONS COUNTY



NORTH DAKOTA
STATE WATER COMMISSION

May 1992

PRELIMINARY ENGINEERING REPORT

Beaver Bay Dam
SWC Project #1277

May, 1992

North Dakota State Water Commission
900 East Boulevard
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I. INTRODUCTION

Study Objectives:

In June of 1991, the North Dakota State Water Commission and the Emmons County Water Resource District entered into an agreement to investigate the feasibility of impounding water upstream of Highway 1804 at Beaver Bay. The agreement called for the State Water Commission to conduct a field survey of the Highway 1804 embankment; conduct a study of the hydrology of the watershed upstream of the Highway 1804 embankment; design the outlet works necessary to safely and efficiently pass the design flood through the embankment; prepare a preliminary cost estimate for all alternatives considered; and prepare a preliminary engineering report presenting the results of the investigation. A copy of the agreement is contained in Appendix A.

This report contains information on the geology and climate of the site; a description of the computer models used in the study; a summary of the preliminary design of the project; a description of additional studies that will be necessary prior to final design of the project; a summary of land and water rights pertaining to the project; a cost estimate based on the preliminary design; and a statement of conclusions and recommendations regarding the project.

Project Location and Purpose:

Highway 1804 crosses Beaver Bay in the SE1/4 Section 14, the NE1/4 Section 23, and the NW1/4 Section 24, Township 132 North, Range 79 West. The crossing presently consists of a roadway embankment and bridge. Beaver Bay is formed when water retained by Oahe Dam backs up into Beaver Creek at its confluence with the Missouri River. Figure 1 shows the location of Beaver Bay within the state.

Prior to the summer of 1988, Beaver Bay and the recreational facilities surrounding it provided numerous recreational opportunities for residents living in South Central North Dakota. During the drought of 1988, the level of Oahe Reservoir dropped significantly. This drop caused the water to recede from Beaver Bay and limited the use of the surrounding recreational facilities. At this time, the level of Oahe Reservoir has not returned to its pre-drought level. Therefore, the use of the recreational facilities surrounding Beaver Bay remains limited.

The purpose of this investigation is to evaluate alternatives for retaining water upstream of the Highway 1804 crossing at Beaver Bay. The goal being to provide a stable water level that is not influenced by the fluctuating Oahe Reservoir levels. A more stable water level upstream of Highway 1804 will enhance recreational opportunities in south-central North Dakota.

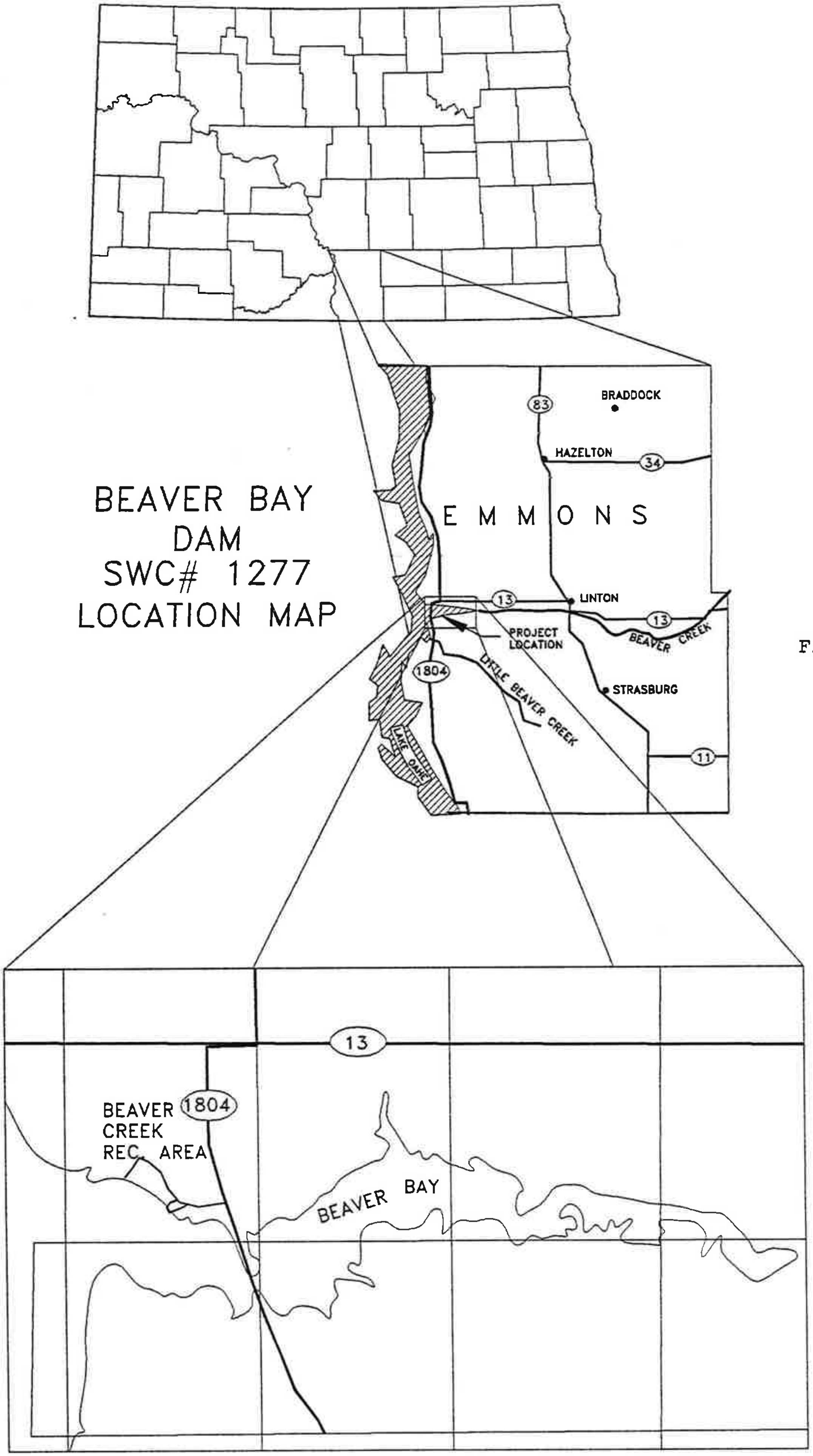


Figure 1 - Location of Beaver Bay

II. GEOLOGY AND CLIMATE

The Beaver Creek drainage basin extends from its origin in southwest Logan County and northwest McIntosh County to its confluence with the Missouri River in western Emmons County. The basin is located in the Missouri Plateau section of the Great Plains physiologic province, which is a major subdivision of the Interior Plains. It is on the Coteau Slope, which is the glaciated section of the Missouri Plateau.

The topography of the basin is mainly rolling to hilly. Extensive areas where bedrock crops out and small areas where glacial deposits are thin characterize the western part of the basin. In many areas severe geologic erosion has resulted in prominent buttes and badlands. The eastern portion of the basin is characterized by many small depressions, potholes, or lakes.

The climate for the basin is characteristic of the interior of the continent and latitude. Relatively large extremes in the weather occur rapidly. Most precipitation falls in summer thunderstorms, which can be intense and accompanied by hail. The average temperature at Linton, North Dakota, located in the west-central portion of the basin, is 42 degrees Fahrenheit. The annual precipitation at Linton is 17.3 inches, of which 82 percent falls in April through September, which is the growing season for most crops. The prevailing wind direction is from the west-northwest.

III. COMPUTER MODELS

HEC-1:

A hydrologic analysis of the Beaver Creek watershed was performed using the HEC-1 computer model, developed by the U.S. Army Corps of Engineers. The model was used to determine the peak discharges and flow volumes of various frequency storms. It formulates a mathematical hydrologic model of the watershed based on the following data: the amount of rainfall, the rainfall distribution, soil type, land use, and the hydraulic characteristics of the channels and drainage areas. The HEC-1 model is designed to compute the surface runoff of the watershed in relation to precipitation by representing the basin as an interconnected system of hydrologic and hydraulic components. Each component of the model represents an aspect of the precipitation-runoff process within a portion of the subbasin. These components were put into the model to determine the magnitude and duration of runoff from hydrologic events with a range of frequencies.

The model was developed to determine the hydrologic response of the Beaver Creek watershed. The results obtained through the use of the model include: (1) inflow hydrographs, (2) reservoir stage hydrographs, and (3) outflow hydrographs.

HEC-2:

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

HMR52:

The HMR52 computer model was used to compute the precipitation distribution for the Probable Maximum Precipitation (PMP) event used for the emergency spillway and freeboard design storms. The HMR52 computer program computes basin-average precipitation for Probable Maximum Storms (PMS), in accordance with the criteria specified in Hydrometeorological Report No. 52 (National Weather Service, 1982). That Hydrometeorological Report (HMR) describes a procedure for developing a temporal and spatial storm pattern to be associated with the PMP estimates provided in Hydrometeorological Report No. 51, "Probable Maximum Precipitation Estimates - United States East of the 105th Meridian." The U.S. National Weather Service (NWS) has determined the application criteria in a cooperative effort with the U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation.

HMR No. 52 requires that a critical storm-area size, orientation, centering and timing be determined which produces the maximum precipitation. The HMR52 computer program will optimize the storm-area size and orientation in order to produce the maximum basin-average precipitation. Data required for application of the HMR52 program are: the X and Y coordinates describing the river basin and subbasin watershed boundaries; PMP from HMR No. 51; and the storm orientation, size, centering, and timing.

Using the time distribution specified by the user, the HMR52 program computes the incremental basin-average precipitation values for every subbasin requested. That precipitation data can subsequently be input into the HEC-1 computer model for computation of the resulting flood.

IV. PRELIMINARY DESIGN

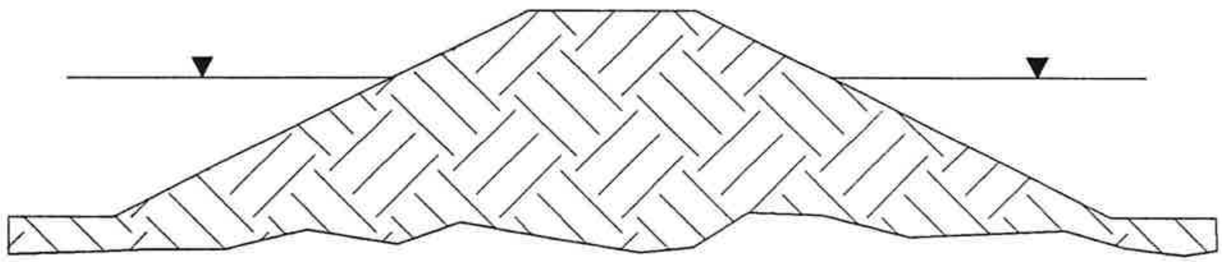
Dam Site Selection:

The first step in the investigation involved the selection of the dam site. Two dam sites were initially considered. The first site is at the existing Highway 1804 crossing and involves upgrading the crossing to retain water. The second site is approximately 2,000 feet upstream of the existing Highway 1804 crossing. This site involves the construction of a new embankment.

Upgrading the existing Highway 1804 embankment to retain water will involve extensive modification. The existing embankment was not designed to retain or store water. Holding water will produce hydraulic head on the embankment when Lake Oahe levels are low. The hydraulic head will increase the rate of seepage through and around the embankment. Figure 2 shows a profile view of how the increased hydraulic head caused by retaining water upstream of the embankment will cause increased seepage.

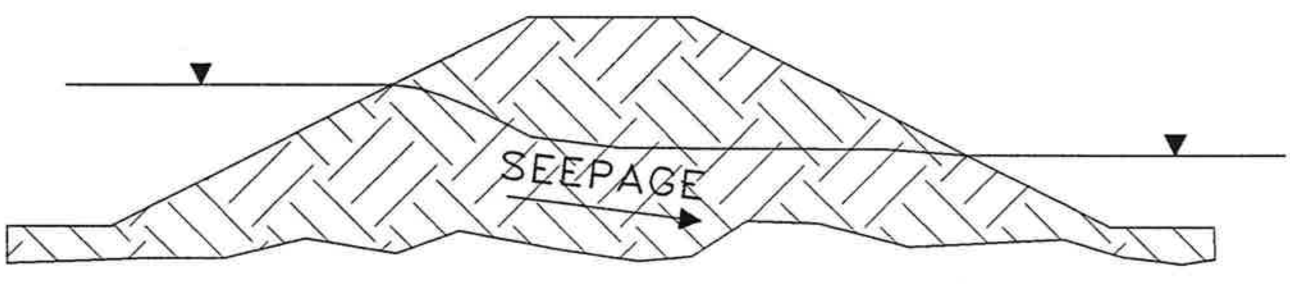
The existing embankment does not have seepage and water pressure treatment measures which are major concerns in dam design. Therefore, it will be necessary to construct a cutoff trench beneath or adjacent to the existing Highway 1804 embankment. This will be accomplished by removing the permeable material to a depth at which less permeable material is encountered, and backfilling it with material of low

EXISTING EMBANKMENT



UPSTREAM WSEL* = DOWNSTREAM WSEL
MINIMAL MOVEMENT OF WATER THROUGH
THE EMBANKMENT DUE TO NO
HYDRAULIC HEAD

EMBANKMENT MODIFIED TO RETAIN WATER



UPSTREAM WSEL* > DOWNSTREAM WSEL
SEEPAGE OCCURS DUE TO INCREASED
HYDRAULIC HEAD ON THE EMBANKMENT

* WATER SURFACE ELEVATION

Figure 2 - Profile
of the Effects of Retaining
Water Upstream of
Highway 1804

permeability. There may also be a need for more extensive foundation and embankment drainage measures, depending on the results of a detailed geotechnical study that will be necessary.

Another problem with retaining water upstream of the existing Highway 1804 crossing is that the topography of the site does not allow for the construction of an emergency spillway. This problem is compounded by Highway 1804 passing over the embankment. The lack of an emergency spillway requires the principal spillway to pass the freeboard precipitation event without overtopping the embankment. This will require a large principal spillway. The roadway embankment may also need to be raised to pass the freeboard precipitation event without overtopping.

The site located approximately 2,000 feet upstream of Highway 1804 appears to be a more suitable dam site. The topography of this site allows for the construction of an emergency spillway adjacent to the embankment. Therefore, the principal spillway will not be required to pass the entire freeboard precipitation event without overtopping the embankment and a smaller principal spillway can be installed. The excavation for the emergency spillway, if found suitable, will provide fill for the construction of the new embankment. Measures to reduce seepage can be incorporated into the construction of the new embankment. Modifications to the existing Highway 1804 crossing will not be necessary if the dam is located at this site.

A preliminary analysis of the two dam sites indicates that it will be more difficult and costly to modify the existing Highway 1804 embankment to retain water than to construct a new embankment farther upstream. Based on this preliminary analysis, the dam site located approximately 2,000 feet upstream of the Highway 1804 crossing was selected as the preferred site. Figure 3 shows the location of the proposed Beaver Bay Dam.

Dam Classification:

The next step in the investigation of Beaver Bay Dam was to determine the dam classification. Design criteria are based on hazard classification and the height of the dam. Hazards are potential loss of life or damage to property downstream of the dam due to releases through the spillway or complete or partial failure of the structure. Hazard classifications listed in the "North Dakota Dam Design Handbook" are as follows:

Low - dams located in rural or agricultural areas where there is little possibility of future development. Failure of low-hazard dams may result in damage to agricultural land, township and county roads, and farm buildings other than residences. No loss of life is expected if the dam fails.

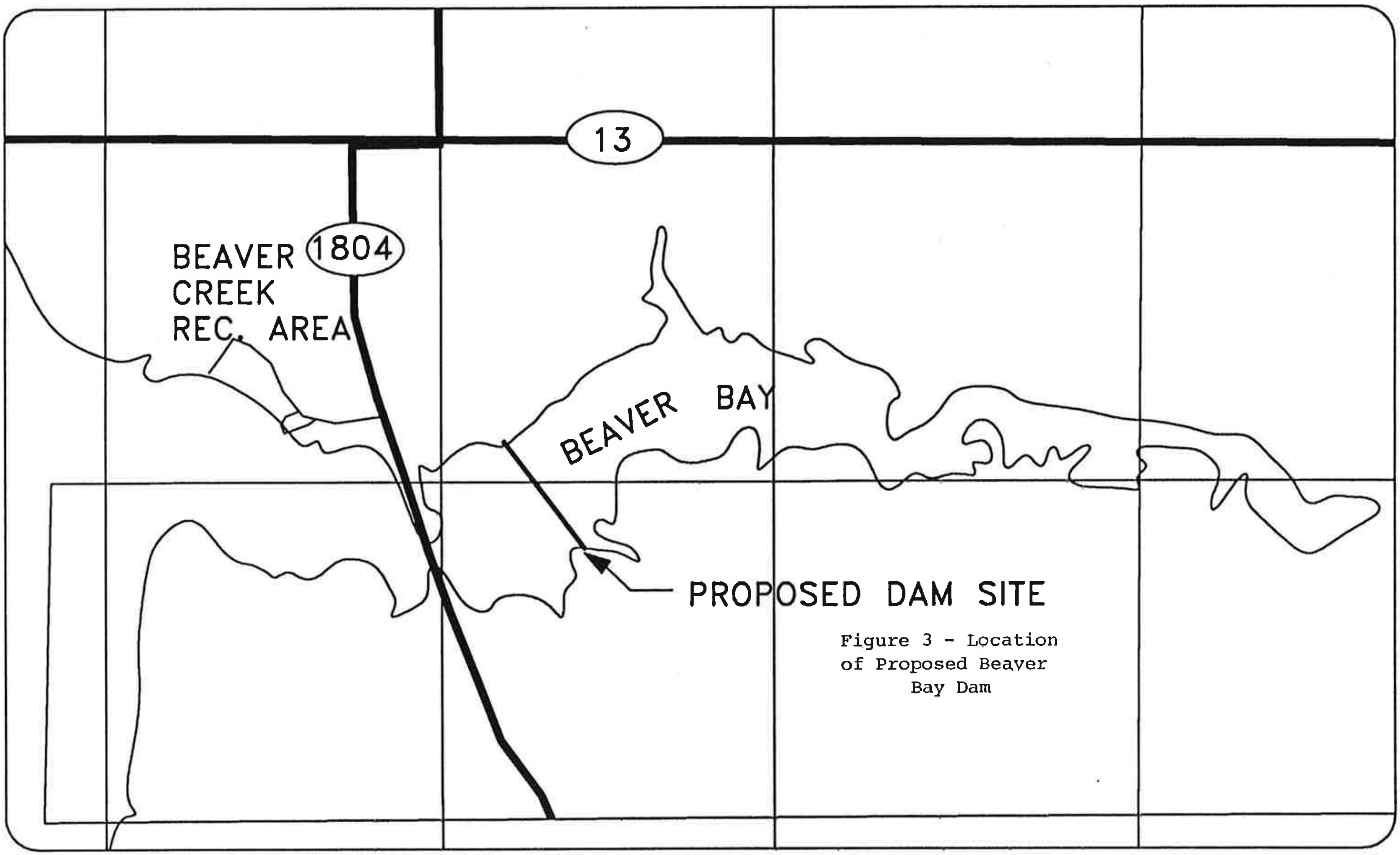


Figure 3 - Location of Proposed Beaver Bay Dam

Medium - dams located in predominantly rural or agricultural areas where failure may damage isolated homes, main highways, railroads, or cause interruption of minor public utilities. The potential for the loss of a few lives may be expected if the dam fails.

High - dams located upstream of developed and urban areas where failure may cause serious damage to homes, industrial and commercial buildings, and major public utilities. There is a potential for the loss of more than a few lives if the dam fails.

Considering that it is located in a predominantly rural area with a main highway and recreational facilities located downstream, Beaver Bay Dam is classified as a medium-hazard dam.

After a dam has been given a hazard category, it can be classified according to its height. The following table was listed in the "North Dakota Dam Design Handbook":

Table 1 - Dam Design Classification

	Hazard Categories		
Dam Height (feet)	Low	Medium	High
Less than 10	I	II	IV
10 to 24	II	III	IV
25 to 39	III	III	IV
40 to 55	III	IV	V
Over 55	III	IV	V

Beaver Bay Dam has a medium-hazard classification and an embankment height of approximately 47 feet. Based on this, it is given a Class IV classification for design purposes.

Based on the "North Dakota Dam Design Handbook," the requirements for a class IV dam are: 1) The principal spillway is to pass the flows due to a 50-year precipitation event without the use of a non-structural emergency spillway, 2) The emergency spillway is to pass the flows due to the 0.3 PMP (velocity hydrograph) event without exceeding the allowable velocity of 8 feet per second, and 3) The dam is to withstand the 0.5 PMP (freeboard hydrograph) event without overtopping.

Hydrology:

The watershed above Beaver Bay Dam was defined using USGS 7.5-minute quadrangle maps of the area. The drainage area for the dam was calculated to be 900 square miles, of which approximately 90 square miles is non-contributing. Figure 4 shows the drainage basin above Beaver Bay Dam.

Stream gage records from a gage located on Beaver Creek near Linton, North Dakota were incorporated into the hydrology for the project. Records of yearly peak mean daily flow dating back to 1949 were input into a Log Pearson Type III distribution to determine the flow due to various recurrence interval precipitation events. Table 2 contains the results of the Log

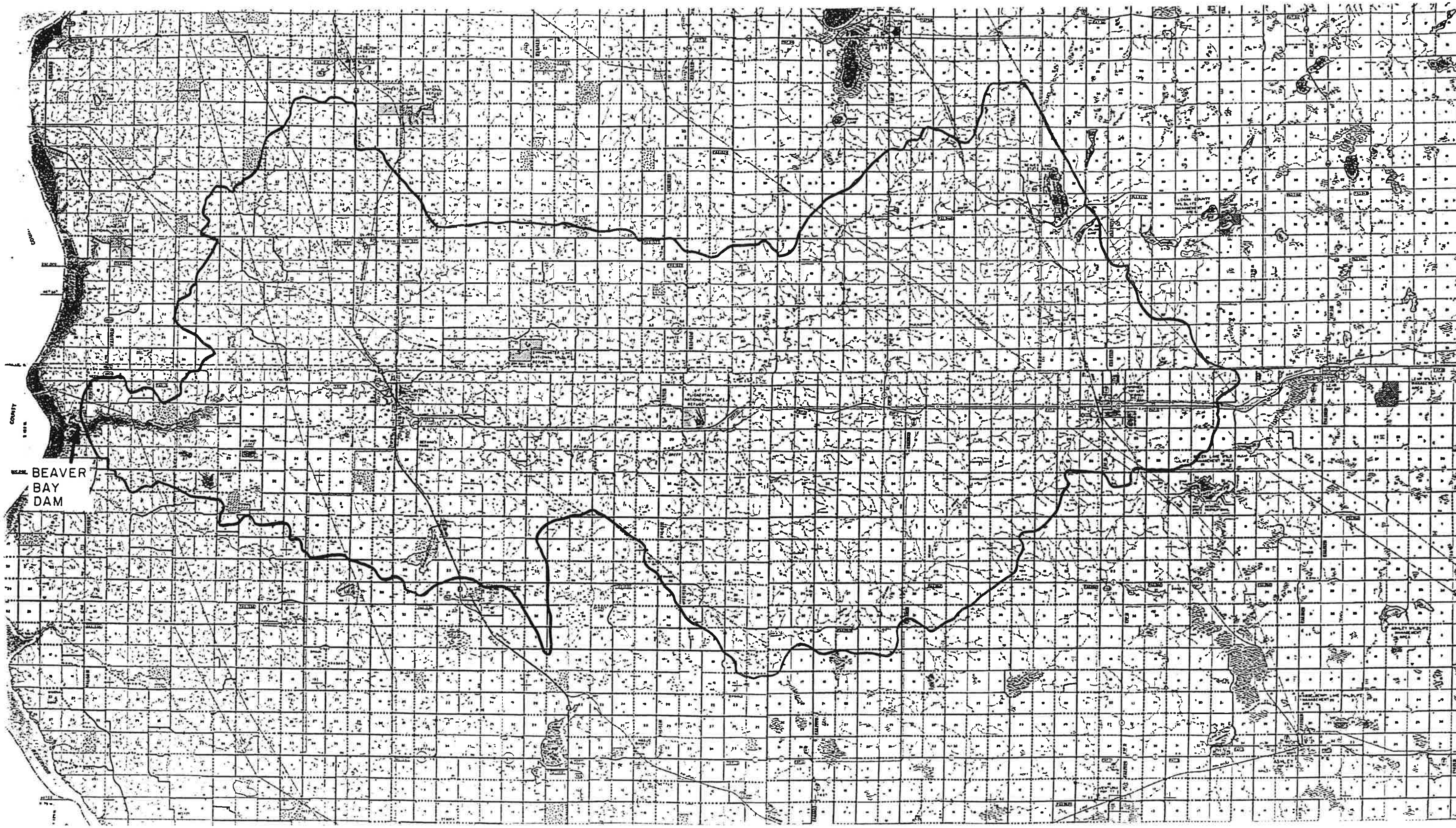


Figure 4 - Drainage Basin Above Beaver Bay Dam

Pearson Type III distribution that was performed on the Linton stream gage data.

Table 2 - Results of Log Pearson Type III Distribution

Recurrence Interval	Flow (cfs)
10-year	3,786
25-year	6,223
50-year	8,435
100-year	10,969

The peak mean daily flow resulting from the 1952 spring snowmelt at the Linton stream gage was 7,420 cfs. This event was approximated as a 50-year snowmelt for preliminary design purposes. The maximum flow recorded during the 1952 spring snowmelt was 9,800 cfs and the total inflow volume was calculated to be 83,772 acre-feet.

There are 573 square miles of contributing drainage area upstream of the Linton stream gage. An additional 237 square miles of drainage area contributes to Beaver Creek downstream of the Linton stream gage prior to entering Beaver Bay. This accounts for a total contributing drainage area of 810 square miles. To account for the additional drainage area downstream of the stream gage, a HEC-1 model of the basin upstream of the gage was developed. The basin upstream of the gage was broken into four subbasins and runoff parameters were adjusted to approximate the 1952 spring snowmelt. The resulting model yielded a 50-year snowmelt hydrograph with a peak flow of 9,229 cfs and a total inflow volume of 82,215 acre-feet. Figure 5 shows a comparison of the hydrographs resulting from the 1952 spring runoff and the HEC-1 model used to approximate the 1952 spring runoff.

The 50-year snowmelt inflow hydrograph for Beaver Bay Dam was developed by incorporating the 237 square miles of contributing area downstream of the Linton stream gage into the HEC-1 model developed for the 573 square miles of contributing drainage area upstream of the gage. The resulting model yielded a peak inflow of 10,049 cfs into Beaver Bay Dam.

The peak mean daily flow resulting from a 1953 summer rainfall at the Linton stream gage was 4,050 cfs. This event was approximated as a 10-year rainfall to estimate the runoff parameters for the PMP event used for developing the velocity and freeboard hydrographs. The maximum flow recorded during the 1953 summer rainfall was 5,650 cfs and the total inflow volume was calculated to be 31,854 acre-feet.

An analysis similar to that performed for the 1952 spring runoff was performed on the 1953 summer rainfall. A HEC-1 model of the basin upstream of the gage was developed. Runoff parameters were adjusted to approximate the 1953 summer rainfall. The resulting model yielded a 10-year rainfall hydrograph with a peak flow of 4,850 cfs and a total inflow volume of 32,856 acre-feet. Figure 6 shows a comparison of the hydrographs

50-YEAR SNOWMELT

HEC-1 HYDROGRAPH VS. STREAM GAGE HYDROGRAPH

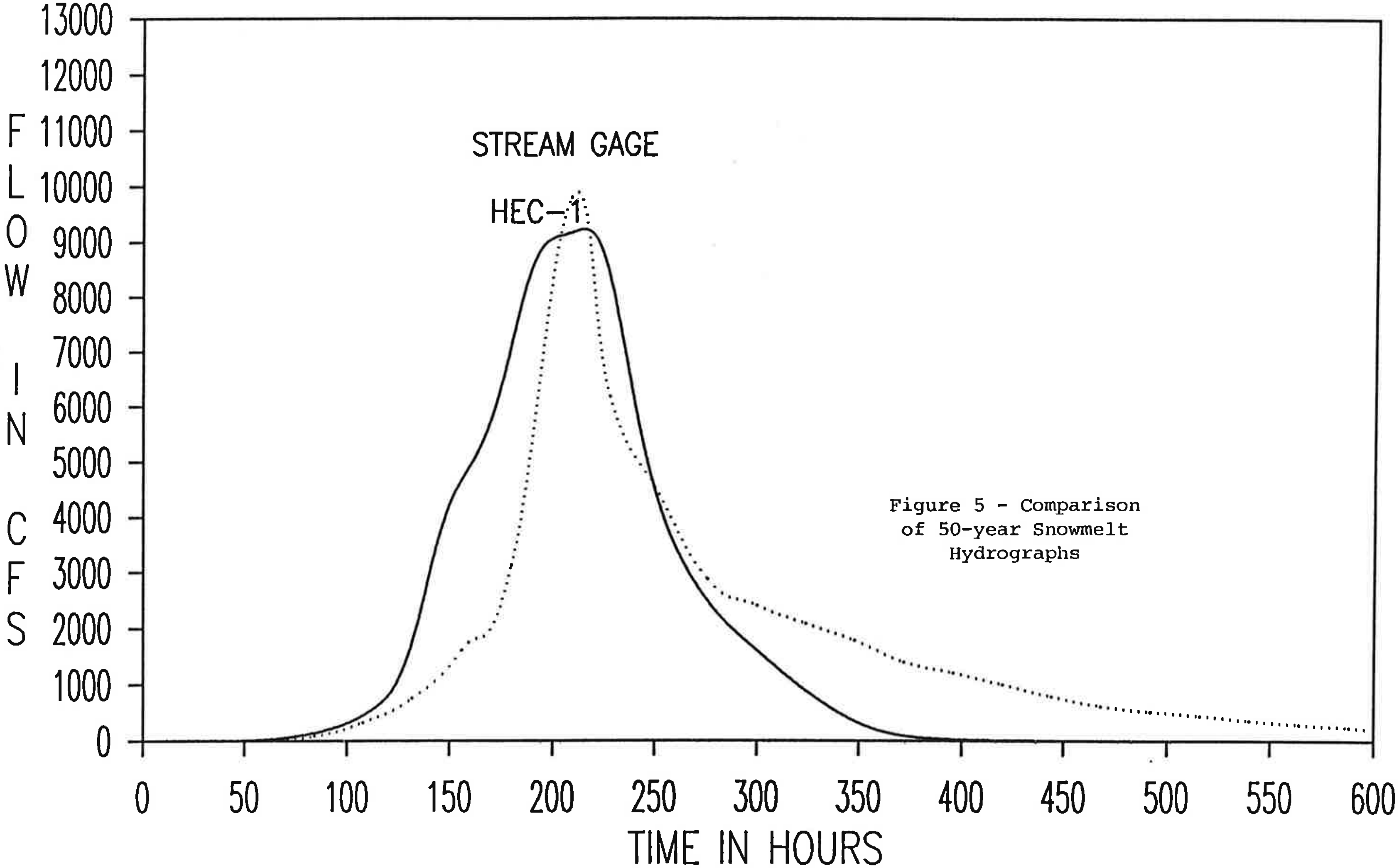


Figure 5 - Comparison of 50-year Snowmelt Hydrographs

10-YEAR RAINFALL

HEC-1 HYDROGRAPH VS. STREAM GAGE HYDROGRAPH

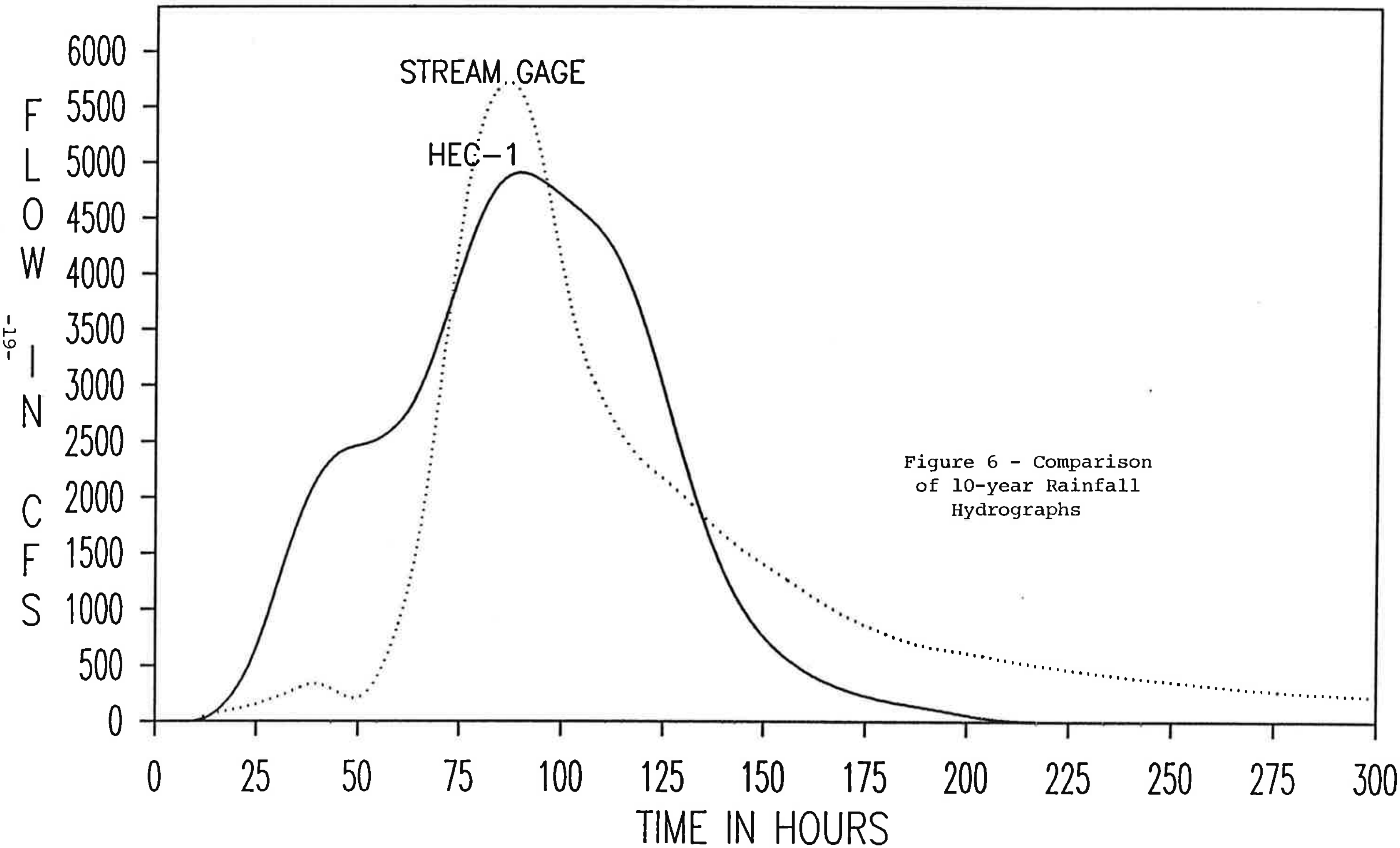


Figure 6 - Comparison of 10-year Rainfall Hydrographs

resulting from the 1953 summer rainfall and the HEC-1 model used to approximate the 1953 summer rainfall.

The 0.5 PMP (freeboard) and 0.3 PMP (velocity) hydrographs for Beaver Bay Dam were developed by incorporating the 237 square miles of contributing drainage area downstream of the Linton stream gage into the HEC-1 model developed for the 573 square miles of contributing drainage area upstream of the gage. The precipitation data used for the 10-year rainfall event were replaced by the precipitation data computed by the HMR52 computer model for the PMP event. The resulting model yielded a peak inflow of 27,721 cfs for the 0.5 PMP event and a peak inflow of 11,940 cfs for the 0.3 PMP event. Table 2 shows the resulting peak inflows and total inflow volumes for Beaver Bay Dam resulting from the HEC-1 computer model.

Table 3 - Peak Inflows and Volumes for Design Frequency

Event	Peak Inflow (cfs)	Total Inflow Volume (acre-feet)
50-year snowmelt	10,049	115,075
0.3 PMP	11,940	114,784
0.5 PMP	27,721	258,685

The hydrology performed as part of this investigation is very preliminary in nature. If the decision is made to pursue the project further, a more detailed hydrologic analysis of the Beaver Creek drainage basin will need to be made prior to the final design of the project.

Reservoir Level:

The first step in the design of the outlet works for Beaver Bay Dam was to select a reservoir level. In selecting a reservoir level, consideration was given to Oahe Reservoir levels, elevation of surrounding recreational facilities, and land acquisition requirements. After considering the above criteria, a reservoir elevation of 1616 msl was selected. At this level, the reservoir will contain approximately 8,970 acre-feet of water, have a surface area of 836 acres, an average depth of 10.7 feet, and a maximum depth of 28 feet. With the water controlled at this elevation, the water level in Beaver Bay will be similar to that which existed prior to the 1988 drought. The normal operating level of Oahe Reservoir is at 1607.5 msl.

Hydraulic Design:

The HEC-1 computer model was used to simulate the precipitation versus runoff response for the basin and to route the flows through the proposed reservoir. The area-capacity curve for the reservoir and the rating curve for the spillway were needed in order to use the HEC-1 model. The area-capacity curve for Beaver Bay Dam was obtained using USGS 7.5-minute quadrangle maps of the area and survey data obtained for the investigation. Figure 7 shows the area capacity curve. The rating curve for the principal spillway was calculated based on the equation for weir flow. The rating curve for the emergency spillway was calculated using the Rater computer program developed by the North Dakota State Water Commission. Rater

BEAVER BAY DAM
AREA-CAPACITY CURVE

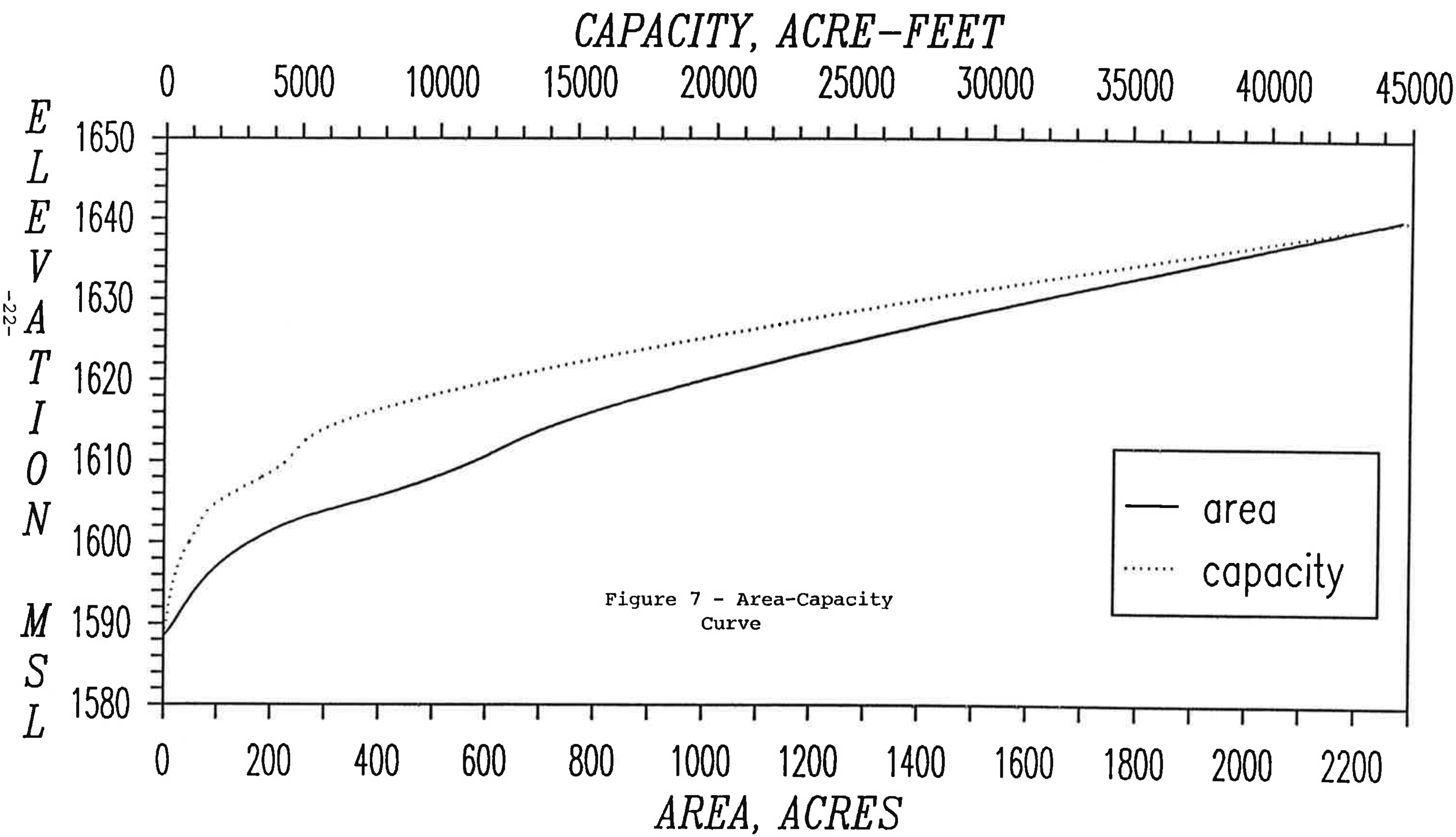


Figure 7 - Area-Capacity Curve

develops a rating curve for an open channel using Manning's equation. The rating curve for the proposed spillway system is contained in Table 4.

Table 4 - Rating Curve for Proposed 70-foot Chute Spillway

Elevation	Q-Principal (cfs)	Q-Emergency (cfs)	Q-Total (cfs)
1616	-	-	-
1618	614	-	614
1620	1,736	-	1,736
1622	3,189	-	3,189
1624	4,910	-	4,910
1626	6,862	-	6,862
1628	9,021	-	9,021
1629	10,171	-	10,171
1630	11,367	432	11,799
1632	13,888	3,806	17,694
1634	16,572	8,981	25,553
1636	19,409	15,515	34,924
1638	22,392	23,534	45,926

In developing the rating curve for the proposed spillway system, the fluctuating level of Oahe Reservoir and the tailwater effects it will provide for the spillway were taken into account. For passage of the 50-year snowmelt, it was assumed that Oahe Reservoir was at its 50-year level, or 1616 msl. For passage of the 0.5 PMP event, it was assumed that Oahe Reservoir was at its 500-year level, or 1620 msl.

<u>Principal Spillway</u>:

Several spillway alternatives were considered as part of this investigation. In evaluating the alternatives, consideration was given to their ability to pass the design flood as well as construction cost. An effort was made to balance earthwork quantities between the excavation for the emergency spillway and the fill required for the embankment.

The results of the preliminary investigation show that a 70-foot wide straight inlet chute spillway will most efficiently pass the principal spillway design flow. The inlet of the 70-foot chute will be set at an elevation of 1616 msl. Figure 8 shows the layout of the proposed principal spillway. Table 5 gives the inflow, outflow, and stage for the different precipitation events for the proposed new spillway obtained from the HEC-1 model. Figures 9 and 10 show the various inflow-outflow relationships for the proposed new outlet.

Table 5 - Hydrologic Results for the Proposed 70-foot Wide Chute Spillway

Event	Inflow (cfs)	Outflow (cfs)	Stage (msl)
50-year snowmelt	10,049	9,743	1628.6
0.3 PMP	11,940	11,157	1629.6
0.5 PMP	27,721	25,705	1634.1

A Saint Anthony Falls (SAF) stilling basin will be used to dissipate the energy of the water passing through the principal spillway. The SAF stilling basin is designed assuming Oahe Reservoir levels are low, resulting in no initial tailwater. When Oahe Reservoir levels are high, the SAF stilling basin will be submerged and will not function as designed, rather, the energy of the water passing through the chute will be dissipated via a hydraulic jump when it enters Oahe reservoir downstream. A

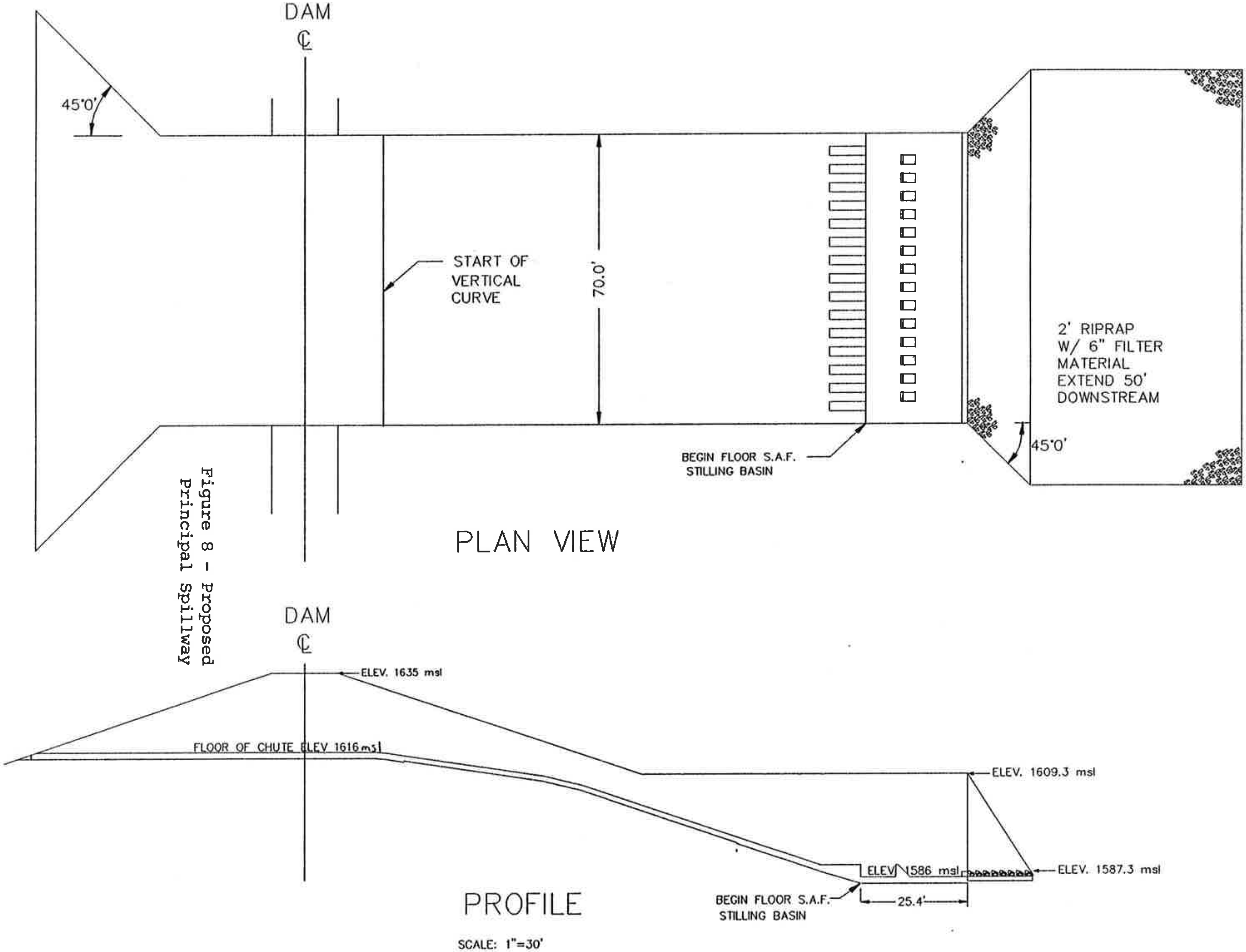


Figure 8 - Proposed Principal Spillway

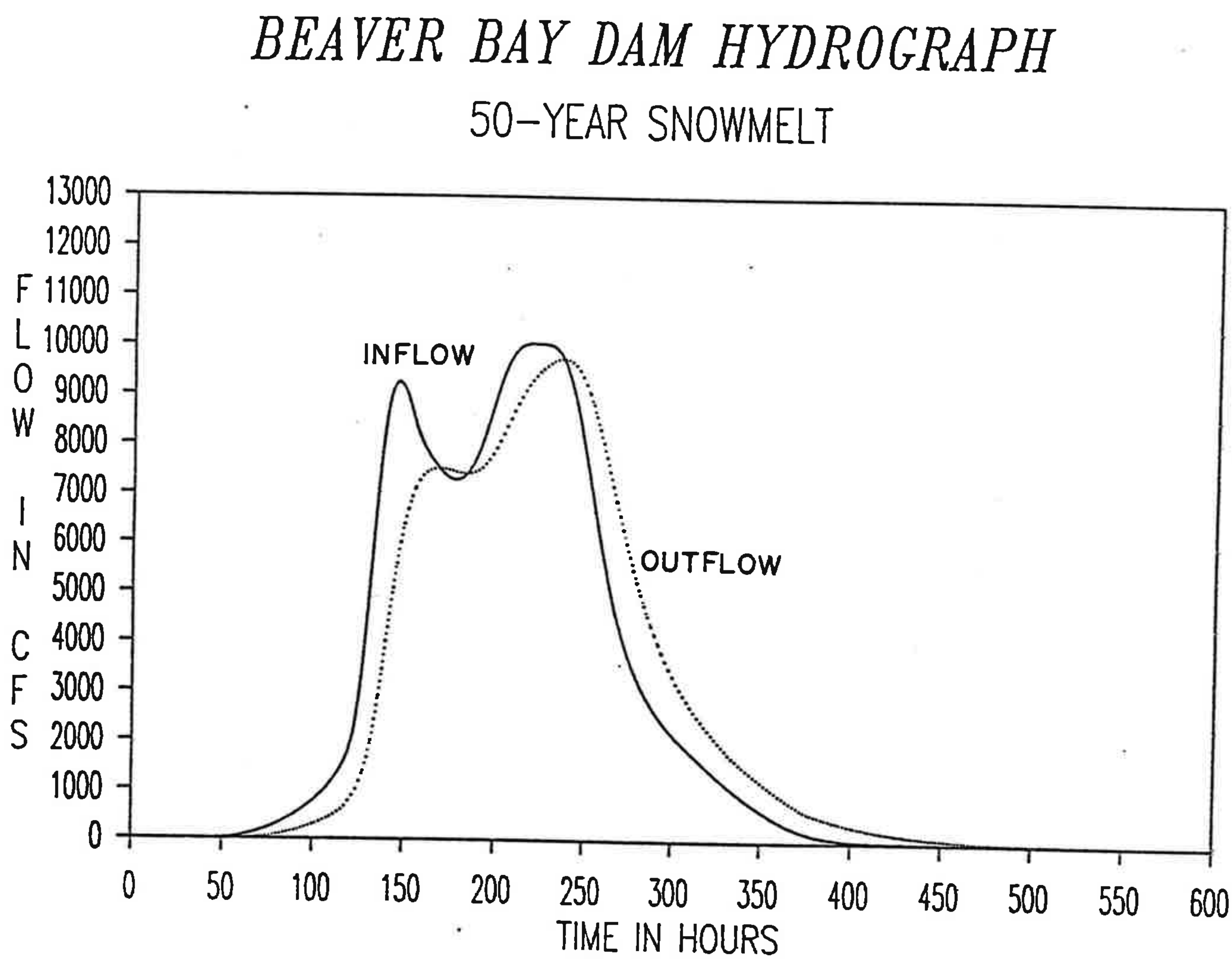
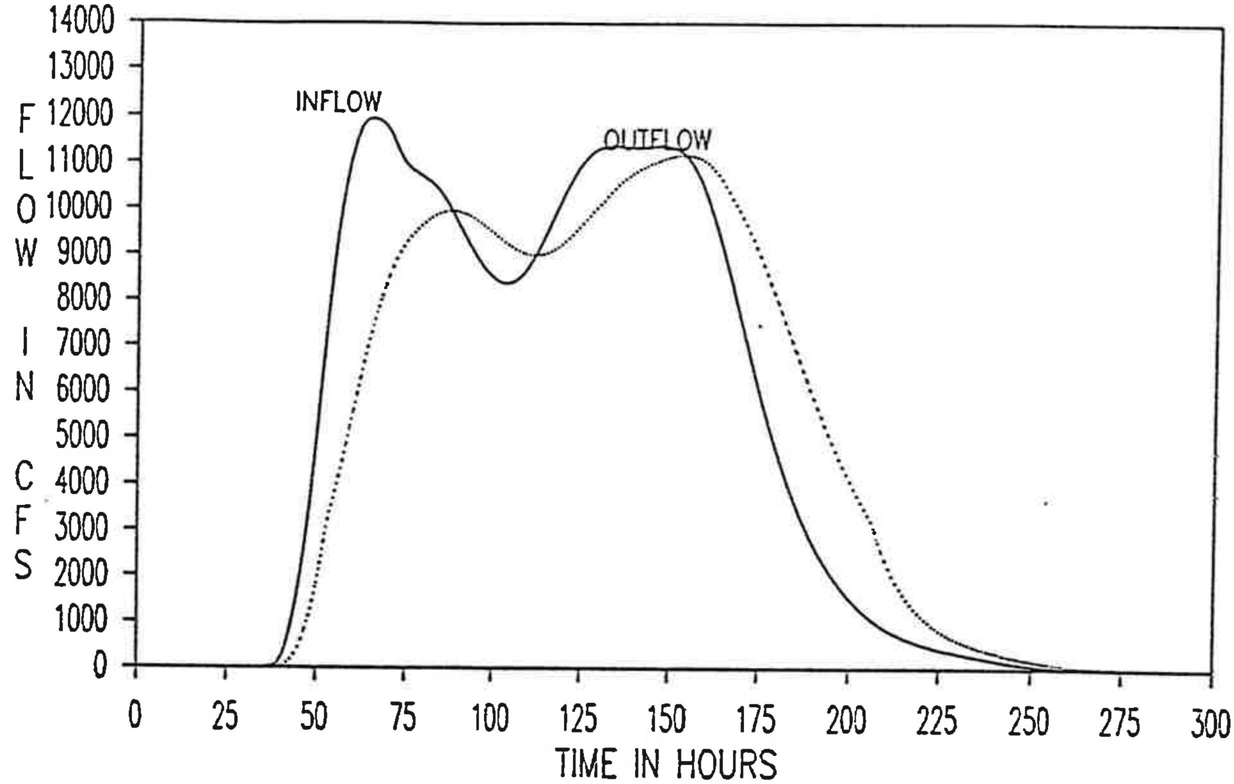


Figure 9 - Beaver Bay
Dam Hydrograph

BEAVER BAY DAM HYDROGRAPH

30% OF PROBABLE MAXIMUM PRECIPITATION



50% OF PROBABLE MAXIMUM PRECIPITATION

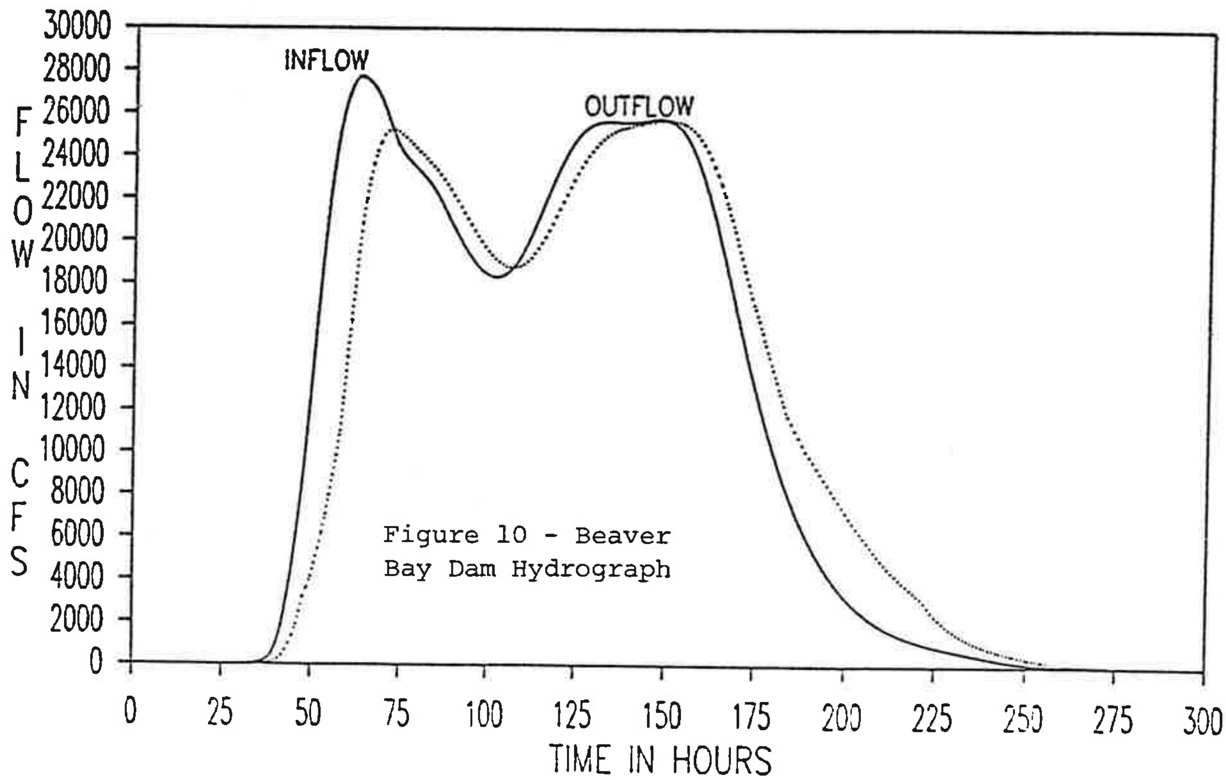


Figure 10 - Beaver Bay Dam Hydrograph

preliminary analysis indicates that significant erosion will not occur to the downstream face of the dam during high tailwater. Prior to the final design of the project, it is recommended that a detailed model study be performed on the proposed spillway to evaluate the performance of the spillway for various tailwater levels.

Emergency Spillway:

The use of a 70-foot wide straight inlet chute principal spillway requires that the emergency spillway be set at an elevation of 1629 msl. The proposed emergency spillway for Beaver Bay Dam is a 300-foot wide grass-lined channel with 3:1 side slopes located in the left abutment. The rating curve for the emergency spillway was developed using the rater computer program. The rating curve was used to route the velocity and freeboard hydrographs. The velocity hydrograph consists of 30 percent of the PMP and the freeboard hydrograph consists of 50 percent of the PMP.

Embankment:

The proposed spillway system will require an embankment with a crest elevation of 1635 msl in order to pass the freeboard precipitation event without overtopping. The proposed embankment will be located approximately 2,000 feet upstream of Highway 1804. The embankment will have a top width of 16 feet, 3:1 side slopes, and will be approximately 2,700 feet long. A cutoff trench will be excavated beneath the embankment to reduce seepage. Construction of the embankment will require 520,000 cubic yards of earthfill material. The earthfill material will be obtained during the excavation of the emergency spillway if this material is found to be suitable. In calculating the volume of earthfill that will be required, it was assumed that the material will shrink by 20 percent following construction. This 20 percent shrinkage value will need to be verified during the geotechnical investigation that is needed to determine the suitability of the borrow material. Figure 11 shows the layout of Beaver Bay Dam.

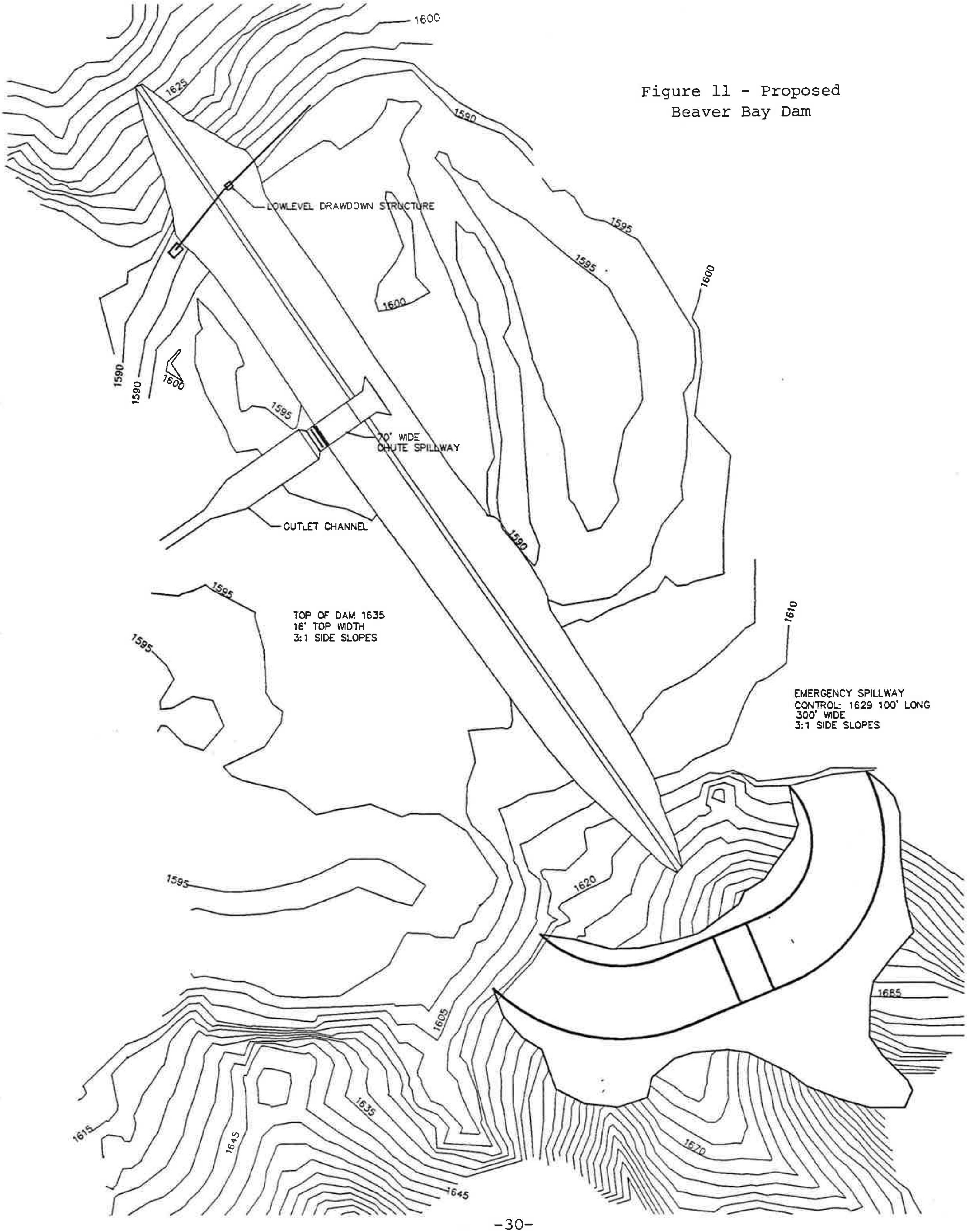
Riprap:

Rock riprap will be placed on both the upstream and downstream faces of Beaver Bay Dam to protect it against erosion. The riprap on the upstream face of the dam will extend from elevation 1610 msl to elevation 1630 msl. This will protect the upstream face of the dam during fluctuating reservoir levels. The riprap on the downstream face of the dam will extend from the toe of the dam to elevation 1623 msl. This will protect the downstream face of the dam during fluctuating Oahe Reservoir levels. The riprap will be approximately 18 inches thick and will be placed on top of 6 inches of filter material.

Low-Level Drawdown:

A low-level drawdown structure was included in the design of Beaver Bay Dam. The low-level drawdown structure, also known as a cold water return or hypolimnetic discharge structure, is

Figure 11 - Proposed Beaver Bay Dam



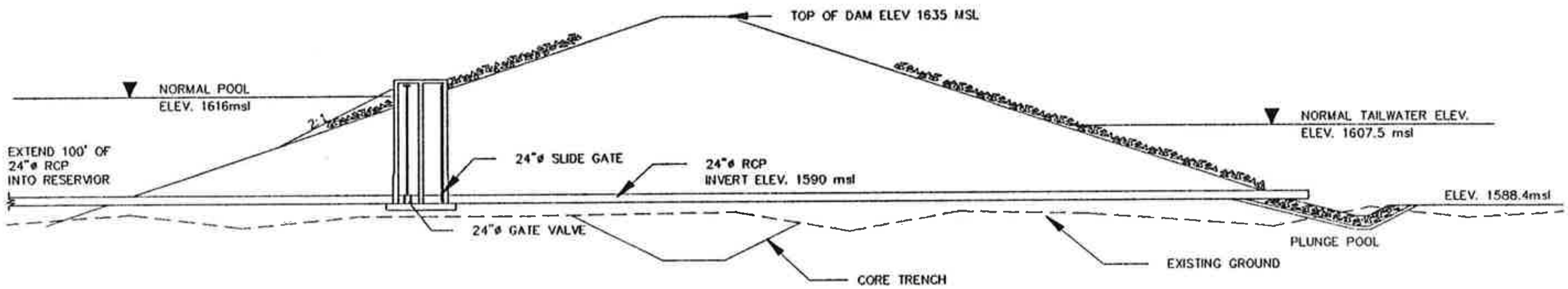
designed to counteract accelerated aging in reservoirs. The low-level drawdown structure removes nutrient-rich water from the bottom of a thermally stratified reservoir, leaving the better quality water behind, and thus increasing the usefulness and life span of the reservoir. Improved water quality conditions result in a positive benefit to the fishery and to all other recreational uses.

A rule of thumb used in the design of low-level drawdown structures is that they should pass 10 percent of the reservoir volume in a 14-day time period. For Beaver Bay Dam, a 24-inch diameter Reinforced Concrete Pipe (RCP) is sufficient to act as a low-level drawdown. The proposed low-level drawdown structure will be located in the portion of the embankment that passes through the Beaver Creek channel. Figure 12 shows a transverse profile of the low-level drawdown structure.

In designing the low-level drawdown structure, it was assumed that Oahe Reservoir was at its normal operating level of 1607.5 msl. Therefore, the low-level drawdown structure will be able to pass greater flows when Oahe Reservoir is lower and smaller flows when it is higher.

<u>Downstream Modifications</u>:

The principal spillway for Beaver Bay Dam will be located near the center of the embankment. This will require the construction of an outlet channel to tie into the Highway 1804



LOW LEVEL DRAWDOWN SYSTEM

1" = 40'

Figure 12 - Transverse Profile of Low-Level Drawdown Structure

bridge located downstream. The channel is sized to provide sufficient tailwater for operation of the SAF stilling basin when Oahe Reservoir levels are low. The HEC-2 computer model was used to determine the capacity of the downstream channel.

The proposed downstream channel consists of a 100-foot wide channel with 2:1 side slopes. At the outlet of the SAF stilling basin, the channel invert elevation is 1587.3 msl. The channel will be 100-foot wide for a distance of 200 feet. At that point it will taper to a width of 30 feet. The taper will occur over a distance of 100 feet. The channel will be 30 feet wide for a distance of 900 feet at which point it will tie into the existing channel at elevation 1587.2 msl.

Water Control:

It is preferred that project construction occur when Beaver Bay is dry. Water control at this time will consist of only diverting Beaver Creek flows around the proposed dam site. Minimal water control will help keep the construction costs lower. A rise in Oahe Reservoir levels during construction could increase the construction costs significantly.

Building Relocation:

There are several houses located adjacent to Beaver Bay. The lowest house, located in the NE1/4, SW1/4 Section 18, Township 132 North, Range 78 West, lies at an elevation of 1631.1 msl. This is below the top-of-dam elevation (1635 msl) of Beaver

Bay Dam. Therefore, relocation of the house is required. A shed located near the house lies at an elevation of 1621.3 msl and should also be relocated. The estimated cost to relocate the house and shed is $30,000. The other houses located adjacent to Beaver Bay lie above the top-of-dam elevation and will not need to be relocated.

V. ADDITIONAL STUDIES

If the decision is made to pursue the construction of Beaver Bay Dam, additional studies will be necessary. These studies include a geotechnical exploration of the proposed dam site and a model study of the proposed principal spillway. The geotechnical exploration will determine if the subsurface condition of the proposed dam site is suitable for the construction of a new embankment. Potential borrow areas will also be evaluated as part of the geotechnical exploration. It is estimated that the cost of the geotechnical exploration will be $50,000. The model study of the proposed principal spillway will help in evaluating the hydraulic performance of the spillway under varying tailwater conditions. It is estimated that the cost of the model study will be $10,000.

VI. LAND AND WATER RIGHTS

The exclusive flood zone for Oahe Reservoir is at elevation 1620 msl. The U.S. Army Corps of Engineers owns the land below this level. The proposed reservoir level of 1616 msl for Beaver Bay Dam is below the exclusive flood zone. Therefore, no additional land will be permanently inundated. During passage of the freeboard precipitation event, the water level upstream of the dam will approach elevation 1635 msl. Flood easements will need to be obtained for the land up to this level. Additional land will also need to be purchased on the north and south end of Beaver Bay for construction of the embankment and the emergency spillway. An easement will need to be obtained from the Corps of Engineers to construct the dam on their land.

Prior to the construction of Beaver Bay Dam, a dam permit and water use permit will need to be obtained from the North Dakota State Engineer. Federal permits that will need to be obtained through the Corps of Engineers include a Section 10 Permit required through the Rivers and Harbors Act and a Section 404 Permit required through the Clean Water Act.

VII. PRELIMINARY COST ESTIMATE

As proposed, the cost to construct Beaver Bay Dam is estimated to be $3,000,000. This cost estimate does not include the cost of land acquisition or additional studies that will be necessary prior to construction. Table 6 shows the cost breakdown for the proposed dam.

Table 6 - Beaver Bay Dam Cost Estimate

Item	Quantity	Unit	Unit Price	Total
Mobilization	1	LS	$ 20,000.00	$ 20,000
Water Control	1	LS	60,000.00	60,000
Embankment Construction				
(a) Stripping and Spreading topsoil	131,000	SY	0.25	32,750
(b) Core Trench Excavation	42,000	CY	2.50	105,000
(c) Fill	520,000	CY	1.30	676,000
(d) Rock Riprap	19,000	CY	30.00	570,000
(e) Rock Riprap Filter Material	6,300	CY	15.00	94,500
(f) Seeding	27	Ac.	200.00	5,400
Chute Spillway				
(a) Concrete	1,400	CY	275.00	385,000
(b) Reinforcing Steel	196,000	Lbs.	0.50	98,000
(c) Sheet Pile (8'x1.5')	2,080	LF	25.00	52,000
Miscellaneous Metals	1	LS	15,000.00	15,000
Outlet Channel Construction	1	LS	100,000.00	100,000
Low-Level Drawdown	1	LS	60,000.00	60,000
House Relocation	1	LS	30,000.00	30,000
Subtotal				$2,303,650
Contingencies (+/- 10%)				232,117
Contract Administration (+/- 10%)				232,117
Engineering (+/- 10%)				232,116
Total				$3,000,000

VIII. SUMMARY

The feasibility of impounding water upstream of Highway 1804 has been examined. The proposed dam site is located approximately 2,000 feet upstream of Highway 1804 on Beaver Creek in the SW1/4 Section 13, Township 132 North, Range 79 West and the NW1/4 Section 24, Township 132 North, Range 79 West.

The proposed Beaver Bay Dam is located in a predominantly rural area. Failure may result in damage to a main highway and/or the loss of a few lives. Considering this, the dam is classified in the medium hazard category. Based on a 47-foot embankment height and a medium hazard classification, Beaver Bay Dam is classified as a class IV dam for design purposes.

Design events for the various hydraulic structures are as follows: 1) the principal spillway is to pass the flows of a 50-year precipitation event without the use of a non-structural emergency spillway; 2) the emergency spillway is to pass the flows of a 0.3 PMP extreme rainfall event within acceptable velocity limits; and 3) the dam is to pass the flows of a 0.5 PMP extreme rainfall event without overtopping.

Two dam sites were initially considered, one located at the existing Highway 1804 crossing and the other approximately 2,000 feet upstream of the existing Highway 1804 crossing. Due to the considerable modifications that will be necessary to upgrade the existing crossing to satisfy North Dakota Dam Design Guidelines, the site located approximately 2,000 feet upstream of the existing Highway 1804 crossing was selected as the preferred site.

The Beaver Creek Basin was analyzed using stream gage data from the Linton stream gage and the HEC-1 computer model. Several spillway-embankment combinations were studied. Analysis indicates that a 70-foot wide straight inlet chute spillway is the most efficient principal spillway. The inlet to the chute spillway will be at elevation 1616 msl. The flows will be conveyed through the chute to a SAF energy dissipater. A 300-foot wide grass-lined emergency spillway located at elevation 1629 msl will be used to convey high flows. A top-of-dam elevation of 1635 msl is required for passage of the freeboard precipitation event through the spillway system without overtopping the dam. The embankment will have a 16-foot top width and 3:1 side slopes. Riprap will be placed on both the upstream and downstream faces of the embankment to reduce erosion.

A low-level drawdown structure has been designed to allow for the removal of water from the bottom of the reservoir. The low-level drawdown will consist of a 24-inch diameter RCP extending through the embankment at the location of the existing Beaver Creek channel.

A downstream channel will need to be constructed to provide sufficient tailwater for the operation of the SAF energy dissipater during low Oahe Reservoir levels. The channel will be 100 feet wide at the SAF outlet. It will taper to 30 feet wide farther downstream and eventually tie into the existing channel upstream of the Highway 1804 bridge.

Two additional studies will be necessary prior to the final design of the project. These studies include a geotechnical exploration and a hydraulic model study of the proposed principal spillway during varying tailwater levels. The costs to perform these studies are estimated to be $50,000 and $10,000 respectively.

The cost to construct the proposed project is $3,000,000. This cost does not include the cost for the additional studies or land acquisition.

IX. RECOMMENDATIONS

Fluctuating Oahe Reservoir levels limit the use of recreational facilities surrounding Beaver Bay. The construction of a structure to retain water upstream of Highway 1804 at Beaver Bay will help maximize the use of these facilities by providing a stable water surface during low Oahe Reservoir levels. The modification of the Highway 1804 crossing to retain water is not feasible due to the considerable modifications that will be necessary for it to satisfy North Dakota Dam Design Guidelines. Therefore, the construction of a new embankment approximately 2,000 feet upstream of the Highway 1804 crossing is recommended. The construction of an embankment to retain water in Beaver Bay presents a unique design situation in that during high Oahe Reservoir levels, significant tailwater will exist on the embankment. Therefore, it is recommended that a model study of the proposed spillway be undertaken prior to the final design of the structure. Additionally, a geotechnical exploration should be performed on the proposed dam site to determine if the subsurface conditions of the site are suitable for the construction of a dam. The decision to proceed with this project is the responsibility of the Emmons County Water Resource Board.

BIBLIOGRAPHY

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3. U.S. Army Corps of Engineers, HEC-1 Flood Hydrograph Package, September, 1987.

4. U.S. Army Corps of Engineers, HEC-2 Water Surface Profiles September, 1990.

5. U.S. Army Corps of Engineers, HMR52 Probable Maximum Storm March, 1984.

6. Soil Conservation Service, U.S.D.A., Chute Spillways.

APPENDIX A - COPY OF AGREEMENT

SWC Project #1277
June 10, 1991

AGREEMENT

Investigation of the Feasibility of Impounding Water Upstream of Highway 1804 at Beaver Bay

I. PARTIES

THIS AGREEMENT is between the North Dakota State Water Commission, hereinafter Commission, through its Secretary, David Sprynczynatyk; and the Emmons County Water Resource District, hereinafter District, through its Chairman, Glenn McCrory.

II. PROJECT, PURPOSE, AND LOCATION

The District has requested the Commission to investigate the feasibility of impounding water upstream of Highway 1804 at Beaver Bay in Emmons County. Highway 1804 crosses Beaver Bay in the NE1/4 Section 23 and the SE1/4, Section 14, Township 132 North, Range 79 West. The crossing presently consists of a roadway embankment and bridge.

III. PRELIMINARY INVESTIGATION

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

1. A field survey of the Highway 1804 embankment;
2. A study of the hydrology of the watershed upstream of the Highway 1804 embankment;
3. A preliminary design of the outlet works necessary to safely and efficiently pass the design flood through the embankment;

4. A preliminary cost estimate for all alternatives considered; and

5. Prepare a preliminary engineering report presenting the results of the investigation.

IV. DEPOSIT

The District shall deposit a total of $2,500, with the Commission to help defray the field costs associated with this investigation.

V. RIGHTS-OF-ENTRY

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

VI. INDEMNIFICATION

The District agrees to indemnify and hold harmless the State of North Dakota, the Commission, its Secretary, their employees and agents, from all claims, suits or actions of whatsoever nature resulting out of the design, construction, operation, or maintenance of the project. In the event a suit is initiated or judgment is entered against the State of North Dakota, the Commission, its Secretary, their employees or their agents, the District shall indemnify any or all of them for all costs and expenses, including legal fees, and any judgment arrived at or satisfied or settlement entered.

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.

NORTH DAKOTA STATE WATER COMMISSION	**EMMONS COUNTY WATER RESOURCE DISTRICT**
By: David A Sprynczynatyk	By: Glenn McCrory
DAVID A. SPRYNCZYNATYK Secretary	GLEN MCCRORY Chairman
WITNESS: Dale L Frink	**WITNESS:** Helen Renschler
DATE: 19 Jun 91	**DATE:** 7/24/91