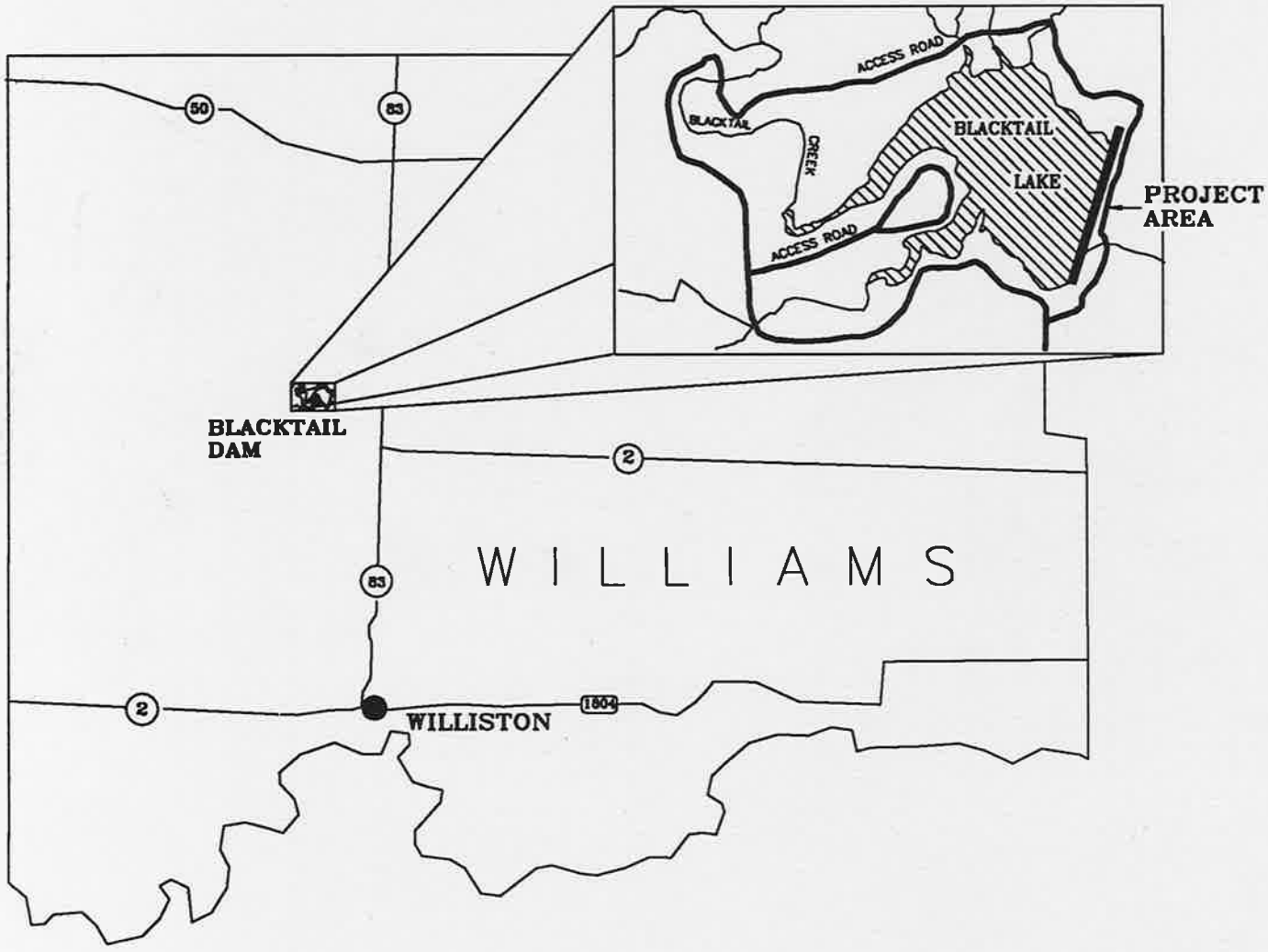
PRELIMINARY ENGINEERING REPORT

BLACKTAIL DAM

SWC #560

WILLIAMS COUNTY



NORTH DAKOTA

STATE WATER COMMISSION

SEPTEMBER 1990

Office of the State Engineer

August 2, 1990

Mr. Julian Gunlikson, Chr.
Williams County Park Board
Williston, ND 58801

RE: SWC Project #560 - Blacktail Dam

Dear Mr. Gunlikson:

This letter is in response to your letter of July 24, 1990, regarding the modifications and improvements proposed for Blacktail Dam.

A meeting was held in Bismarck on February 22, 1989. Those in attendance were representatives of the Williams County Park Board, the Williams County Water Resource District, ND Game and Fish Department, and the State Water Commission.

At that meeting, it was proposed to construct a new spillway system at Blacktail Dam to bring the structure up to a current level of dam safety standards. Part of the work (Phase 1) was done during the summer of 1989, which involved the following operations.

1. A 17-foot high, 48-inch diameter, reinforced concrete riser pipe (RCP), located at the upstream end of the 18-inch diameter corrugated metal pipe (CMP), was pumped full of grout (cement slurry).

2. An 18-inch diameter CMP and a 4-inch diameter iron pipe were pumped full of grout.

3. A 65-foot long, 36-inch diameter RCP, outletting at the toe of the embankment's downstream slope, was pumped full of grout.

Both the 18-inch and 4-inch diameter pipes were plugged with grout because they were in poor condition and presented a structural deficiency and a dam safety hazard. The 36-inch concrete pipe is far too small for current design floods and is also too steep, causing a slugging potential which could shake the pipe apart. In addition, it was constructed without a cradle support, which makes it more vulnerable to structural failure.

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As mentioned previously, the aforementioned work pertained to Phase I. After this phase was completed, two ramps were constructed, one on the upstream slope and one on the downstream slope of the embankment. The ramps were constructed in the area where the new spillway is to be located. The ramps provided access to the embankment slopes for a drill rig, which was used to conduct soil borings during the Phase II geotechnical investigation. This investigation began in the fall of 1989 and was completed in the spring of 1990.

In addition to the structural and geotechnical operations, the State Water Commission survey crew performed survey work in the summer of 1989. Both the topographic surveys and the geotechnical investigation were necessary in order to determine the scope, magnitude, and the approximate benefits and costs of the project with sufficient dependability to support project authorization or approval for construction.

The State Water Commission is using this geotechnical information to complete a preliminary engineering report on the replacement of the main spillway. This report should be available in about one month. According to cost estimates in the initial draft of this report, the modifications needed are in the range of $500,000, which are considerably higher than the previous cost estimates.

The North Dakota State Water Commission may have funds available to cost-share on the project in 1991. Therefore, it is important that we continue to move forward, if you can support this size of a project.

Based on the studies conducted, we disagree with your statement "that very little work has been completed." We have completed the work and studies, as outline in our previous correspondence, and we are definitely moving into the design stage of project development. Therefore, with one exception, we feel we have performed the field work and office studies in a timely and satisfactory manner.

The one exception or work item that was to be performed during Phase I and was omitted was the placement of rock. On March 2, 1989, Gary McDowall, construction superintendent for the State Water Commission met with Dwight Blikre, Roy Trogstad, and other county officials regarding the hauling and placement of rock at Blacktail Dam. At that time, rock had been stockpiled at the dam and more was to be hauled and stockpiled.

The initial rock contained a large amount of dirt and was very irregular in size and gradation. The local Board was told that this rock was unsatisfactory and would have to be cleaned prior to placement. Local Board members indicated that they would require cleaner rock to be hauled in. This was not done and now it is questionable how useful any of the rock is. Although no immediate plans were made for placing the rock at that time, local officials were instructed not to place the rock within an area that the new spillway structure was to be located. The local officials were also informed that if the rock hauled to the dam continued to contain excessive amounts of dirt, trash, or deleterious material, the rock would be rejected in accordance with our standard specifications for slope protection. The foreign material would then have to be removed within the limits as determined by the specifications or the Engineer, prior to its placement on the embankment.

On June 27, 1989, during Phase I of project improvements, Arland Grunseth, construction engineer, inspected construction operations and the stockpiled rock. Based on this inspection, he informed our construction crew not to place the rock because of excessive amounts of dirt and deleterious material. At a later date, Arland informed Dwight Blikre by phone of his inspection and decision to reject the stockpiled rock. On August 5, 1989, the cost report for Phase I of the dam modifications was forwarded to the county water resource district. At that time, we again informed the Board of our decision not to place the rock on the embankment.

If local officials want the stockpiled rock removed from its existing location(s) and placed on the upstream slope, we will consider inspecting the site again and determine if the stockpiles could create a blockage or hazard to the passage of flood flows. However, the rock prior to its placement at designated locations, must be cleaned at no expense to the Water Commission. We will consider cost-sharing for the placement of the rock. During the rock work, we can also fill in the ramp slots. We do not consider the cuts as a potential danger to the dam, but we agree that the slots should be repaired.

In closing, I recommend that the State Water Commission and the Williams County Board Members meet after the preliminary report is available to discuss further actions regarding Blacktail Dam. Please feel free to call or write us, if you have questions prior to this meeting.

Sincerely,

David A. Sprynczynatyk, P.E.
State Engineer

DAS:ACG:dm
cc: Dwight Blikre

PRELIMINARY ENGINEERING REPORT

Blacktail Dam Spillway Replacement
SWC Project #560

September 1990

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

Prepared by:

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DAVID A. SPRYNCZYNATYK, P.E.
State Engineer

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I. INTRODUCTION

Study Objectives:

In October, 1989, the North Dakota State Water Commission entered into an agreement with the Williams County Water Resource District. The purpose of the agreement was to investigate the feasibility of improving the discharge capability of Blacktail Dam, located approximately 25 miles north of Williston, North Dakota. The modifications include the installation of a larger principal spillway and the possible enlargement of the emergency spillway. A copy of the agreement is included in Appendix A. Figure 1 shows the location of Blacktail Dam within the state.

This report contains information on the geology of the site; results of a geotechnical survey conducted on the embankment; results of a hydrologic and hydraulic analysis of the drainage basin; a summary of the preliminary design of the project; a cost estimate based on the preliminary design; and a statement of conclusions and recommendations regarding the project.

Basin Location and Description:

Blacktail Dam is located on Blacktail Creek, approximately 25 miles north of Williston, North Dakota, in Sections 9, 10, 15, and 16, Township 157 North, Range 101 West. The dam was built primarily for recreation and fish and wildlife propagation and conservation. The topography of the area is moderate, with drainage patterns well-defined. The drainage area for the dam is

Figure 1 – Location Map

28.0 square miles. Land use in the basin is primarily agricultural. Figure 2 is a map of Blacktail Dam and the adjacent area.

The embankment is a zoned, rolled earthfill structure. The embankment is 2250 feet long, 57 feet high at the maximum section, and 10 feet wide at the crest. The crest of the embankment is at 2094 msl and has an alignment of north-northeast to south-southwest, with the right abutment on the south side. The upstream slope is 3:1 and the downstream slope is 2:1, with a 12-foot wide berm across the maximum embankment section.

The reservoir is controlled at an elevation of 2079 msl by the use of an uncontrolled drop inlet structure. The inlet structure has a 36-inch slide gate that can control the reservoir between the control elevation of 2079 msl, and an elevation of 2073 msl (elevation of top of inlet slab). A 36-inch diameter reinforced concrete pipe (RCP) conveys the discharge from the inlet structure to a stilling basin at the downstream toe of the dam.

The emergency spillway is a grass-lined channel located in the left abutment. The spillway has a variable channel bottom and variable side slopes. The control elevation of the emergency spillway is set at 2086 msl.

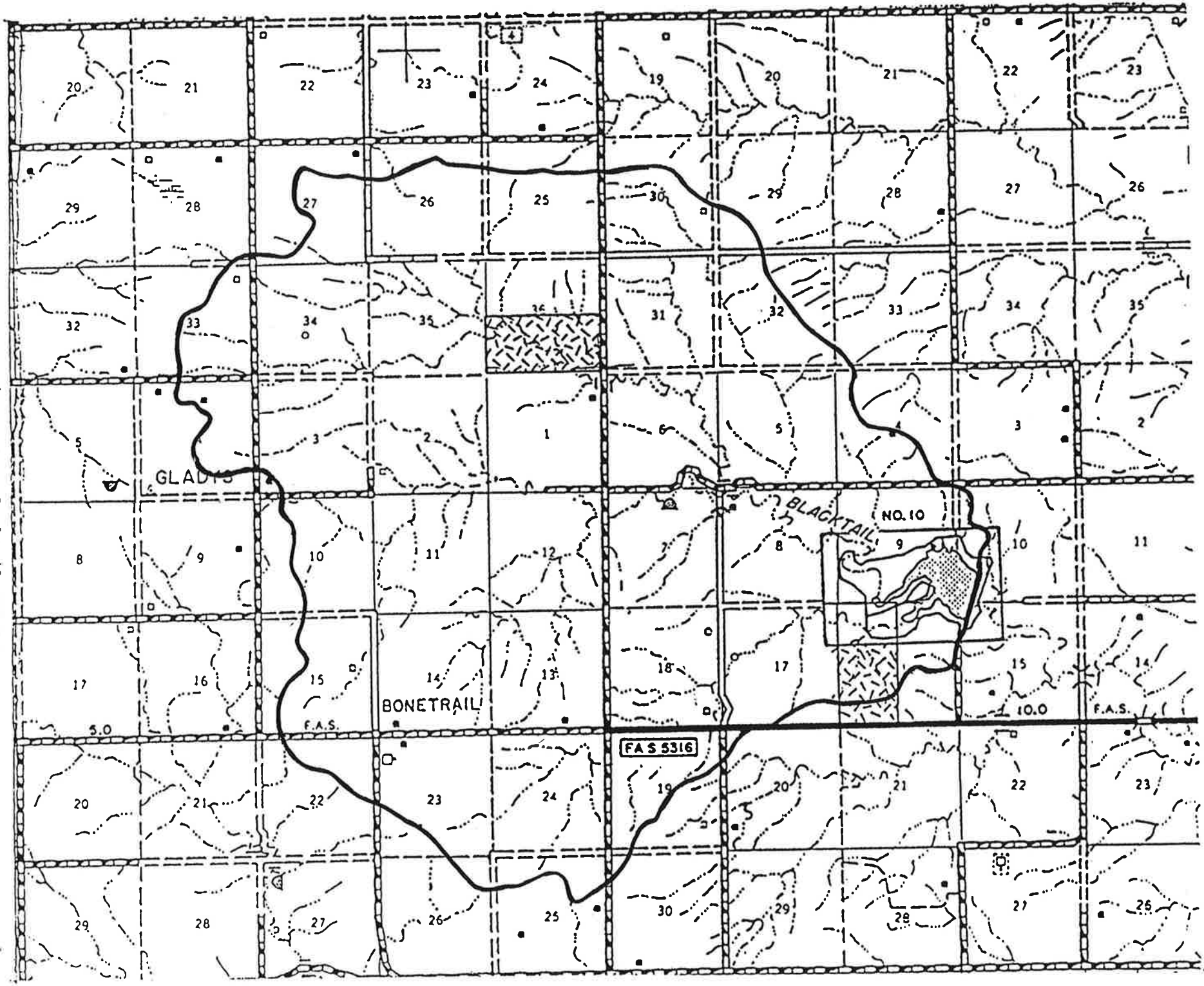


Figure 2 - Blacktail Dam Area

Historical Background:

Blacktail Dam was designed by the North Dakota State Water Commission. The original principal spillway pipe, an 18-inch diameter corrugated metal pipe (CMP), was installed by the State Water Commission's construction crew on a force-account basis.

The Frank Olson Construction Company supplied the equipment and operator for construction of the embankment and outlet works on a rental basis. The Mendenhall Construction Company was the contractor for the riprap. Construction began on September 3, 1959 and ended on January 20, 1960.

In February, 1967, the State Water Commission's force-account crew raised the inlet structure 6 feet. In the spring of 1967, the downstream slope sloughed. The first stage conduit was lengthened and the downstream slope of the embankment was flattened. Rock riprap was also added to the upstream slope to compensate for the 6-foot raise. In April, 1969, a large snowmelt runoff threatened to overtop the dam. The State Water Commission's crew cut a relief channel through the emergency spillway to protect the dam.

It was determined that another larger principal spillway would be needed, so a modification was designed. The contract was awarded to Neshem Peterson Construction Company and the modification work was done in the summer of 1969. This work included the installation of a principal concrete drop inlet and

a 36-inch diameter RCP conduit, with a 36-inch slide gate in the inlet. Also, the emergency spillway was lowered by 2 feet from an elevation of 2088 msl to an elevation of 2086 msl.

In 1971, the inlet structure for the 18-inch CMP was repaired by the State Water Commission. In 1989, this outlet and a 4-inch diameter low-level outlet were grouted closed and some rock riprap was added to the face of the dam.

The existing principal spillway is a 36-inch diameter RCP with a 5'x6'x6' drop inlet structure. The slope of the pipe is such that full-pipe flow is never attained, resulting in orifice control. This could lead to slugging and possible failure of the structure. In addition, the existing spillway does not satisfy the North Dakota Dam Design criteria.

II. GEOLOGY

The structure is located in the glaciated section of the Missouri Coteau slope section of the Great Plains Province. The topography consists of level to dissected uplands, along with knob and kettle features with high relief. Surface features were formed by ground moraine till deposits of undetermined thickness. The material consists mostly of brown and blue clay with strata of sands and gravels. Fort Union sediments underlie the entire area.

III. HYDROLOGY

A hydrologic analysis of the watershed was performed using the HEC-1 computer model, developed by the U.S. Army Corps of Engineers. It was used to simulate the rainfall vs runoff response for the basin, and to route the flows through the reservoir. 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 calculate 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 Blacktail watershed. The results gained from the model included: 1) inflow hydrographs, 2) reservoir stage hydrographs, and 3) outflow hydrographs.

IV. GEOTECHNICAL

Introduction:

A preliminary subsurface exploration was initiated by the State Water Commission. The purpose of the exploration was to assist in evaluating soil and groundwater conditions related to the construction of a new inlet structure and spillway for Blacktail Dam, located approximately 25 miles north of Williston, North Dakota, in Williams County.

This section of the report describes the exploration and testing performed, soil properties, and recommendations.

Exploration and Testing:

The drilling and testing were performed by Braun Engineering Testing of North Dakota, Inc. The location and elevation of all test borings was surveyed by the State Water Commission (Refer to Figure 3).

The penetration test borings were performed on January 3, 1990, and March 27, 1990, with a trailer-mounted rotary drill. A total of three standard penetration tests borings were performed. Sampling for the borings was conducted in accordance with ASTM D1556 "Penetration Test and Split Barrel Sampling of Soils." Using this method, the bore hole was advanced with a hollow-stem auger to the desired depth. A 140-pound hammer falling 30 inches, then drove a standard 2-inch outside diameter, split barrel sampler, a total penetration of 1-1/2 feet below the tip

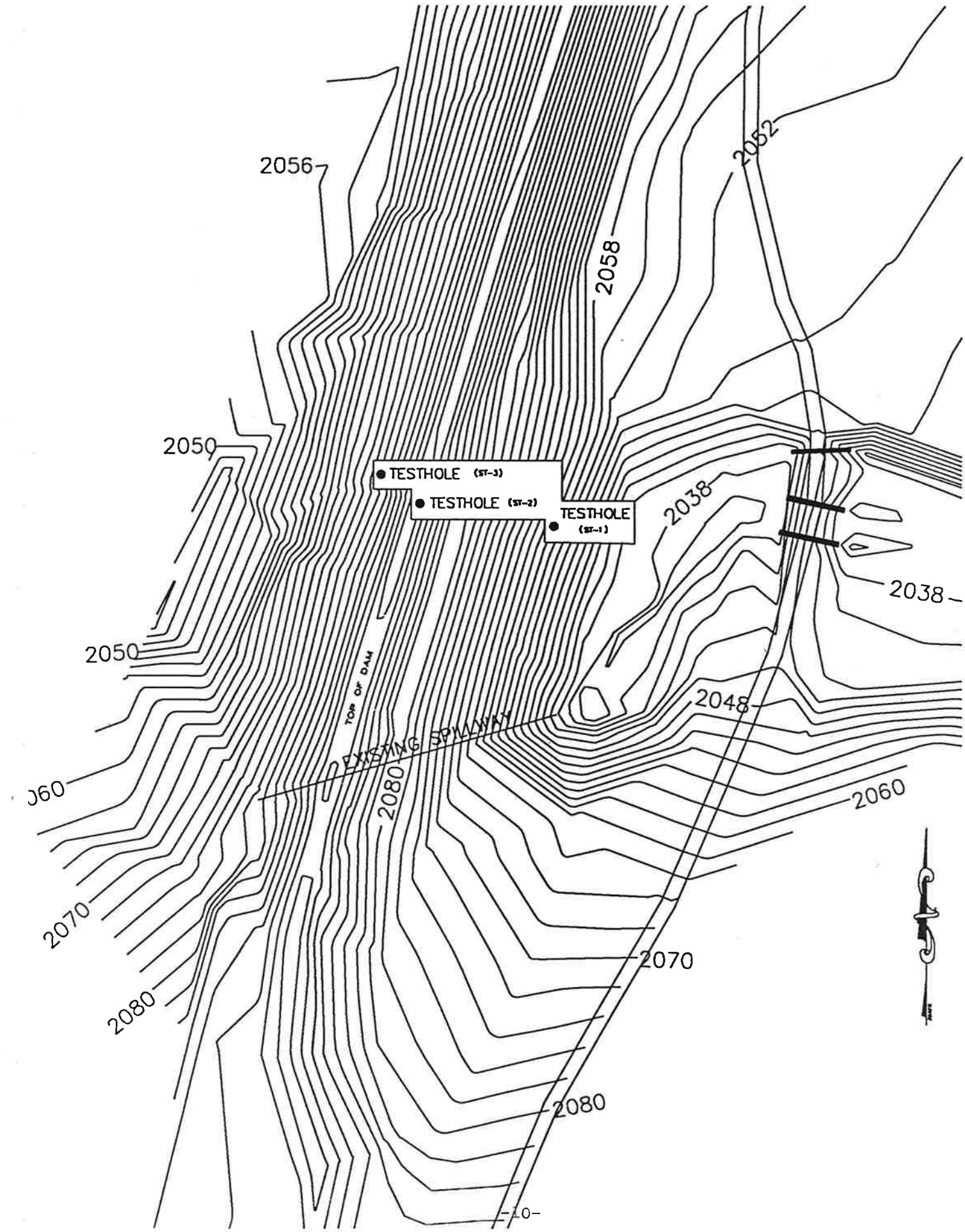


Figure 3 - Location of Test Borings

of the hollow-stem auger. The blows for the last foot of penetration were recorded and are an index of soil strength characteristics.

The soils encountered in the borings were visually and manually classified in the field by the crew chief, in accordance with ASTM D2488 "Recommended Practice for Visual and Manual Description of Soils." All samples were then returned to the laboratory for review of the field classifications. Logs of test borings are contained in Appendix B.

Immediately after the final sample of the boring was taken, the bore hole was probed through the hollow-stem auger to check for the presence of ground water. Immediately after withdrawal of the auger, the bore hole was again probed and the depth to water or cave-in was noted. The boring was finally checked and backfilled just prior to leaving the site.

Laboratory Testing:

Laboratory tests were performed by Braun Engineering Testing. Laboratory tests conducted for this project consisted of indexing tests for verification of classification. Based on their review of soil borings, Braun Engineering felt additional tests were not warranted. Results of the tests performed are contained in Appendix C.

Subsurface Soil Conditions:

The subsurface conditions are indicated by the logs of the test borings which are included in Appendix B. The logs indicate the depth and identification of various soil strata, the penetration resistances, and water level information.

The general soils profile at the boring locations consists of fill comprised of a lean clay. The fill materials extended to the termination depth of the borings. The soils encountered at the probable depth of support for the proposed structure have a design bearing pressure of up to 3000 pounds per square foot (psf).

V. PRELIMINARY DESIGN

Introduction:

Blacktail Dam is a recreation dam located about 25 miles northwest of Williston, North Dakota, on Blacktail Creek, in Williams County. The dam was originally built in 1959, and an additional principal spillway pipe was installed in 1969. In 1989, the original 18-inch diameter CMP spillway and 4-inch diameter low-level outlet were grouted closed in phase I of this investigation. The reservoir stores about 2670 acre-feet of water at the normal pool elevation of 2079 msl. This constitutes a surface area of approximately 158 acres. The present spillway is a 36-inch diameter RCP with a 5'x6'x6' drop inlet. The slope of the pipe is such that pipe flow is never attained, with orifice flow controlling. This could lead to slug flow and possible failure of the dam. Another problem encountered at the site is flooding of cabins around the dam. The following sections describe in detail how the outlet works should be modified.

Dam Classification:

The first step in the investigation of Blacktail 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.

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, and that failure would not result in serious damage to property and/or the loss of a large number of lives, Blacktail 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

Dam Height (feet)	Hazard Categories		
	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

Blacktail Dam has an embankment height of 57 feet, therefore, it is classified as a Class IV dam for design purpose. In a Class IV dam, the principal spillway must pass a 50-year precipitation event without using the emergency spillway. The entire spillway system (emergency and principal) must pass the flows from a .5 PMP (probable maximum precipitation) event without overtopping the dam, and pass the flows from a .3 PMP event without exceeding a velocity of 8.0 feet per second in the emergency spillway.

Precipitation Design:

Once the dam was classified, precipitation design amounts were determined. Outlet works of a dam are to be designed so that they pass the runoff from precipitation events, as suggested by the dams classification.

The event that provides the maximum reservoir level should be used as the design event (i.e., 12-hour rainfall, 10-day rainfall or 10-day snowmelt). For Blacktail Dam, the design event is the 10-day snowmelt. A 6-hour, 10-square mile extreme rainfall table developed from Hydrometeorological Report Number 51, was used for the 0.3 PMP and 0.5 PMP events. Table 2 shows the resulting peak inflows and total volumes for these events.

Table 2 - Peak Inflows and Volumes for Design Frequency

Event	Intensity (in/interval)	Peak Inflow (cfs)	Total Inflow Volume (acre-feet)
50-year 12-hour rainfall	3.46	2319	1720
50-year 10-day rainfall	6.78	1903	3040
50-year 10-day snowmelt	3.04	1994	3671
0.3 PMP	5.38	6062	3855
0.5 PMP	8.97	13344	8479

Hydraulic Design:

The HEC-1 computer model was used to simulate the precipitation vs runoff response for the basin and to route the flows through the 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 was obtained from a previous inspection report for Blacktail Dam and is shown in Figure 4.

The rating curve for the principal spillway was calculated based on the equations for pipe flow. The rating curve for the emergency spillway was calculated using the HEC-2 computer model. The HEC-2 computer model is capable of calculating water surface profiles for steady, gradually varied flow in natural or man-made channels. The rating curve for the existing spillway system is contained in Table 3.

BLACKTAIL DAM

AREA–CAPACITY CURVE

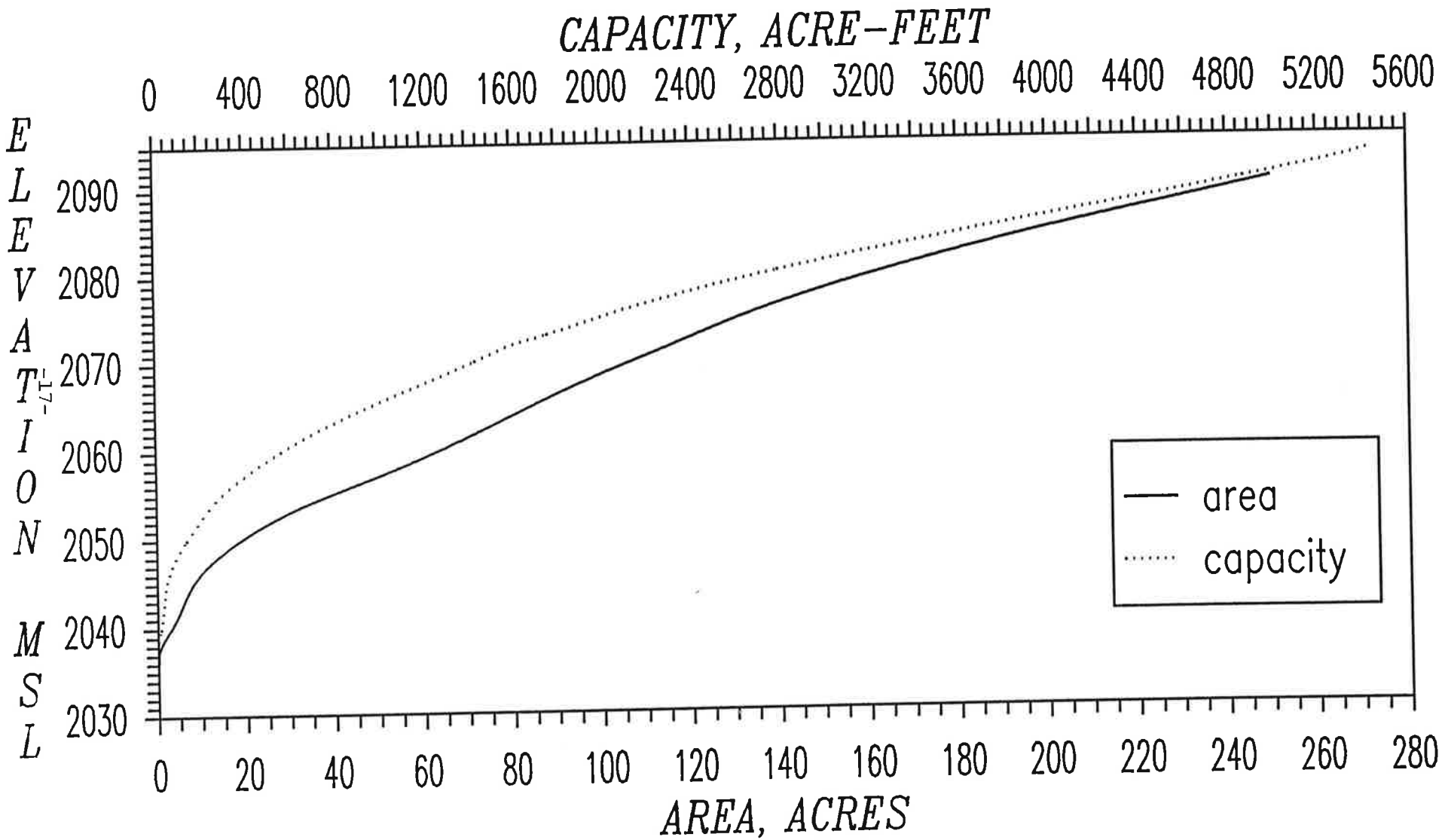


Figure 4 - Area Capacity Curve

Table 3 - Rating Curve for Existing 36-inch Diameter RCP

Elevation	Q-Principal (cfs)	Q-Emergency (cfs)	Q-Total (cfs)
2079	-	-	-
2080	37.2	-	37.2
2081	89.7	-	89.7
2082	96.3	-	96.3
2083	102.5	-	102.5
2084	108.4	-	108.4
2085	114.0	-	114.0
2086	119.3	-	119.3
2087	124.3	400.0	524.3
2088	129.2	1100.0	1229.2
2089	133.9	2500.0	2633.9
2090	138.5	4500.0	4638.5
2091	142.9	7000.0	7142.9
2092	147.1	10000.0	10147.1
2093	151.3	12400.0	12551.3

The rating curve for the proposed 5-foot diameter RCP using the existing emergency spillway is contained in Table 4.

Table 4 - Rating Curve for Proposed 5-foot Diameter RCP

Elevation	Q-Principal (cfs)	Q-Emergency (cfs)	Q-Total (cfs)
2079	-	-	-
2080	93.0	-	93.0
2081	263.0	-	263.0
2082	483.2	-	483.2
2083	638.8	-	638.8
2084	647.5	-	647.5
2085	656.1	-	656.1
2086	664.6	-	664.6
2087	672.9	400.0	1072.9
2088	681.2	1100.0	1781.2
2089	689.4	2500.0	3189.4
2090	697.4	4500.0	5197.4
2091	705.4	7000.0	7705.4
2092	713.3	10000.0	10713.3
2093	721.1	12400.0	13121.1

Principal Spillway Works:

The present principal spillway consists of 270 feet of 36-inch diameter RCP with a 5'x6'x6' drop inlet. The slope of the pipe is approximately 14 percent. The relatively steep slope of the pipe prevents it from reaching full pipe flow. Although problems with the existing spillway have not occurred in the past, the potential for slugging and possible dam failure exist. In addition, the pipe is not capable of handling the design flow required for a Class IV dam. Table 5 gives the inflow, outflow, and stage for the different precipitation events for the existing conditions generated by the HEC-1 model. This data shows that the water surface elevation exceeds the elevation of the emergency spillway (2086 msl) for the 50-year 12-hour rainfall, as well as the 50-year 10-day snowmelt and rainfall.

Table 5 - Results of Hydrologic Study on Existing Conditions

Event	Inflow (cfs)	Outflow (cfs)	Stage
50-year 12-hour rainfall	2319	345	2086.5
50-year 10-day rainfall	1903	354	2086.6
50-year 10-day snowmelt	1994	999	2087.7
0.3 PMP	6062	4203	2089.8
0.5 PMP	13344	12331	2092.9

The results of the preliminary investigation show that a 4.5-foot box culvert or a 5-foot diameter RCP will safely handle the design flow. Past experience with box culverts shows that they must be formed and are more difficult to fabricate and install. It is recommended that the new principal spillway

consist of a 5-foot diameter RCP with a standard drop inlet structure set at an elevation of 2079 msl. Table 6 gives the inflow, outflow, and stage for the different precipitation events for the proposed new outlet obtained from the HEC-1 computer model. Figures 5-7 show the various inflow-outflow relationships for the proposed new outlet. The proposed 5-foot diameter RCP consists of thirteen 16-foot sections and one 22-foot section. Within the length of the spillway there will be six reinforced concrete anti-seep collars. The spillway will be laid at a slope of 2.2 percent with the outlet invert at elevation 2044 msl. Figure 8 shows a transverse section of the dam at the principal spillway, as well as a profile of soils encountered at the proposed depth.

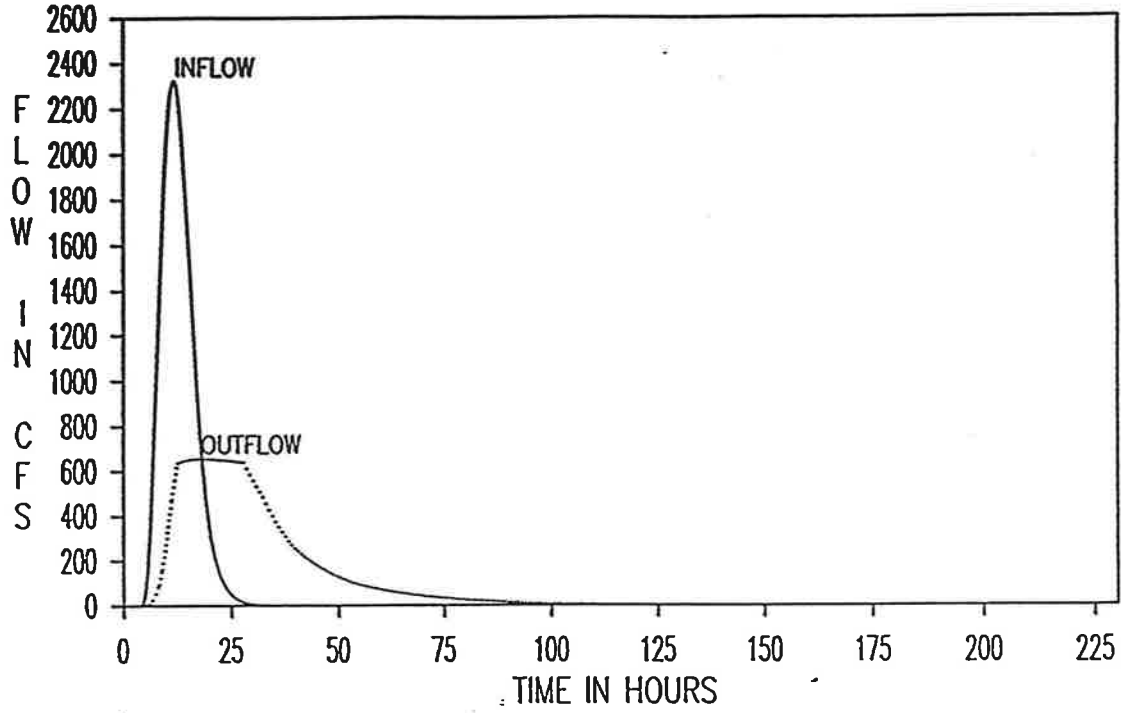
Table 6 - Results of Hydrologic Study for Proposed 5-foot Diameter RCP

Event	Inflow (cfs)	Outflow (cfs)	Stage
50-year 12-hour rainfall	2319	654	2084.77
50-year 10-day rainfall	1903	647	2083.96
50-year 10-day snowmelt	1994	664	2085.91
0.3 PMP	6062	4004	2089.41
0.5 PMP	13344	12307	2092.66

A cantilever outlet and plunge pool are recommended to dissipate energy. A Saint-Anthony Falls type stilling basin was also considered, but due to its considerably higher cost (approximately $35,000), was not recommended. Figure 9 shows the cantilever outlet and plunge pool. The invert of the cantilever

BLACKTAIL DAM HYDROGRAPH

50 YEAR 12-HOUR RAINFALL



50 YEAR 10-DAY RAINFALL

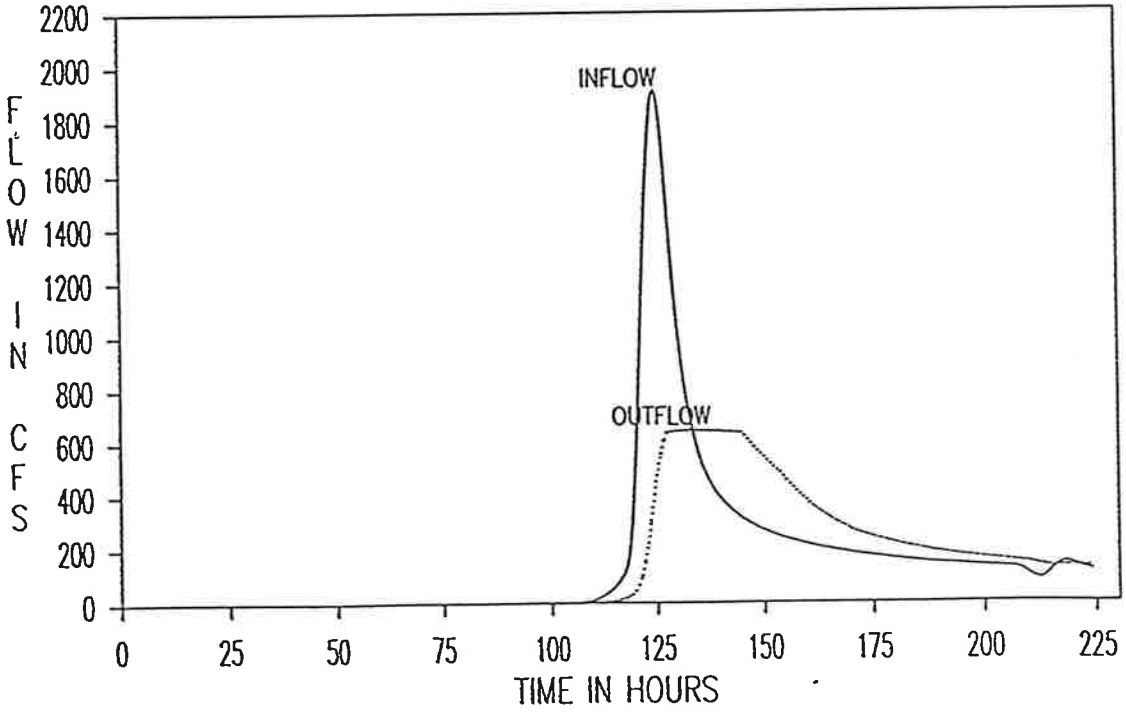


Figure 5 - Blacktail Dam Hydrograph

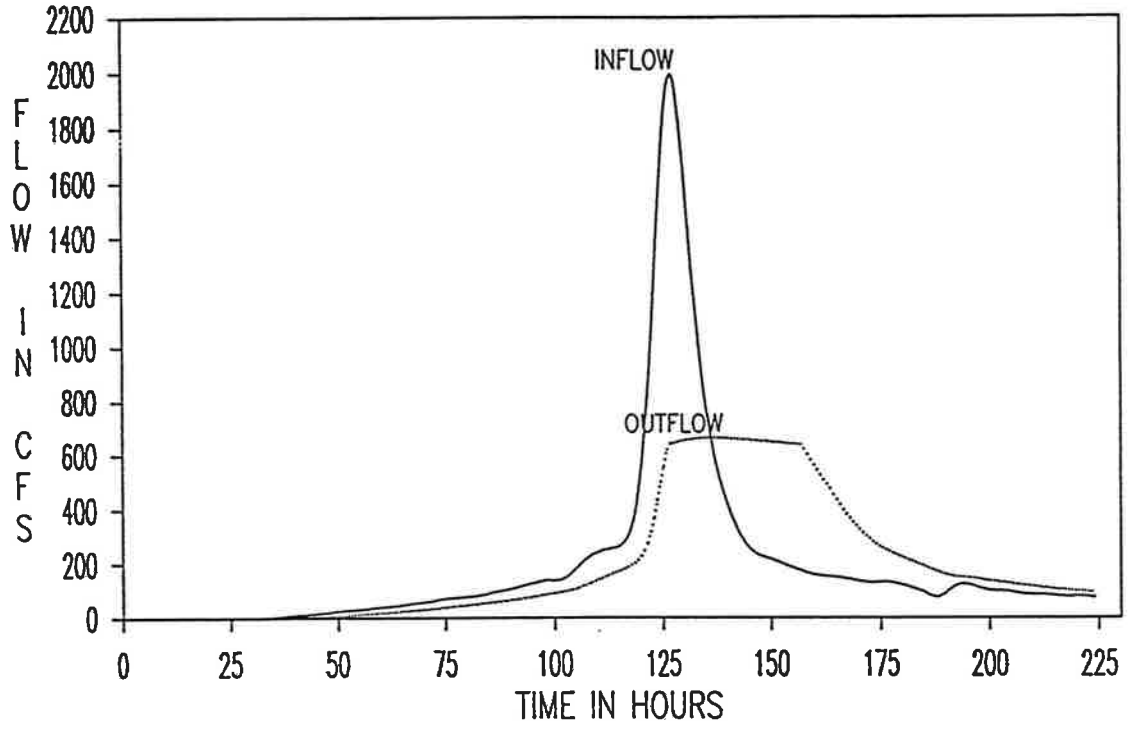
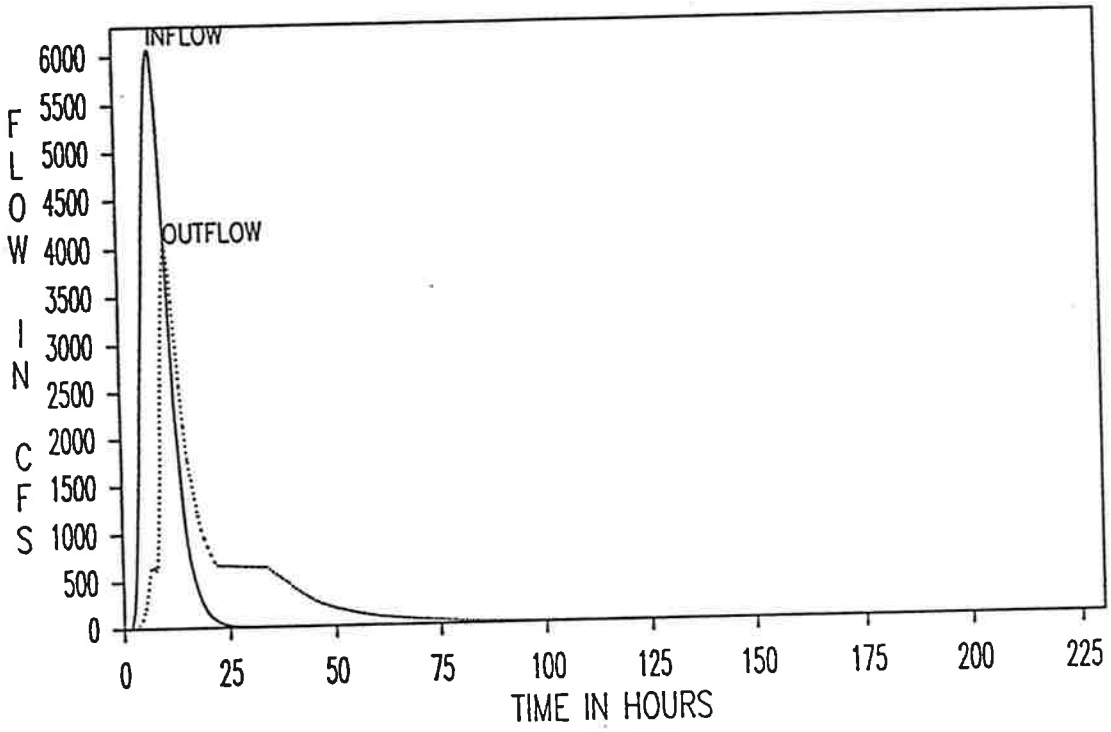


Figure 6 - Blacktail Dam Hydrograph

BLACKTAIL DAM HYDROGRAPH

30% OF PROBABLE MAXIMUM PRECIPITATION



50% OF PROBABLE MAXIMUM PRECIPITATION

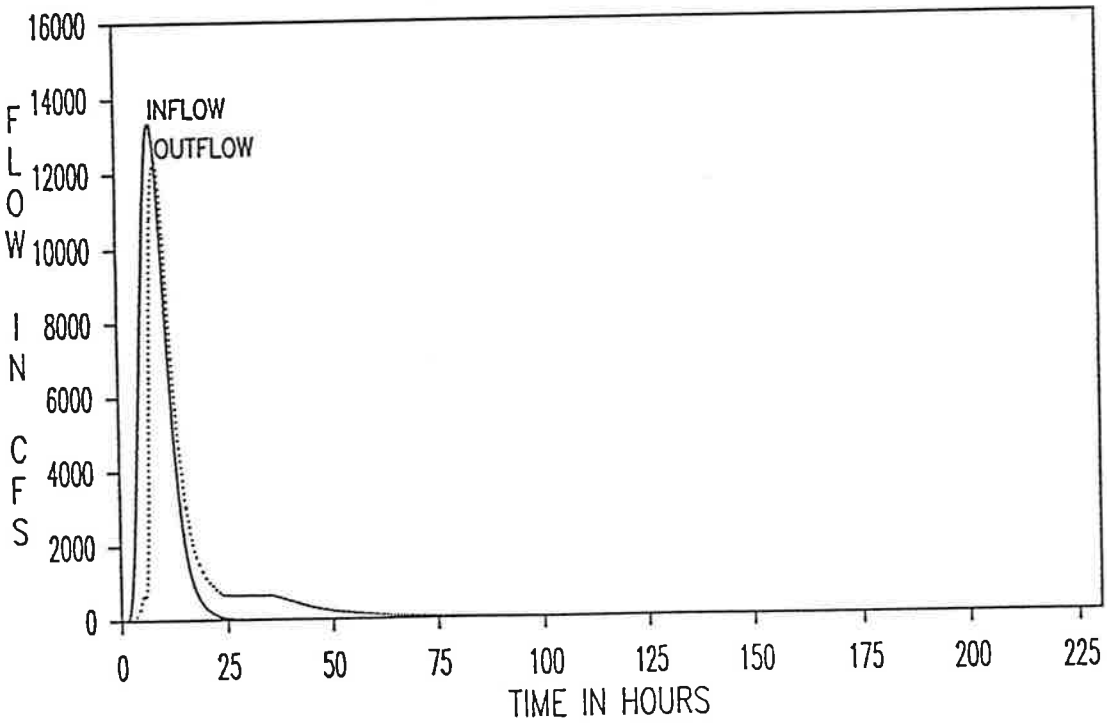


Figure 7 - Blacktail Dam Hydrograph

TRANSVERSE PROFILE OF DAM AT PRINCIPAL SPILLWAY
BLACKTAIL DAM SWC #560

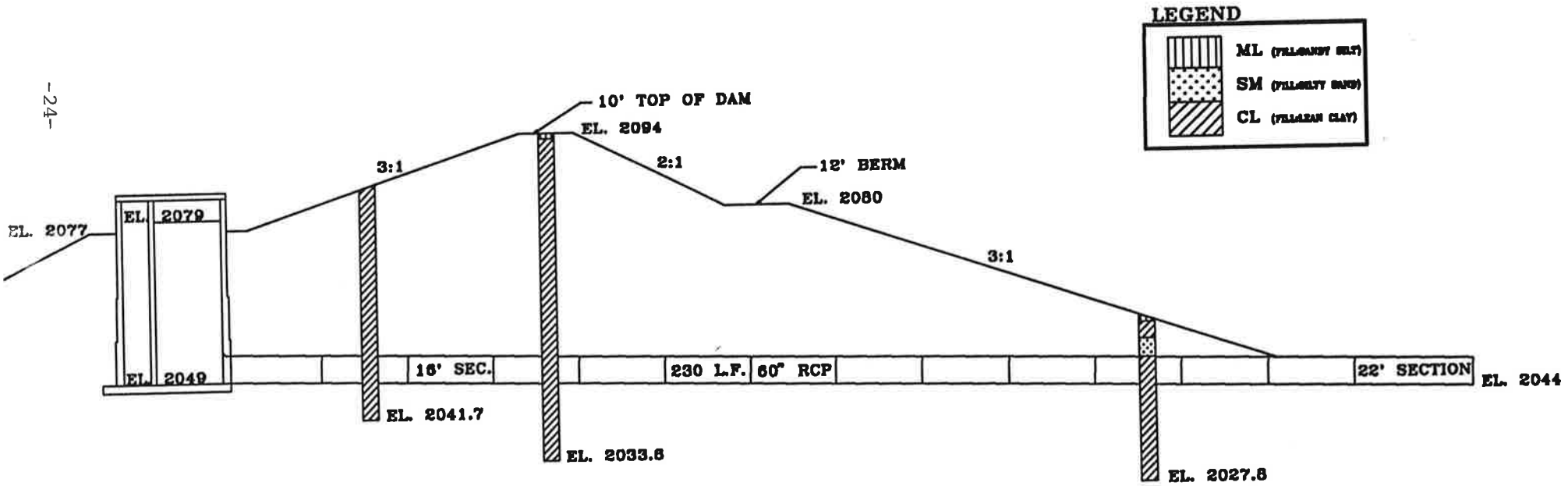
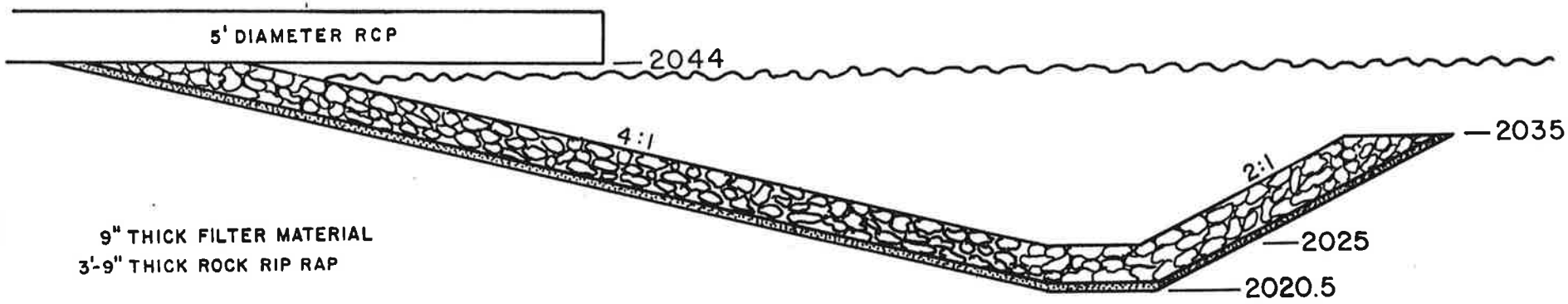


Figure 8 - Transverse Profile
of Dam at Principal Spillway



CANTILEVER OUTLET AND STILLING BASIN

NO SCALE

Figure 9

outlet is to be at least one-foot above the tailwater elevation at maximum discharge.

There will also be a need for a low-level drawdown structure since the existing pipe was grouted closed in 1989. The existing low-level drawdown structure was grouted closed primarily for safety reasons. The condition of the pipe was unknown and it posed a danger to the embankment had it failed.

The low-level drawdown structure, also known as a cold water return or hypolimnetic discharge structure, is 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.

Emergency Spillway:

The emergency spillway consists of a grass-lined channel located in the left abutment. The spillway has a variable channel bottom and variable side slopes. The control elevation of the emergency spillway is set at 2086 msl.

The rating curve for the emergency spillway was developed using the HEC-2 computer model. The rating curve was used to

route the velocity and freeboard hydrographs. The velocity hydrograph consists of 30 percent of the probable maximum precipitation, while the freeboard hydrograph consists of 50 percent of the probable maximum precipitation.

The 0.3 PMP inflow is 6,062 cfs. The routing of the 0.3 PMP event yields a 4,004 cfs outflow. The event causes the reservoir to rise to an elevation of 2089.41 msl. The principal spillway passes 693 cfs while the emergency spillway passes 3,311 cfs of total outflow. The velocity corresponding to this outflow is 6.7 feet per second. The criteria from the North Dakota Dam Design Handbook allows a velocity of approximately 8 feet per second for a group one cover on erosion resistant soils, at a slope under 5 percent, with a 10 percent increase in velocity for infrequent use. This shows that the existing spillway is acceptable based on the velocity hydrograph.

The 0.5 PMP inflow is 13,344 cfs. The routing of the 0.5 PMP event yields a 12,307 cfs outflow. The event causes the reservoir to rise to elevation 2092.66 msl. The North Dakota Dam Design Handbook requires a Class IV dam to pass a 0.5 PMP event without overtopping the dam. The maximum reservoir elevation of 2092.66 msl is below the top of dam height of 2093-2094 msl. The existing emergency spillway is acceptable based on the freeboard hydrograph.

Cabin owners have suggested that the possibility of lowering the emergency spillway be considered. They feel this will help prevent the flooding of cabins during high water levels. A HEC-1 computer model was performed to determine what size principal spillway is required to lower the emergency spillway. To lower the emergency spillway by 2 feet, a 7-foot diameter RCP principal spillway is required for the dam to pass the runoff from precipitation events, as suggested by the dam classification. The installation of a 7-foot diameter RCP principal spillway represents a significant increase in the project cost (approximately $142,000). Based on the cost increase and the fact that the available storage capabilities of the dam would not be utilized, it is recommended that the emergency spillway not be lowered.

Another alternative that will help prevent flooding is to design the principal spillway so that it gives 100-year flood protection. A 6-foot diameter RCP principal spillway will pass the runoff from 100-year precipitation events, without water flowing through the emergency spillway. The cost increase associated with this alternative is $65,000.

Downstream Modifications:

Modifications to the downstream channel will be required in order to accommodate the proposed new spillway. The new location will eliminate the curved channel upstream of the road. A 20-foot wide channel paralleled by berms with 2:1 side slopes is recommended between the plunge pool exit and roadway crossing

(Refer to Figure 10). This channel should be lined with riprap to prevent erosion.

The present roadway crossing consists of one 36-inch and two 48-inch diameter CMP culverts. A HEC-2 computer model was performed on the downstream channel to determine the backwater depth at the culvert outlet. The model indicated that the culvert outlet would not be submerged due to backwater. This means that the culvert inlet will control the flow.

The maximum outflow from the proposed principal spillway is 664 cfs for a 50-year precipitation event. The present crossing is only capable of passing a flow of 275 cfs, based on a Bureau of Public Roads culvert nomograph with inlet control. This means that overtopping of the road will occur when flows greater than 275 cfs are encountered. Overtopping is not desirable since the road has washed out in the past when water passed over it. A Bureau of Public Roads nomograph, based on inlet control, was also used to size the new roadway crossing. A 65' long 12'-10" by 8'-4" arch pipe is recommended as a new roadway crossing. The arch pipe will pass flows of up to 700 cfs, with a maximum upstream water surface elevation equal to that of the top of the pipe.

It is recommended that 2 feet of cover be used over the arch pipe. This will require that the roadway be raised for a length of approximately 200 feet. The two 48-inch diameter CMP culverts

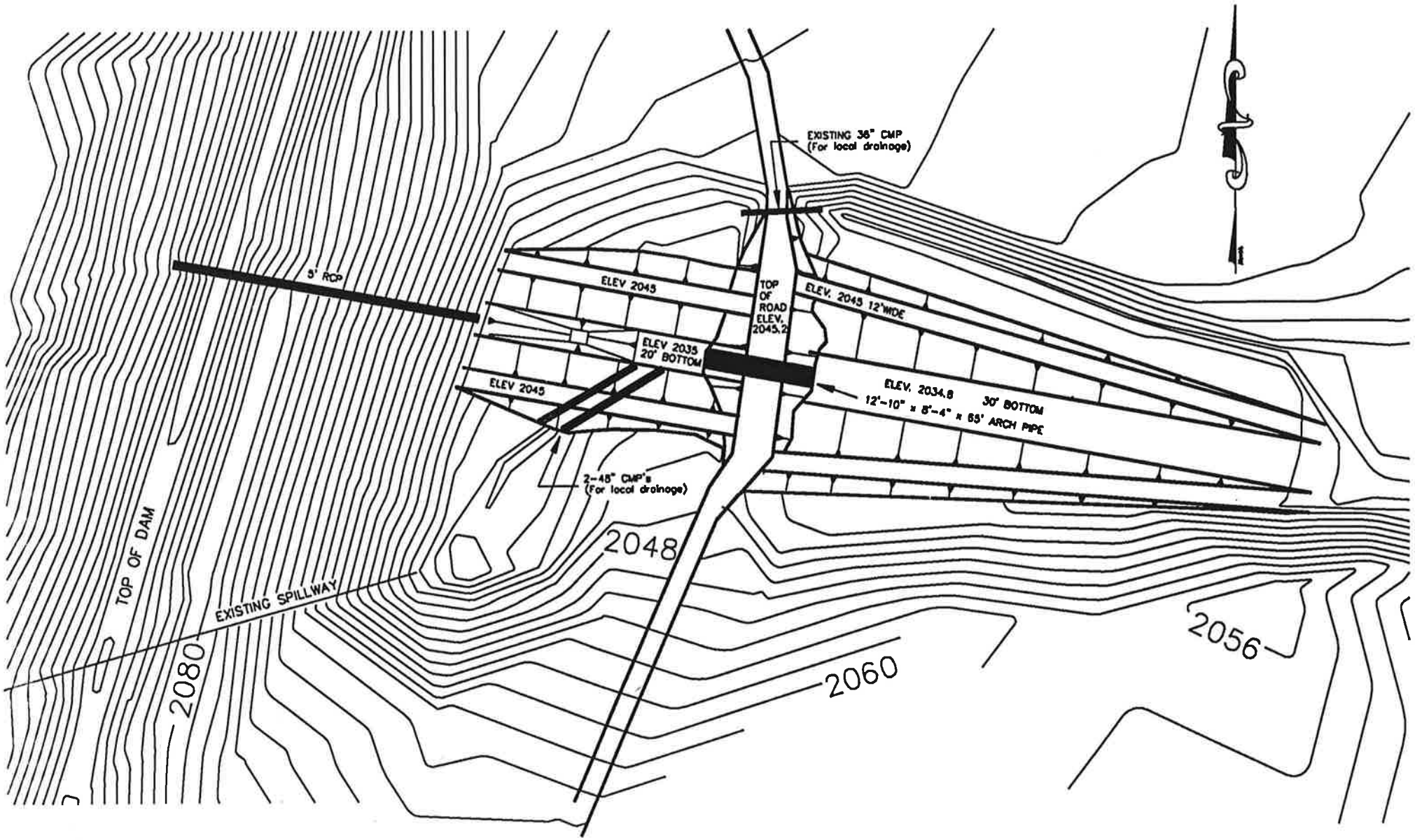


Figure 10 - Downstream Modifications

in the existing crossing can be relocated in the south berm of the outlet channel to pass flows due to local runoff. The 36-inch diameter CMP should remain at its present location to pass runoff from the north.

The channel downstream of the roadway should also be modified to allow for the new roadway crossing. A 30-foot wide channel paralleled by berms with 3:1 side slopes is recommended. This channel will be approximately 300 feet in length and will tie in with the existing channel (Refer to Figure 10).

Existing Spillway Modifications:

Modifications to the existing principal spillway must be performed. The present spillway consists of a 36-inch diameter RCP with a 5'x6'x6' drop inlet. The slope of the spillway is approximately 14 percent. The relatively steep slope of the pipe prevents it from attaining full pipe flow with orifice flow controlling. This could lead to slugging and possible dam failure. The present spillway should not remain in service due to the potential hazard accompanying it. The recommended alternative for dealing with the present spillway is to take it out of service by grouting the intake of the pipe.

Water Control:

Water control represents a significant part of the Blacktail Dam project. Lowering of the water level does not appear to be a feasible alternative because the well established fishery located

in the reservoir would be lost. The proposed alternative for water control is to construct an earthen cofferdam or dike around the area to be excavated for the new spillway installation. The cofferdam will help maintain the reservoir at or near its current elevation and will help retain the fishery. The exact details of the cofferdam will be left up to the contractor for the project.

VI. LAND AND WATER RIGHTS

No additional land or water rights will be required in order to modify Blacktail Dam, since the control elevation of the reservoir water surface is to remain at its present elevation of 2079 msl.

VII. PRELIMINARY COST ESTIMATE

As proposed, the modifications to Blacktail Dam are estimated to cost $546,000. Table 7 shows the breakdown of costs for the modifications.

Table 7 - Blacktail Dam Cost Estimate

No.	Item	Quantity	Unit	Unit Price	Total
1.	Mobilization	1	LS	$ 5,000.00	$ 5,000
2.	Water Control	1	LS	60,000.00	60,000
3.	Stripping and Spreading Topsoil	10,280	SY	.25	2,570
4.	Trench Excavation	33,600	CY	2.20	73,920
5.	Trench Fill	39,600	CY	1.10	43,560
6.	Concrete	257	CY	275.00	70,675
7.	Reinforcing Steel	35,100	Lbs	.50	17,550
8.	Rock Riprap	874	CY	25.00	21,850
9.	Low-Level Drawdown Pipe	1	LS	6,000.00	6,000
10.	Low-Level Drawdown Valve	1	LS	4,000.00	4,000
11.	Plunge Pool				
	(a) Riprap	515	CY	25.00	12,875
	(b) Filter Material	165	CY	15.00	2,475
	(c) Excavation	1,050	CY	1.50	1,575
12.	Roadway and Channel Modifications				
	(a) Relocate 2-48" CMP	1	LS	1,000.00	1,000
	(b) Fill for Roadway	202	CY	1.10	222
	(c) Fill	2,740	CY	1.10	3,014
	(d) Cut (Excavation)	1,671	CY	1.50	2,500
	(e) Gravel	180	CY	15.00	2,700
13.	Arch Pipe (12'-10"x8'-4"x65')	1	LS	17,500.00	17,500
14.	60" RCP (Installed)	230	LF	275.00	63,250
15.	Trash Rack & Misc. Metal	1	LS	6,000.00	6,000
16.	Existing Spillway Modifications	1	LS	1,000.00	1,000
16.	Seeding	4	Ac.	200.00	800
	Subtotal				$420,036
	Contingencies (+/-10%)				41,988
	Contract Administration (+/- 10%)				41,988
	Engineering (+/- 10%)				41,988
	Total				$546,000

VIII. SUMMARY

The feasibility of improving the discharge capability of Blacktail Dam has been examined. The dam site and reservoir is located on Blacktail Creek, approximately 25 miles north of Williston, North Dakota, in Sections 9, 10, 15, and 16, Township 157 North, Range 101 West. The dam was built primarily for recreation and fish and wildlife propagation and conservation.

Blacktail Dam is located in a predominantly rural area. Failure would not result in serious damage to property and/or the loss of a large number of lives. Considering this, the dam is classified in the medium-hazard category. Based on an embankment height of 57 feet and a medium hazard classification, Blacktail 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 12-hour rainfall event, a 50-year 10-day rainfall event, and a 50-year 10-day snowmelt 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.

The resulting hydraulic structure can be described as follows. The principal spillway should consist of a 5-foot by 15-foot reinforced concrete drop inlet. A 5-foot diameter rein-

forced concrete pipe extends through the embankment. The RCP consists of thirteen 16-foot sections and one 22-foot section. The principal spillway will be placed north of the existing spillway. A cantilever outlet and plunge pool is designed to dissipate the energy. There will also be a low-level water quality control structure to help improve the water quality by removing stagnant water from the bottom of the reservoir. An emergency spillway with variable channel bottom and variable side slopes is located in the north abutment. The existing emergency spillway is capable of passing flows due to large events without overtopping the dam, therefore, modifications to the existing emergency spillway are not recommended. The subsurface soil exploration revealed adequate bearing capacity to support the new principal spillway structure.

Modifications to the downstream channel and roadway crossing must be made in order to facilitate the principal spillway at its new location. It is recommended that a new channel be constructed between the plunge pool and roadway crossing. A 65-foot long 12'-10"x8'-4" arch pipe will handle flows for the roadway crossing. Another channel should be constructed for a distance of about 300 feet beyond the roadway crossing to tie in with the existing channel.

The existing 36-inch RCP spillway is a potential hazard and it is recommended that it be taken out of service. The proposed alternative for dealing with the existing spillway is to grout

the pipe intake. In 1989, the original 18-inch CMP spillway and 4-inch low-level outlet were grouted closed as a part of Phase 1 of this project.

The dam modifications, as proposed, will cost $546,000. This cost includes $420,036 for construction costs and $125,964 for contingencies, contract administration and engineering.

IX. RECOMMENDATIONS

It is recommended that the existing spillway system for Blacktail Dam be replaced. The recommended alternative includes a 5-foot by 15-foot concrete drop inlet and a new 5-foot diameter RCP main spillway. This spillway system will pass a 50-year flood without the use of the emergency spillway. The cost of this alternative was estimated at $546,000.

Two other alternatives were also analyzed. A 6-foot diameter RCP main spillway will pass a 100-year flood without the use of the emergency spillway. This would provide additional, but not total, protection for the existing cabins around the lake. This would increase the cost by $65,000 ($611,000 total).

Lowering the emergency spillway was also analyzed. Lowering the emergency spillway 2 feet would require a 7-foot diameter RCP main spillway to meet state standards. This spillway system is capable of passing a 50-year flood without the use of the lowered emergency spillway. The additional cost for this system was estimated to be $142,000 ($688,000 total).

Since the project presently meets State Water Commission cost-share eligibility guidelines, the Commission would consider cost-sharing if funds were available. The decision to proceed with this project is the responsibility of the Williams County Water Resource District.

APPENDIX A - A COPY OF AGREEMENT

SWC Project #560
October 27, 1989

A G R E E M E N T

Investigation of Improving Discharge Capacity of Blacktail Dam

I. PARTIES

THIS AGREEMENT is entered into by the North Dakota State Water Commission, hereinafter Commission, through its Secretary, David A. Sprynczynatyk, hereinafter Secretary; and the Williams County Water Resource District, hereinafter District, through its Chairman, Dwight Blikre.

II. PROJECT, PURPOSE, AND LOCATION

The District wishes to investigate the feasibility of making modifications to Blacktail Dam. The modifications will include: the installation of a larger principal spillway and the possible enlargement of the emergency spillway. A geotechnical survey will be conducted on the embankment to determine its stability. The purpose of this project is to determine the most cost effective method to increase the discharge capability of the dam to meet the current dam safety requirements. The dam is located approximately 25 miles north of the city of Williston in Section 10, Township 157 North, Range 101 West, on Blacktail Creek in western Williams County.

III. PRELIMINARY INVESTIGATION

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

1. Study the hydrology of the basin to determine the flows for use in the design of the new principal spillway, and the modification to the emergency spillway, if necessary;

2. A field survey of the embankment and other pertinent areas;

3. A geotechnical investigation of the embankment to determine soil types and engineering properties;

4. Soil tests on samples taken;

5. A preliminary design of a new principal spillway and emergency spillway, if necessary. Engineering properties of soils will be used to determine the stability of the existing embankment;

6. A preliminary cost estimate; and

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

IV. DEPOSIT-REFUND

The District shall deposit a total of $3,500 with the Commission to help defray the field costs, the field survey and geotechnical investigation of the investigation. Upon receipt of a request from the District 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 District with a statement of all expenses incurred in the investigation and shall refund to the District any unexpended funds.

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 hereby accepts responsibility for and holds the Commission, its employees and their agents, and the State Engineer free from all claims and damages to public or private property, rights, or persons arising out of this investigation. In the event a suit is initiated or judgment rendered against the Commission, its employees and their agents, the District shall indemnify it for any judgment arrived at or judgment satisfied.

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

By: David A. Sprynczynatyk

DAVID A. SPRYNCZYNATYK
Secretary

WITNESS: Bruce T. Bensen

DATE: 27 Oct 1989

WILLIAMS COUNTY WATER RESOURCE DISTRICT

By: Dwight Blikre

DWIGHT BLIKRE
Chairman

WITNESS: Gilbert Peterson

DATE: Nov 7 - 89

APPENDIX B - LOG OF TEST BORINGS

LOG OF BORING

BRAUN ENGINEERING TESTING

PROJECT: NDB90-001
SUBSURFACE EXPLORATION
Blacktail Dam
Williams County
Williston, North Dakota

BORING: ST-1

LOCATION:
Downstream Side - See Sketch

DATE: 1/3/90

SCALE: 1" = 4'

(See Report and Standard Plates for evaluation and descriptive terminology.)

Elev.	Depth	ASTM Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
2058.3	0.0					
2057.8	0.5	ML	FILL: SILT, roots very dark brown, frozen.	37		
		CL	FILL: SANDY CLAY, trace of gravel, olive brown, frozen.			
2054.8	3.5	SM	FILL: SILTY SAND, fine to coarse grained, trace of gravel, very dark brownish gray, waterbearing, loose.	9	▽	
2050.3	8.0	CL	FILL: SANDY LEAN clay, dark brown.	11		
				12		
2041.3	17.0	CL	FILL: SILTY CLAY, layers of silt, sand, dark gray, wet, rather soft to rather stiff.	12		
				5		* Water level down 5' immediately after withdrawal of auger.
2027.8	30.5			6		** Boring then backfilled.
			END OF BORING.			

LOG OF BORING

BRAUN ENGINEERING TESTING

PROJECT: NDB90-001
SUBSURFACE EXPLORATION
Blacktail Dam
Williams County
Williston, North Dakota

BORING: ST-2

LOCATION:
Top of Dike - See Sketch

DATE: 3/27/90

SCALE: 1" = 4'

(See Report and Standard Plates for evaluation and descriptive terminology.)

Elev.	Depth	ASTM Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
2094.1	0.0					
2093.1	1.0	ML	FILL: SANDY SILT, roots, very dark brown, dry (Topsoil).	9		
		CL	FILL: LEAN CLAY, dark olive brown, moist, rather stiff to very stiff.	25		
2087.1	7.0	CL	FILL: LEAN CLAY, olive brown, moist, stiff to very stiff.	16		
				15		
				19		
2072.1	22.0	CL	FILL: SANDY LEAN clay, seams of sand, dark brownish gray, moist, rather stiff to very stiff.	16		
				12		
2062.1	32.0					

LOG OF BORING

BRAUN ENGINEERING TESTING

PROJECT: NDB90-001
SUBSURFACE EXPLORATION
Blacktail Dam
Williams County
Williston, North Dakota

BORING: ST-2 (cont.)

LOCATION:
Top of Dike - See Sketch

DATE: 3/27/90

SCALE: 1" = 4'

(See Report and Standard Plates for evaluation and descriptive terminology.)

Elev.	Depth 32.0	ASTM Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
		CL	FILL: SANDY LEAN clay, seams of sand, dark brownish gray, moist, rather stiff to very stiff.	20		
				18		
				16		
				14		
				16		
2033.6	60.5			19		* Boring then backfilled with grout.
			END OF BORING.			
			Water level not encountered with 60' of hollow-stem auger in the ground.			

LOG OF BORING

BRAUN ENGINEERING TESTING

PROJECT: NDB90-001
SUBSURFACE EXPLORATION
Blacktail Dam
Williams County
Williston, North Dakota

BORING: ST-3

LOCATION:
Lake Side - See Sketch

DATE: 3/27/90

SCALE: 1" = 4'

(See Report and Standard Plates for evaluation and descriptive terminology.)

Elev.	Depth	ASTM Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
2082.2	0.0	CL	FILL: SANDY LEAN clay, with gravel, dark olive brown, frozen.	31		
2079.2	3.0	CL	FILL: LEAN clay, very dark olive brown, moist, rather stiff to stiff.	15		
				12		
2070.2	12.0	CL	FILL: LEAN clay, dark brownish gray, moist, medium to rather stiff.	7		
				11		
2060.2	22.0	CL	FILL: SANDY LEAN clay, seams of sand, grayish brown, moist, stiff to very stiff.	13		
				17		
2050.2	32.0					

LOG OF BORING

BRAUN ENGINEERING TESTING

PROJECT: NDB90-001
SUBSURFACE EXPLORATION
Blacktail Dam
Williams County
Williston, North Dakota

BORING: ST-3 (cont.)

LOCATION:
Lake Side - See Sketch

DATE: 3/27/90 SCALE: 1" = 4'

(See Report and Standard Plates for evaluation and descriptive terminology.)

Elev.	Depth	ASTM Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
	32.0	CL	FILL: SANDY LEAN clay, seams of sand, grayish brown, moist, stiff to very stiff.	18		
2041.7	40.5			19		
			END OF BORING. Water level not encountered with 40' hollow-stem auger in the ground. Boring then backfilled.			

APPENDIX C - LABORATORY TEST RESULTS

BRAUN ENGINEERING TESTING OF NORTH DAKOTA, INC.

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
ASTM Designation: D 2487

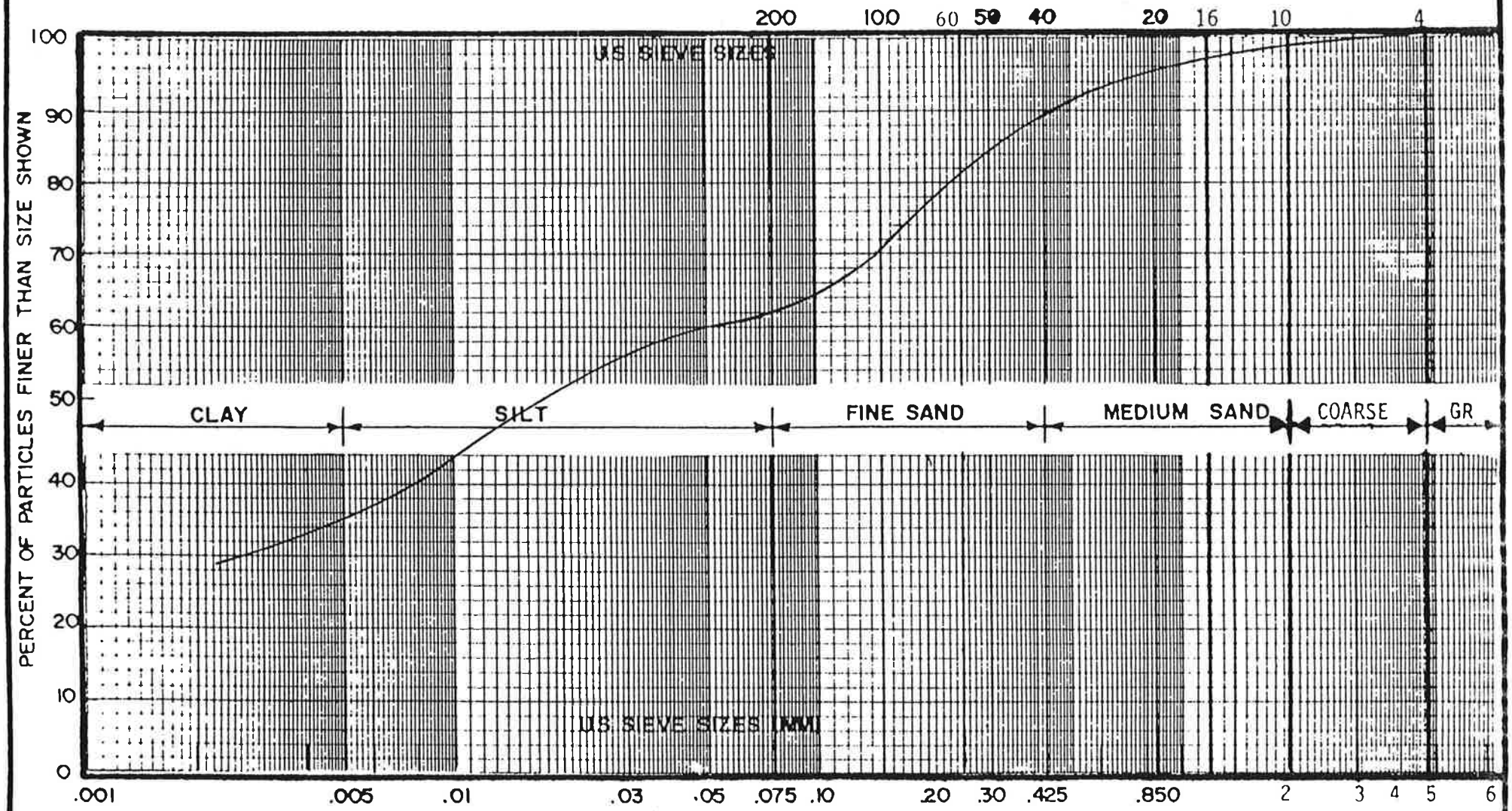
REPORT OF TESTS OF SOILS SAMPLES

Project Name: Blacktail Dam Test Boring No. 1

Project No. : NDB90-001 County: Williams

Sample No.			
Depth, Feet			
(1) Gravel, Pass 3" & Retained on #4			
(a) % Coarse Gravel (-3" + 3/4")	0		
(b) % Fine Gravel (-3/4" + #4)	0		
(2) Sand, Pass #4 & Retained on #200			
(a) % Coarse Sand (-#4 + #10)	1		
(b) % Medium Sand (-#10 + #40)	10		
(c) % Fine Sand (-#40 + #200)	27		
(3) % Silt Size (0.074-0.005 mm)	27		
(4) % Clay Size (Smaller than 0.005 mm	35		
(5) % Shale & Soft Rock	---		
Moisture Content %			
Liquid LImit %	31		
Plasticity Index	18		
Shrinkage Limit %	---		
Shrinkage Ratio	---		
Specific Gravity			
Color	dark brown		
Typical Name	CL		
Soil Group (U.S.C.S.)	---		

GRAIN SIZE ACCUMULATION CURVE



BRAUN
ENGINEERING TESTING

PROJECT: NDB90-001
Blacktail Dam

NOTES: S.T.1. Sample #4
F' - 14'-15.5'

GRAVEL	0
C. SAND 1	
M. SAND 10	38
F. SAND 27	
SILT	27
CLAY	35

CLASSIFICATION:

CL-SANDY LEAN Clay,
Dark brown
L.L. - 31, P.L.- 13, P.I.-18
ssi #20(

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3. U.S. Army Corps of Engineers, HEC-1 Flood Hydrograph Package, September, 1981.

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