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NATIONAL DAM SAFETY PROGRAM. BLACKWELL MINE DAM (MO 30709), MIS--ETC(U)
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PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY INSPECTION

St. Louis District

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 TUCKER BOULEVARD, NORTH
ST. LOUIS, MISSOURI 63101

REPLY TO
ATTENTION OF

SUBJECT: Blackwell Mine Dam (MO 30709) Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Blackwell Mine Dam.

It was prepared under the National Program for Inspection of Non-Federal Dams.

This dam has been classified as unsafe, non-emergency by the St Louis District as a result of the following criteria:

1) The dam has no spillway and the dam cannot contain 50 percent of the Probable Maximum Flood.

2) Overtopping could result in dam failure.

3) Dam failure significantly increases the hazard to life and property downstream.

For Phase I reports, the extent of the downstream damage zone has been determined assuming that all the materials contained by the tailings dam are in a liquid state.

SUBMITTED BY: SIGNED — Chief, Engineering Division — 1 OCT 1980 Date

APPROVED BY: SIGNED — Colonel, CE, District Engineer — 1 OCT 1980 Date

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BLACKWELL MINE DAM

Washington County, Missouri

Missouri Inventory No. 30709

Phase I Inspection Report

National Dam Safety Program.

Blackwell Mine Dam (MO 30709),
Mississippi-Kaskaskia - St. Louis Basin,
Washington County, Missouri. Phase I
Inspection Report.

Prepared by

Woodward-Clyde Consultants

Chicago, Illinois

(9) Final rept.

(15) DACW43-80-C-0066

(10) Richard G. /Berggreen
Leonard M. /Krazynski

Under Direction of

St Louis District, Corps of Engineers

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for

Governor of Missouri

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PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams for Phase I Investigations. Copies of these guidelines may be obtained from the Office of the Chief of Engineers, Washington, D. C., 20314. The purpose of a Phase I investigation is not to provide a complete evaluation of the safety of the structure nor to provide a guarantee on its future integrity. Rather the purpose of the program is to identify potentially hazardous conditions to the extent they can be identified by a visual examination. The assessment of the general condition of the dam is based upon available data (if any) and visual inspections. Detailed investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify the need for more detailed studies. In view of the limited nature of the Phase I studies no assurance can be given that all deficiencies have been identified.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with any data which may be available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action removes the normal load on the structure, as well as the reservoir head along with seepage pressures, and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through frequent inspections can unsafe conditions be detected, so that corrective action can be taken. Likewise continued care and maintenance are necessary to minimize the possibility of development of unsafe conditions.

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam	Blackwell Mine Dam
State Located	Missouri
Country Located	Washington
Stream	Unnamed tributary of Maddin Creek
Dates of Inspection	15 and 16 July 1980

The General Barite Dam, Missouri Inventory Number 30709, hereinafter referred to as the Blackwell Mine Dam, was inspected by Richard Berggreen (engineering geologist), Leonard Krazynski (geotechnical engineer) and Sean Tseng (hydrologist). The dam is an active barite tailings dam.

The dam inspection was made following the guidelines presented in the "Recommended Guidelines for Safety Inspection of Dams". These guidelines were developed by the Chief of Engineers, U.S. Army, Washington, D.C., with the help of federal and state agencies, professional engineering organizations, and private engineers. The resulting guidelines represent a consensus of the engineering profession. They are intended to provide an expeditious identification, based on available data and a visual inspection, of those dams which may pose hazards to human life or property. In view of the limited nature of the study, no assurance can be given that all deficiencies have been identified.

The St Louis, Corps of Engineers, has classified this dam high hazard; we concur with this classification. The downstream damage zone was estimated by the St Louis District as approximately 10 miles. Approximately 10 occupied permanent or vacation homes are located within the damage zone, suggesting significant loss of property and life is possible in the event of overtopping and failure of this dam.

The Blackwell Mine Dam is in the intermediate size classification based on its maximum height of 87 ft. The storage capacity is approximately 1800 ac-ft. Intermediate classification includes dams between 40 and 100 ft in height or 1000 to 50,000 ac-ft in storage capacity.

Our inspection and evaluation indicate the dam is in a generally poor condition. The cohesionless nature of the embankment materials suggests the dam would be severely eroded in the event of overtopping. The very steep slopes of the embankment (36-39°) appear to be at or near the natural angle of repose and would be subject to failure if significantly disturbed, such as by overtopping or erosion. There is no spillway constructed at this dam and there is minimal storage capacity. Our inspection indicates significant precipitation (such as 1 percent probability-of-occurrence event) will fill the available storage capacity and result in overtopping of the embankment. As a result of the minimal storage, it was computed that a storm greater than 10% of the Probable Maximum Flood (PMF) will result in overtopping the dam. The PMF is defined as the flood event that may be expected to occur from a combination of the most severe critical meteorologic and hydrologic conditions that are reasonably possible in the region.

It is recommended that a spillway and discharge channel be designed and constructed, based on a hydrologic and hydraulic analysis, to meet the following objectives:

1. Minimize storage behind the dam;
2. Maximize dam crest height above pool elevation; and
3. Direct the discharge channel so erosion at the toe of the embankment will not occur.

The action concerning the spillway and discharge channel should be taken immediately.

A study of Cruise Mill-Fertile Fault zone is recommended. The fault is believed to be in very close proximity to the dam. This study should be done without undue delay.

A study is recommended without undue delay to evaluate the effect on embankment stability of the presence of heavy tree growth. Removal of large trees should be done under supervision of personnel experienced in maintenance of dams. Indiscriminate clearing of trees could jeopardize the safety of the dam.

It is also recommended that a periodic inspection and monitoring program be initiated at this dam. This program should include:

1. Inspection of the embankment to identify areas of slope instability, such as slumping, and erosion of the face of the dam. Particular attention should be given to areas where minimum dam crest elevation may allow overtopping and erosion of the embankment.

2. Monitor seepage at the toe of the dam to identify changes in the volume of flow or in the turbidity of the seepage water.

An analysis of the practicality of a warning system for this dam is recommended to evaluate the available options for advising downstream residents and traffic should unsafe emergency conditions develop at the dam.

WOODWARD-CLYDE CONSULTANTS

Richard G. Berggreen
Registered Geologist

Leonard M. Krazynski, P.E.
Vice-President

OVERVIEW

BLACKWELL MINE DAM

MISSOURI INVENTORY NO. 30709

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

BLACKWELL MINE DAM - MISSOURI INVENTORY NO. 30709

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
BLACKWELL MINE DAM, MISSOURI INVENTORY NO. 30709

SECTION 1
PROJECT INFORMATION

1.1 General

a. **Authority.** The National Dam Inspection Act, Public Law 92-367, provides for a national inventory and inspection of dams throughout the United States. Pursuant to the above, an inspection was conducted of the Blackwell Mine Dam, Missouri Inventory Number 30709.

b. **Purpose of inspection.** "The primary purpose of the Phase I investigation program is to identify expeditiously those dams which may pose hazards to human life or property... The Phase I investigation will develop an assessment of the general condition with respect to safety of the project based upon available data and a visual inspection, determine any need for emergency measures and conclude if additional studies, investigations and analyses are necessary and warranted." (Chapter 3, "Recommended Guidelines for Safety Inspection of Dams").

c. **Evaluation criteria.** The criteria used to evaluate the dam were established in the "Recommended Guidelines for Safety Inspection of Dams"; Engineering Regulation No. 1110-2-106 and Engineering Circular No. 1110-2-188, "Engineering and Design National Program for Inspection of Non-Federal Dams," prepared by the Office of Chief of Engineers, Department of the Army, and "Hydrologic/Hydraulic Standards Phase I Safety Inspection of Non-Federal Dams," prepared by the St Louis District, Corps of Engineers. These guidelines were developed with the help of several federal agencies and many state agencies, professional engineering organizations, and private engineers.

1.2 Description of Project

a. **Description of dam and appurtenances.** Blackwell Mine Dam is an active tailings dam. Although its construction and usage is typical of barite tailings dam in the area, it is atypical of dams constructed for the impoundment of water. The unique nature of tailings dams construction and usage has a significant impact on their evaluation. A brief description of the construction and usage of this dam is necessary to appreciate the differences between this dam and a water-retaining dam.

At the start of a barite mining operation in this area, a 10 to 20-ft high starter dam is typically constructed across a natural stream channel. Generally the streams are intermittent so that construction is carried out in the dry. Trees and other vegetation are removed from the dam site and then a cutoff is often made to shallow bedrock. Locally obtained earth, usually a gravelly clay, is then placed to form the embankment. Compaction is limited to that provided by the construction traffic.

The barite ore is contained within the residual gravelly clay which is mined with earth-moving equipment. At the processing plant, the ore is washed to loosen and remove the soil. This water is obtained from the reservoir area behind the dam. The soil-laden wash water and water from other steps in the process is then discharged into the reservoir. There the soil is deposited by sedimentation and the water recycled. Another step in the process removes the broken gravel-sized waste which is called "chat".

As the level of the fine tailings increases, the dam is raised. The usual method is to place, by dumping, chat on the dam crest. Then the chat is spread over the crest so that a relatively constant crest width is maintained as the dam is raised. Generally the crest centerline location is also maintained. However, the crest centerline location may migrate upstream if there is insufficient chat available and downstream if an excessive quantity of chat is available. The latter is uncommon because it is indicative of a poor ore deposit.

This method of construction results in slopes which are close to the natural angle of repose for the chat. They can be considered to be near a state of incipient failure.

A large quantity of water is required for a processing operation on the order of 2000 to 5000 gal/min. Thus it has been the operators' practice to construct the dam so that all inflow to the reservoir is recycled in order to have sufficient water for the operation. The result is that formal spillways or regulating outlets are generally not constructed. In some cases a low point on or near the dam is provided should the storage capacity be exceeded.

The fine tailings typically fill more than 80 percent of the total storage volume. This results from the operator's practice of maintaining only a 2 to 5 ft elevation differential between the level of the tailings and the dam crest. The differential is usually greater further away from the discharge point and also typically farther away from the dam.

The geotechnical characteristics of the fine tailings are somewhat similar to recent lacustrine clay deposits. Where the tailings have been continuously submerged, they have a very soft consistency and high water content. When evaporation causes the water level to recede and the tailings are exposed, a stiff crust forms as the tailings dry out. Below the crest, the tailings retain their soft consistency for long periods of time. The consistency is very gradually modified by a slow process of consolidation.

Blackwell Mine Dam is representative of barite tailings dams. The embankment is composed of chat. The downstream slope is very steep and the upstream slope is covered by the fine tailings. There are no regulating outlets. A spillway has not been constructed, although the owner's representative indicated one had existed near the west end of the dam, and they planned on reopening it soon. Dimensions of the dam are presented in Section 1.3.

b. **Location.** The dam is located approximately 10.5 mi northeast of the town of Potosi and approximately 2.5 mi southeast of Washington State Park, along Missouri Highway CC, in Washington County Missouri, USGS Tiff 7.5 minute quadrangle (Fig 1). The dam and impoundment are in survey 1875 of the Washington County Barite District, T38 and 39N, R3E. Drainage confluence with the Big River is approximately 2 miles downstream of the dam.

c. **Size classification.** The dam is classified intermediate size due to its 87 ft height. The storage capacity is approximately 1800 ac-ft. Intermediate size dams are from 40 to 100 ft in height or 1000 to 50,000 ac-ft in storage capacity.

d. **Hazard classification.** The St. Louis District, Corps of Engineers (SLD) has classified this dam as high hazard; we concur with this classification. The estimated damage zone extends approximately 10 miles downstream of the dam. Located within this zone are more than 10 occupied structures (including vacation homes) Missouri Highway CC and Missouri Highway 21. As a result, the potential for loss of life and property damage is high within this downstream hazard zone.

e. **Ownership.** We understand the dam is owned by the Baroid Division of National Lead, and leased to General Barite Co. Correspondence should be addressed to Mr Charles Faulkner, General Barite Company, 119 West Clement St, Desoto, Missouri 63020.

f. **Purpose of dam.** The dam was constructed to impound fine tailings produced by the washing of barite ore mined in the vicinity. Water impounded by the dam is recycled from the reservoir and used in the barite processing operation. The dam is currently active although operations were temporarily shutdown during the inspection due to a shortage of water resulting from dry and hot weather.

g. **Design and construction history.** Information on the construction history of the dam was obtained from Mr Charles Faulkner of General Barite Co. The mill began operations in 1951 and the dam was constructed shortly before this date. A clay starter dam, approximately 20 ft high was constructed with rubber tired scrapers and bulldozers. This dam was keyed to bedrock. Soil was used to build up the upstream face, and bullrock and chat tailings were used to build the downstream face. Following the construction of the starter dam, the dam was raised by end-dumping chat on the crest of the dam. No records were found documenting compaction of the starter dam or the remainder of the embankment. Fine tailings, consisting of clay, silt and fine sand, were sluiced into the impoundment area from the processing plant.

h. **Normal operating procedure.** Normal operating procedure at the tailings dams in this area is to continually raise the embankment with chat (gravel and coarse sand tailings less than 3/4 in. in diameter) to maintain the dam crest elevation above the impoundment level as fine tailings (clay, silt and sand) are sluiced into, and fill the impoundment. At the Blackwell Mine Dam the ore currently being processed is very high grade, predominantly residual clay soil and barite. Only minimal chat is available to raise the embankment. As a result, the fine tailings have raised the pool level without a corresponding increase in embankment height. At present the elevation difference between the dam crest and impoundment elevation is minimal to nonexistant. Near the processing plant where water is discharged into the pond and sedimentation is relatively rapid, a dragline is used to dredge a channel through the deposited tailings to facilitate flow into the lower parts of the pool area (see Fig. A-1, Appendix A). As a result of this draging, the current tailings level is above the embankment at several points (particularly along the east margin of the impoundment) and overflow is prevented only by the mounded spoil from the dredged channel(Photo 1). Some evidence of past overflows was found east of this point, where tailings-type mud was found to depths of greater than 3 ft outside the impoundment area. After the fine tailings have settled out, the water flows into a clearwater pond located at the upstream end of the tailings impoundment. As a result of the deposition of fine tailings, the tailing impoundment is at a higher elevation than the clear water pond. A low diffle dike (5 ft high) separates the tailings settlement pond from the clearwater pond (see Fig. A-1).

1.3 Pertinent Data

a. **Drainage area.** approximately 0.45 mi^2

b. **Discharge at damsite.**

Maximum known flood at damsite	Unknown
Warm water outlet at pool elevation	Not applicable (N/A)
Diversion tunnel low pool outlet at pool elevation	N/A
Diversion tunnel outlet at pool elevation	N/A

Gated spillway capacity at pool elevation	N/A
Gated spillway capacity at maximum pool elevation	N/A
Ungated spillway capacity at maximum pool elevation	N/A
Total spillway capacity at maximum pool elevation	N/A

c. **Elevations (ft above MSL)**

Top of Dam	760.8 to 778.0
Maximum pool-design surcharge	N/A
Full flood control pool	N/A
Recreation pool	N/A
Spillway crest (gated)	N/A
Upstream portal invert diversion tunnel	N/A
Downstream portal invert diversion tunnel	N/A
Streambed at centerline of dam	Unknown
Maximum tailwater	N/A
Toe of dam at maximum section	677.4

d. **Reservoir.**

Length of maximum pool	2470 ft
Length of recreation pool	N/A
Length of flood control pool	N/A

e. **Storage (acre-feet).**

Recreation pool	N/A
Flood control pool	N/A
Design surcharge	N/A
Top of dam	1800

f. **Reservoir surface (acres).**

Top of dam	99
Maximum pool	99
Flood control pool	N/A

Recreation pool	N/A
Spillway crest	N/A

g. **Dam.**

Type	Tailings
Length	4532 ft
Height	87 ft (max. section)
Crest width	25 ft (typical)
Side slopes	Upstream - unknown Downstream - approximately 1.5H:1V
Zoning	Unknown (probably none)
Impervious core	Unknown (probably limited to clay soil starter dam)
Cutoff	Trench of unknown dimensions excavated to rock
Grout curtain	Unknown (probably none)

h. **Diversion and regulating tunnel.**

Type	None
Length	N/A
Closure	N/A
Access	N/A
Regulating facilities	N/A

i. **Spillway.**

Type	None, other than low spot on dam crest
Length of weir	N/A
Crest elevation	760.8 ft
Gates	N/A
Upstream channel	N/A
Downstream channel	N/A

j. **Regulating outlets.**

None

SECTION 2
ENGINEERING DATA

2.1 Design

No design drawings or other design data were found for this facility.

2.2 Construction

Construction of the dam was started in 1950 or 1951, according to Mr Charles Faulkner of General Barite Co. According to Mr Faulkner a clay starter dam, approximately 20 ft tall, was built and keyed to bedrock. The downstream face was built of bullrock and chat. No records were found of construction of the remainder of the embankment above the starter dam. Construction was likely as described for typical barite tailings dams in this area, Section 1.2.a.

2.3 Operation

No operating records were available. At the time of the inspection the processing mill was inactive due to a lack of wash water resulting from an extended dry period. Operations will resume when sufficient water is available.

2.4 Evaluation

a. **Availability**. There are no engineering data available.

b. **Adequacy**. The lack of engineering data precludes the evaluation of adequacy of the design of this facility.

Seepage and stability analysis comparable to the requirements of the guidelines are not on record. This is a deficiency which should be rectified. These analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record. These analyses should be performed by an engineer experienced in the design and construction of dams.

c. **Validity.** The only design or construction data obtained for this dam was through the recollections of an employee of the mining company. This information was not independently substantiated; however, there is no reason to believe the information is not valid.

2.5 Project Geology

The dam is located on the northern flank of the Ozark structural dome. The regional dip of the bedrock is to the north. The bedrock in the vicinity of the dam is mapped on the Geologic Map of Missouri (Fig 4) as Cambrian age limestone and dolomite formations. Mineralization of these formations deposited the barite minerals being mined in this area. Several investigators (Wagner, 1970, and others) suggest the mineralization occurred along the well developed fault and fracture system in the bedrock formations.

The Cruise Mill-Fertile Fault Zone is mapped directly beneath the Blackwell Mine Dam (Fig 4). However, the scale of the map (1 inch equals approximately 8 miles) does not allow for precise location of the fault trace. No evidence of the fault was noted during the field inspection. The fault zone is approximately 6 miles long with a northwest-southwest trend, and may connect with the Richwoods Fault Zone, to the northwest, resulting in a zone approximately 15 miles long. The fault is mapped as northeast side up.

The ore mined in the vicinity of the Blackwell Mine was described by the mine employee as relatively high grade, with minimal amounts of waste rock or "chat". This high grade may be the result of the proximity to the fault zone.

The Cruise Mill-Fertile Fault Zone, like others in the Ozark area, appears confined to the Paleozoic bedrock and is likely Paleozoic in age. The area is not considered seismically active. However, the presence of a fault in the immediate vicinity, and perhaps underlying the dam, suggests further study is necessary to evaluate the potential for groundwater solutioning along the fault in the foundation of this dam.

Bedrock northeast of the fault, probably underlying the dam, is mapped as Bonneterre Formation and Elvins Group. The Bonneterre Formation typically consists of gray, medium to fine grained dolomite with clean pink limestone interbeds. The formation also contains glauconitic to shaley interbeds. The Elvins Group, consisting of the Davis Formation and the Derby-Doerun Formation, conformably overlies the Bonneterre Formation and contains shale, siltstone, fine-grained sandstone, dolomite, and limestone conglomerate. Siltstone and shale are predominant.

Southwest of the fault, apparently underlying the reservoir area, bedrock is mapped as Potosi and Eminence dolomite formations. The Potosi Formation is a massive, medium- to fine-grained dolomite that typically contains an abundance of quartz druse characteristic of chert bearing carbonate formations. The Eminence Formation is a similar appearing dolomite, but contains less chert and quartz.

The soil exposed at the damsite is a dark red-brown, very stoney plastic clay (CL-CH), characteristically developed as a residual soil of insoluble residue on the weathered carbonate bedrock in the area. The soil is mapped on the Missouri General Soils Map as Union-Goss-Gasconade-Peridge Association.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. **General.** A field inspection of the Blackwell Mine Dam was conducted on 15 July 1980. The inspection team was accompanied by Corps of Engineers personnel Joe Kellett, Randy Dreiling, Dave Busse, and Wayne Richter. A supplementary visit was made 16 July 1980, accompanied by Mr Lawrence Miller of General Barite to discuss features at the dam which were identified on the initial visit and needed clarification. These site visits lead to the conclusion that the dam is in a generally poor condition.

b. **Dam.** The embankment is comprised of coarse tailings or "chat". This material (sandy gravel and sand, GW-SW) is cohesionless and permeable and would likely be severely eroded if the dam were overtopped.

The ore mined in the vicinity is relatively high grade, and only minimal amounts of chat waste are generated in the milling process. This has resulted in only minor amounts of chat available for raising the embankment as the impoundment is filled with fine tailings. At present, portions of the impoundment, particularly near the discharge from the plant where sedimentation is more rapid, are above the level of the main embankment, impounded only by a relatively narrow dike or berm (see Photo 1). The impoundment area is nearly full at present and any significant inflow would result in overtopping the dam crest. No erosion protection has been placed on the upstream face of the dam. However, the dense vegetation in the impoundment suggests little wave action is likely and the chat which forms the embankment is likely sufficient protection from the anticipated waves.

Along the east margin of the embankment, dredging has been done to maintain a channel deep enough to prevent overflow of the mill discharge water (Photo 1). East of and outside the embankment in this area, tailings mud has been deposited in excess of 3 ft deep (Fig A1, Appendix A; Photo 2). This material could be either the result of overtopping and spillage in the past, or rain water washing the dredge spoil (Photo 3, 4) into this low area. The owner's representative indicated that to his knowledge the dam had not been overtopped.

Along the main (facing north) portion of the embankment, the downstream face (Photo 5) has been covered with bullrock (coarse tailings from approximately 6 in. to 2 ft in diameter). Vegetation density on the dam varies from barren areas to scattered brush and small trees (Photo 6). The embankment face appears excessively steep, from approximately 36^{o} on the barren parts to 38^{o} to 40^{o} where vegetated. The steep slopes are probably a result of the veneer of bullrock covering the face. These slopes are at or slightly oversteepened beyond the angle of repose for the chat material. Other chat piles typically have slopes of 35 to 36^{o} maximum. This suggests the slopes are only marginally stable in their present configuration and slight changes such as erosion of the toe, overtopping of the embankment or heavy vibrations could precipitate a slope failure.

Minor seepage was noted at the toe of the maximum section (Photo 7). Seepage from a single flowing source was estimated at approximately 2 gpm, with total seepage from the toe of less than 5 gpm. A second area of minor seepage, estimated at 2 gpm was noted at the toe of the northwest corner of the embankment. The seepage was clear and did not appear to be carrying any fines.

No evidence of settlement, cracking, horizontal or vertical development or animal burrowing was noted on the embankment.

c. **Appurtenant structures.**

1. Spillway. No spillway existed at this dam at the time of the visual inspection. The owner's representative, Mr Miller, indicated the location of a former spillway and discharge channel (Fig A-1, Appendix A). The dimensions of this former spillway were estimated to be 3 ft deep and 30 ft wide. Mr. Miller indicated a new spillway is planned at this same location. However construction had not begun at the time of our inspection and no dimensions had been established.

2. Clearwater pond. At the upstream end of the tailings deposition area, a baffle dike has been constructed to separate the tailings from a clearwater pond which supplies water to the plant. Water and tailings discharged into the main impoundment, circulate toward the baffle dike. Most of the tailings settle out and clear water flows through the dike into the clear water pond, which is 2 to 3 ft lower than the tailings pond. In that the clear water pond is upstream of the tailings impoundment, runoff from the drainage basin is stored in the clearwater pond rather than the tailings pond.

d. **Reservoir area.** The reservoir area is divided into two parts, the active tailings deposition area, and a clear water pool (see Fig. A-1, Appendix A). A baffle dike approximately 5 to 7 ft tall separates the two (Photo 8). A third small pond is used as a pumping pool to supply water to the plant. However, as it is at the same elevation as the clear water pool and connected by a 6 ft diameter culvert (Photo 9) it is considered part of the clear water pond. Deposition in the tailings area has resulted in the tailings area being higher than the clear water pool, even though it is farther downstream. This configuration allows water to be impounded by the baffle dike upstream from the tailings area. However, when the pool is full to the level of the baffle dike, overflow from the pool will likely cause overflow over the dam crest.

The tailings deposition area was nearly dry at the time of the inspection visit, as low water levels caused a temporary cessation of milling operations (Photo 10). The majority (95 percent) of the area was covered with cattail and willow vegetation. The clear water pool contained some water, although parts of it were also above water and the margins were also vegetated with willow and cattails.

The natural slopes surrounding the reservoir area are quite flat, on the order of 5(H) to 1(V) or flatter. No indications were found of unstable slopes in this area. The principal post-construction change in the area is mining which has locally stripped the vegetation and soil from adjacent slopes.

e. **Downstream channel.** Discharge through the proposed spillway would flow through a densely vegetated mined-out area into a natural drainage to the west. Substantial amounts of clearing may be necessary to clear obstructions from this discharge channel. However, the proposed spillway and discharge channel locations are attractive from the point of view that they direct overflow away from the toe of the dam, precluding potential erosion at the toe of the steep dam face.

3.2 Evaluation

Our visual inspection indicated the impoundment is nearly full; there is only minimal storage afforded by the clear water pool upstream of the main impoundment. The steep, erodable slopes on the embankment likely cannot accomodate disruption. There is no spillway at this dam to prevent overtopping of the embankment. If the dam is overtopped there is a significant potential for failure. The downstream area is sufficiently populated to expect substantial loss of property and life in the event of a failure.

Seepage at the toe of the dam did not appear to constitute a hazard due to the low volume and lack of soil in the flow.

SECTION 4
OPERATIONAL PROCEDURES

4.1 Procedures

No records of operating procedures were found for this facility.

4.2 Maintenance of Dam

Maintenance at this dam is apparently limited to periodically dredging a channel along the inside edge of the embankment to prevent overflow. The embankment is raised using the dredge spoil and chat produced by the milling process.

There is currently no spillway at this facility.

4.3 Maintenance of Operating Facilities

There are no facilities requiring mechanical operation at this dam.

4.4 Description of Any Warning System in Effect

Our visual inspection did not disclose any warning system in effect at this dam.

4.5 Evaluation

There is apparently no plan for periodic inspection and maintenance of this dam. This is considered a deficiency.

In view of the potential for overtopping the reservoir, an evaluation should be made of providing a practical warning system at this facility.

SECTION 5
HYDROLOGY & HYDRAULICS

5.1 Evaluation of Features

a. **Design data.** No hydrologic or hydraulic information was available for evaluation of the dam. Pertinent dimensions of the dam and reservoir were surveyed on 24 July 1980, measured during the field inspection or estimated from topographic mapping. The map used in the analysis was an advance print of the USGS Tiff 7.5-minute quadrangle map.

b. **Experience data.** No recorded rainfall, runoff, discharge or pool stage data were available for this reservoir or watershed. No evidence of prior overtopping was observed, with the possible exception of the mud deposit east of the dam. This, however, could be dredge spoil washed into a low area. Mr. Faulkner did not recall the dam being overtopped.

c. **Visual observations.** The elevation of the surface of the tailings slopes from a high near the plant discharge to a low in the northwest corner. In some areas, particularly near the plant discharge, the level of the tailings is at the level of the top of the embankment. Minor disruption of a relatively narrow berm could result in overflow at this point. In the low area of the tailings impoundment, the level of the tailings is about 2 to 3 ft below the dam crest elevation. At the upstream end of the tailings impoundment is a baffle dike, which separates the tailing settlement area from the clearwater pond, from which water is pumped into the plant. The clearwater pond is several feet below the elevation of the tailings and during normal operations, water flows from the tailings pond into the clear water pond, through a channel cut in the dike (Photo 8). However, should runoff from the drainage basin fill the clearwater pond, flow would be from the clearwater pond to the tailings impoundment. It is unlikely that substantial erosion to this dike would occur due to the small elevation difference between the clearwater pond and the tailings pond (on the order of 2 to 3 ft).

d. **Overtopping potential.** Because of the unique configuration of this dam the lowest embankment crest elevation was considered to be the elevation of the spillway crest, el 760.8 ft. Starting elevation for flood routing for floods less than 50 percent PMF was the high water mark, el 758.5 ft. Hydrologic/hydraulic analyses indicate a 1 percent probability-of-occurrence event will result in overtopping of the dam to a depth of approximately 0.2 ft. These analyses also indicate that for a hydrologic event which produces greater than 10 percent of the PMF the reservoir will be filled and the dam will be overtopped. The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region. The following table presents the expected severity of overtopping for various percentages of the PMF.

Precipitation Event	Max. Reservoir W.S. Elev.	Max. Depth over Dam, ft	Max. Outflow, ft^3/sec	Duration of Overtopping, hrs
10% PMF	760.8	0	0	0
50% PMF	762.0	1.2	980	48.0
100% PMF	762.4	1.6	2200	48.0

As the embankment material is considered to be highly erodible, overtopping could rapidly lead to failure of the dam. Since the dam crest is composed of loose gravel, discharge velocities greater than 3 ft/sec are likely to cause erosion. Based on this erosive velocity, flooding events of greater than 22 percent of the PMF are considered sufficient to endanger the dam.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual observations. The visual inspection of the Blackwell Mine Dam did not reveal any evidence of horizontal or vertical displacement of the dam crest alignment. No cracking, detrimental settlement, slides, depressions, sinkhole development, or other signs of instability were observed.

b. Design and construction data. The only design or construction data found were obtained from interviews with Mr Charles Faulkner of General Barite Company. Mr Faulkner indicated a clay starter dam was constructed prior to the start of the embankment of chat. The starter dam was approximately 20 ft high and was keyed to rock. Mr Faulkner said bullrock and chat were placed on the downstream slope. Compaction was by rubber tired scrapers.

Seepage and stability analyss as recommended in the guidelines were not on record. This is a deficiency which should be rectified by an engineer experienced in the design and construction of earth dams.

c. Operating records. No facilities requiring mechanical operation exist at this dam. No records are maintained of water level, available storage, or flow through the spillway.

d. Post-construction changes. Construction and use of this dam are continuing. The embankment is continually being raised with available chat as the sediment level in the reservoir rises. Discussion with Mr Lawrence Miller indicated the high grade ore currently being processed has not produced sufficient chat to significantly raise the embankment. This has resulted in inadequate of storage capacity for heavy storm runoff.

e. Seismic stability. The dam is in Seismic Zone 2, to which the guidelines assign a moderate damage potential. Since no static stability analysis is available for review, the seismic stability cannot be evaluated. However, as the tailings are fine-grained, saturated materials and the dam is constructed of loose, granular material, substantial deformation damage or failure could occur in the event of a severe seismic event.

SECTION 7
ASSESSMENT/REMEDIAL MEASURES

7.1 Dam Assessment

a. **Safety.** Based on the visual inspection, the dam appears to be in a generally poor condition. This is based primarily on the minimal reservoir storage capacity and the lack of a spillway to prevent overtopping of the embankment. Seepage and stability analyses are not on record. This is considered a deficiency.

As a consequence of the widely-used construction procedure, the downstream slopes of tailings dams are placed at the angle of natural repose for the "chat" material at any given operation. This results in slopes that are very steep and exist in a state close to incipient failure with safety factors close to 1.0. This situation is subject to some gradual improvement with time as consolidation and/or desiccation of the fine-grained tailings results in an increase in strength and a resultant decrease in lateral pressures on the dam. Such increase in strength, however, will be very slow.

The slopes placed at angle of natural repose will only remain stable, if they are protected against potential harmful changes, among which are:

1. Overtopping by water
2. Higher pore pressures (or seepage forces)
3. Undercutting of the toe of the slope by erosion or mining activity
4. Increase in the height of the dam
5. Harmful effects of vegetation (particularly tree roots)
6. Liquefaction (such as may result from a seismic event).

The first five changes are subject to control by owners and operators and must receive careful attention to order to maintain stable and safe dam embankments. The sixth influence represents a risk the magnitude of which is not well understood without further study.

b. **Adequacy of information.** The lack of stability and seepage analyses for the dam as recommended in the guidelines precludes an evaluation of the structural and seismic stability of the dam. This is a deficiency which should be rectified to meet the recommended guidelines.

c. **Urgency.** The deficiencies described in this report could affect the safety of the dam. Corrective actions should be initiated immediately.

d. **Necessity for Phase II.** In accordance with the Recommended Guidelines for Safety Inspections of Dams, the subject investigation was a minimum study. This study revealed that additional in-depth investigations are needed to complete the assessment of the safety of the dam. Those investigations which should be performed without delay are described in Section 7.2.b. It is our understanding from discussions with the St Louis District that any additional investigations are the responsibility of the owner.

7.2. Remedial Measures

a. **Alternatives.** There are a number of general alternatives to consider when selecting remedial measures to avoid the serious consequences of dam failure resulting from overtopping. These alternatives include:

1. Remove or breach the dam.
2. Increase the height of the dam and/or spillway size to pass the probable maximum flood without overtopping the dam.
3. Purchase downstream land that would be adversely impacted by dam failure and restrict human occupancy.
4. Enhance the stability of the dam to permit overtopping without failure.
5. Provide a highly reliable flood warning system (generally does not prevent property damage but avoids loss of life).

b. **Recommendations.** It is recommended that a study be initiated for the design and construction of an adequate spillway and discharge channel, based on a hydrologic and hydraulic evaluation. The objectives to be met in design are:

1. Minimize live storage behind the dam;

2. Maximize elevation differences between dam crest and impoundment level; and

3. Direct discharge so that erosion at the embankment toe does not occur.

The action concerning the spillway and discharge channel should be taken immediately.

The effect of trees on the embankment stability should be investigated. Removal of large trees should be done under the supervision of personnel experienced in maintenance of dams. Indiscriminate clearing of trees could jeopardize the safety of the dam.

A study should also be made of the Cruise Mill-Fertile-Fault zone, as described in this report in Section 2.5 Project Geology, to determine the location of the trace of this fault and to evaluate whether or not it represents any unusual hazards to the dam. This study should be undertaken without undue delay. Seepage and stability analyses should be performed by a professional engineer experienced in the design and construction of dams.

It is further recommended that an analysis be made of the practicality of a warning system at this dam to advise downstream residents and traffic should unsafe, emergency conditions develop at this dam.

b. <u>O & M procedures.</u> A program of periodic inspections is recommended for the Blackwell Mine Dam. This program should include, but not be limited to:

1. Inspection of seepage areas to identify increases in volume of seepage or turbidity (soil) in the seepage water.

2. Inspection of slopes to identify evidence of slope instability such as cracking or slumping of the embankment.

Records should be kept of the inspections and any required maintenance. All remedial measures should be performed under the guidance of an engineer experienced in the design and construction of dams.

The evaluation of a practical and effective warning system is recommended to alert downstream traffic and residents should hazardous conditions develop at this dam.

REFERENCES

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McCracken, Mary H., 1971, Structural Features Map of Missouri: Missouri Geological Survey, Scale 1:500,000.

Missouri Geological Survey, 1979, Geologic Map of Missouri: Missouri Geological Survey, Scale 1:500,000.

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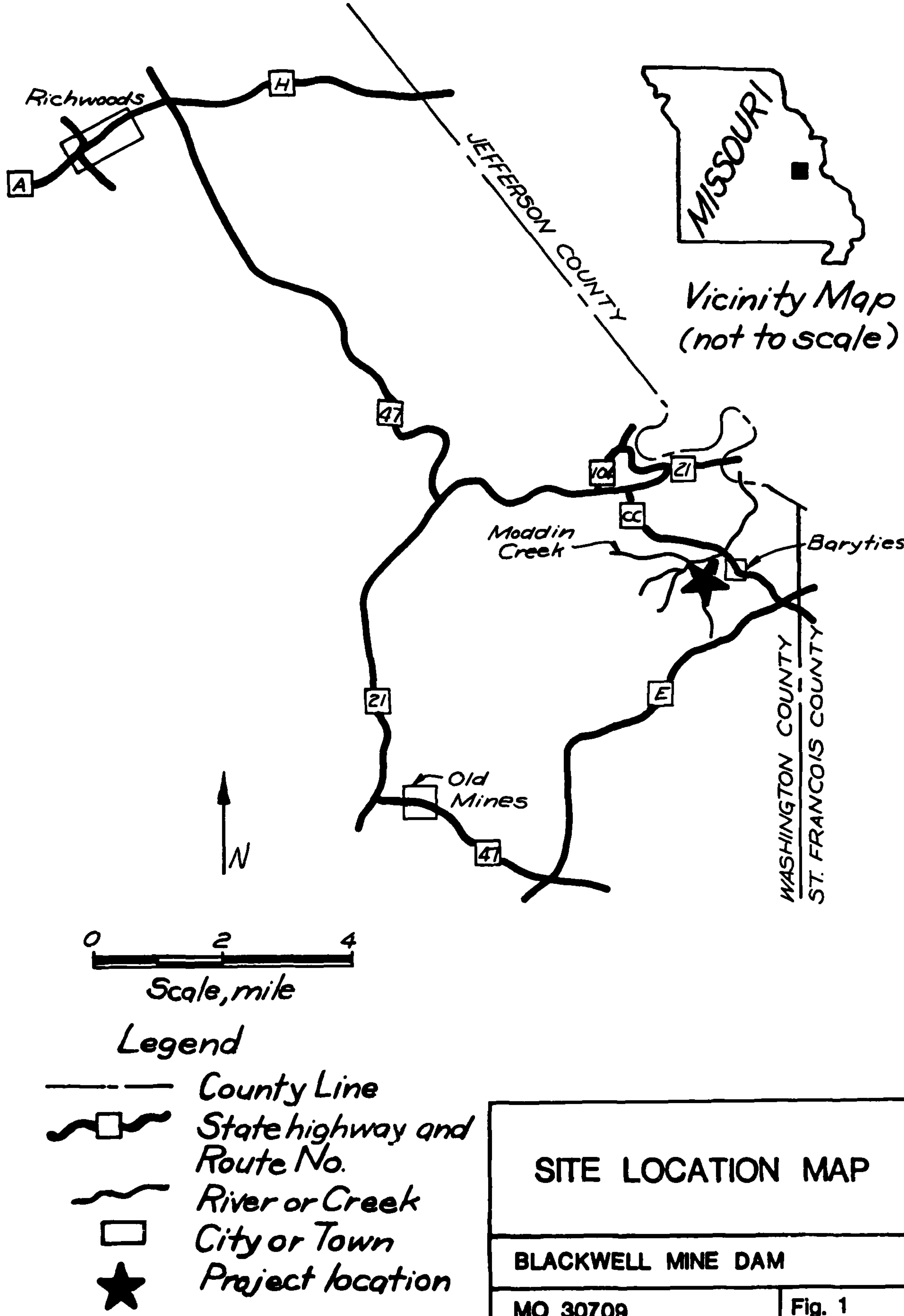
US Department of Commerce, US Weather Bureau, 1956, "Seasonal Variation of the Probable Maximum Precipitation East of the 105th Meridian for Areas from 10 to 1,000 Square Miles and Durations of 6, 12, 24 and 48 Hours," Hydrometeorological Report No. 33.

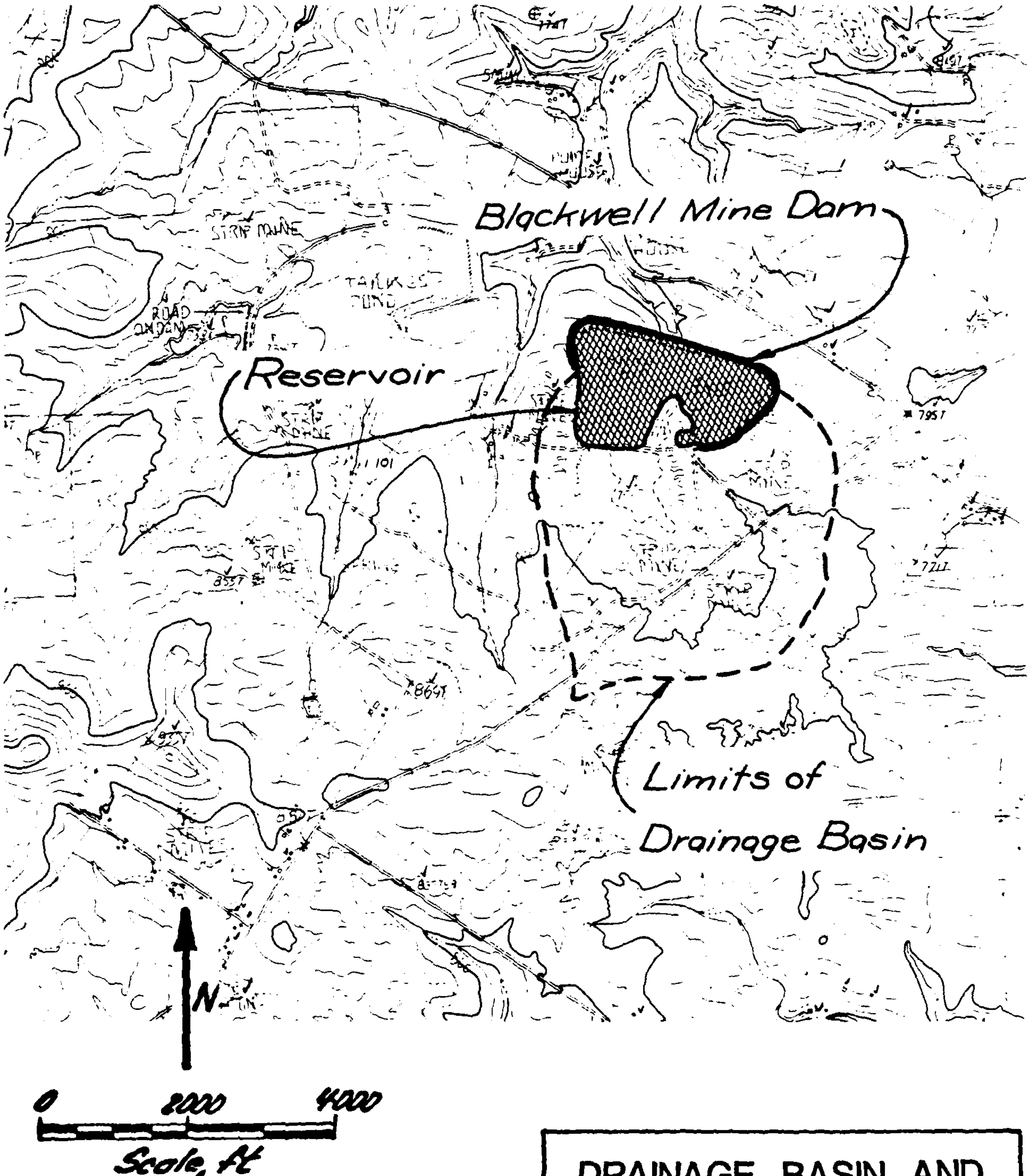
US Soil Conservation Service, 1971, "National Engineering Handbook," Section 4, Hydrology, 1971.



SITE LOCATION MAP

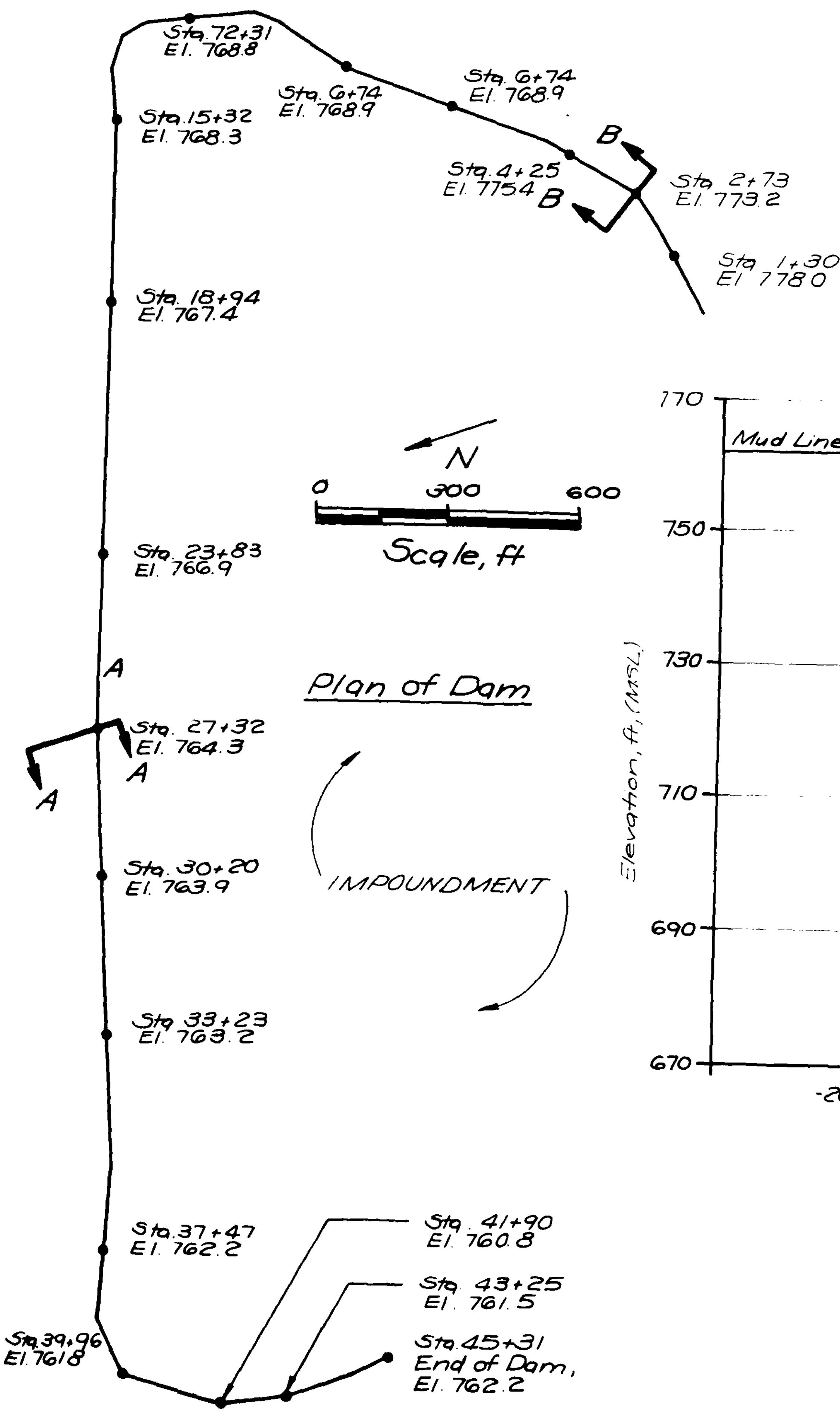
BLACKWELL MINE DAM

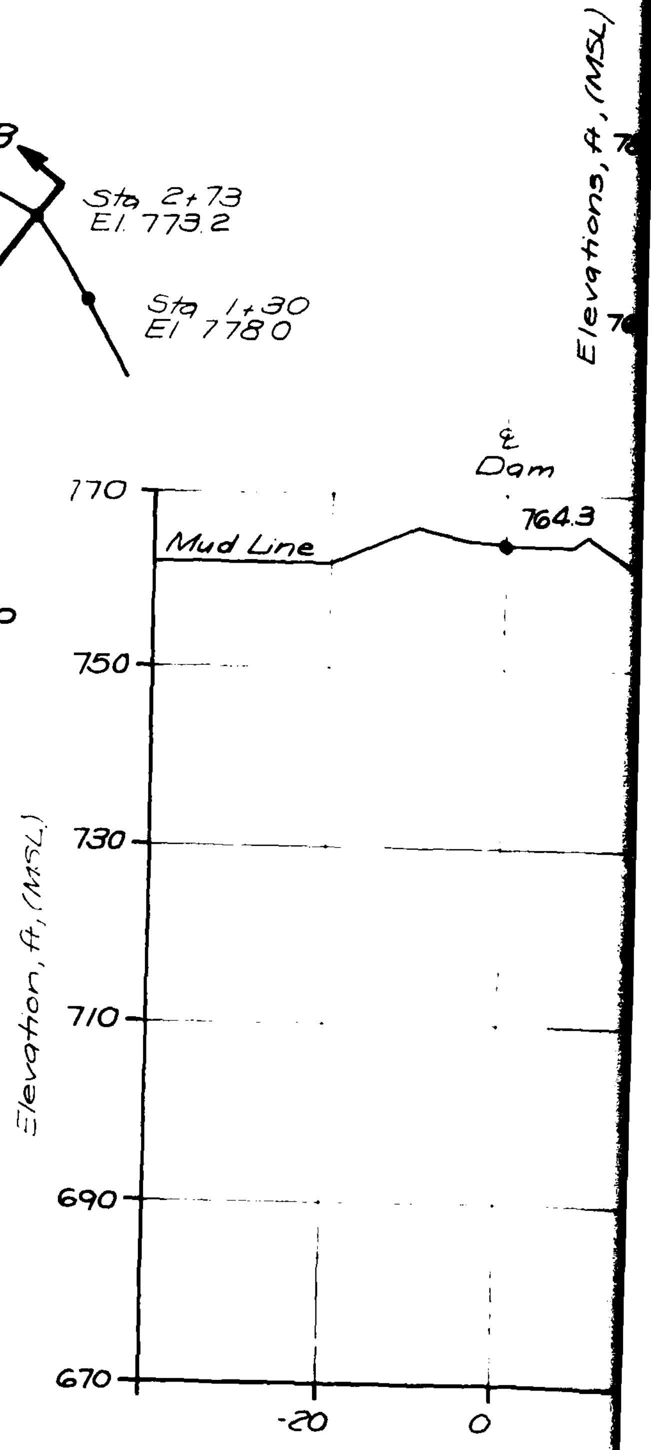
MO 30709 | Fig. 1

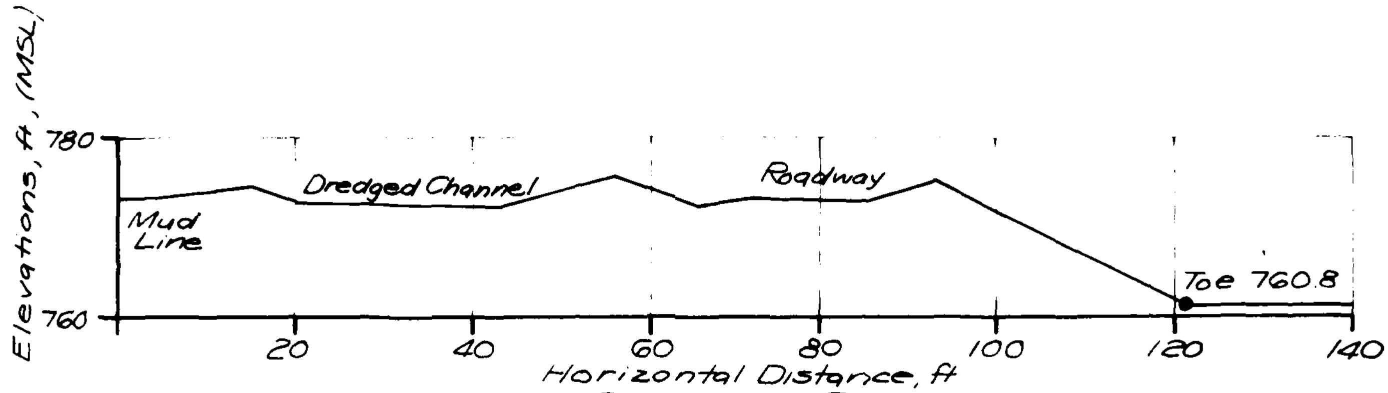


1. Topography from U.S.G.S. Tiff 7 1/2 minute quadrangle map.

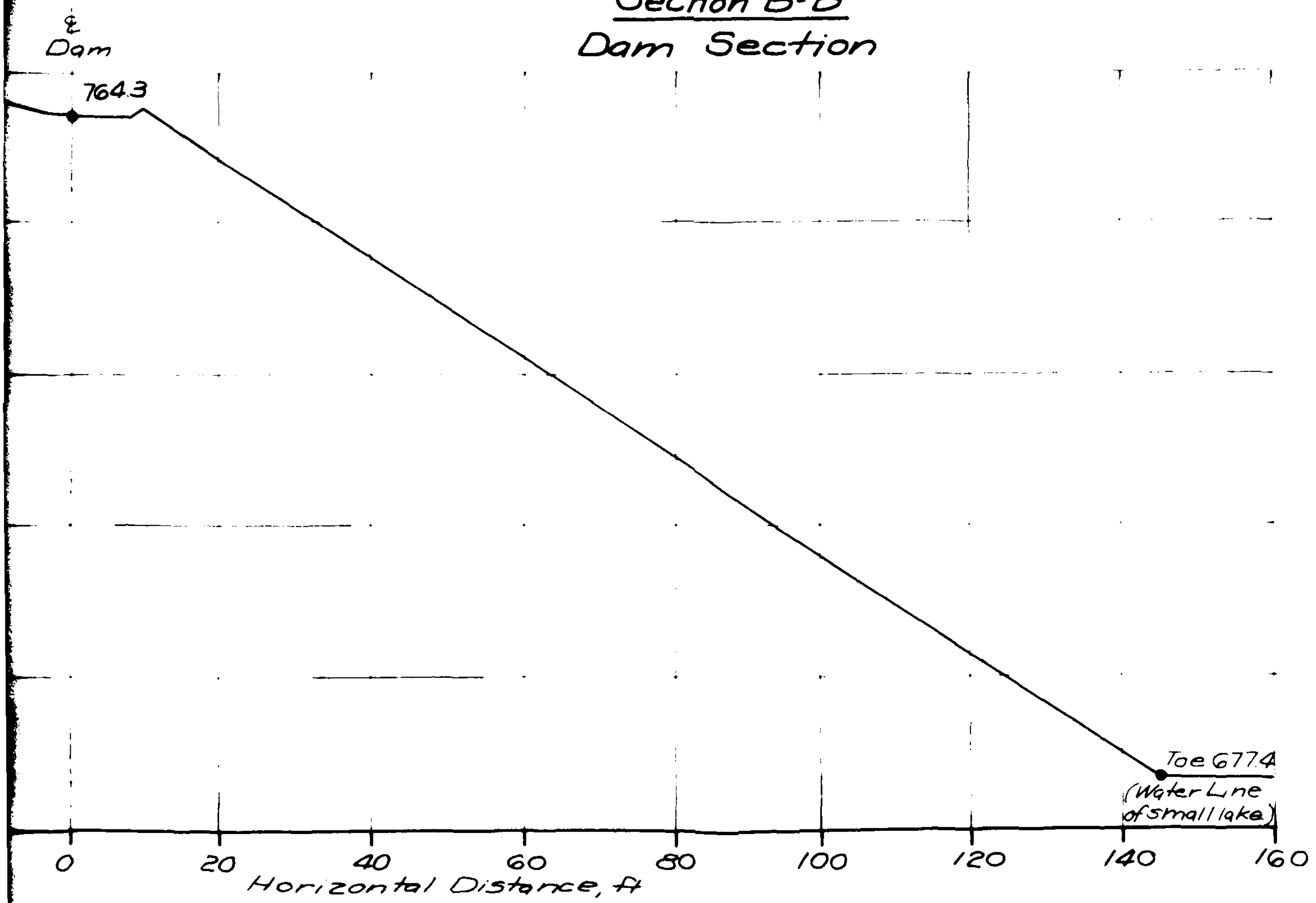
DRAINAGE BASIN AND SITE TOPOGRAPHY	
BLACKWELL MINE DAM	
MO 30709	Fig. 2


Sta. 72+31
El. 768.8
Sta. 6+74
El. 768.9
Sta. 6+74
El. 768.9
Sta. 15+32
El. 768.3
Sta. 4+25
El. 775.4
B
B
Sta. 2+73
El. 773.2
Sta. 1+30
El. 778.0
Sta. 18+94
El. 767.4
N
0
300
600
Scale, ft
Sta. 23+83
El. 766.9
A
Plan of Dam
Sta. 27+32
El. 764.3
A
A
Sta. 30+20
El. 763.9
IMPOUNDMENT
Sta. 33+23
El. 763.2
Sta. 37+47
El. 762.2
Sta. 41+90
El. 760.8
Sta. 43+25
El. 761.5
Sta. 39+96
El. 761.8
Sta. 45+31
End of Dam,
El. 762.2


Elevations, ft, (MSL)
℄
Dam
764.3
Mud Line
770
750
730
710
690
670
Elevation, ft, (MSL)
-20
0



Section B-B
Dam Section

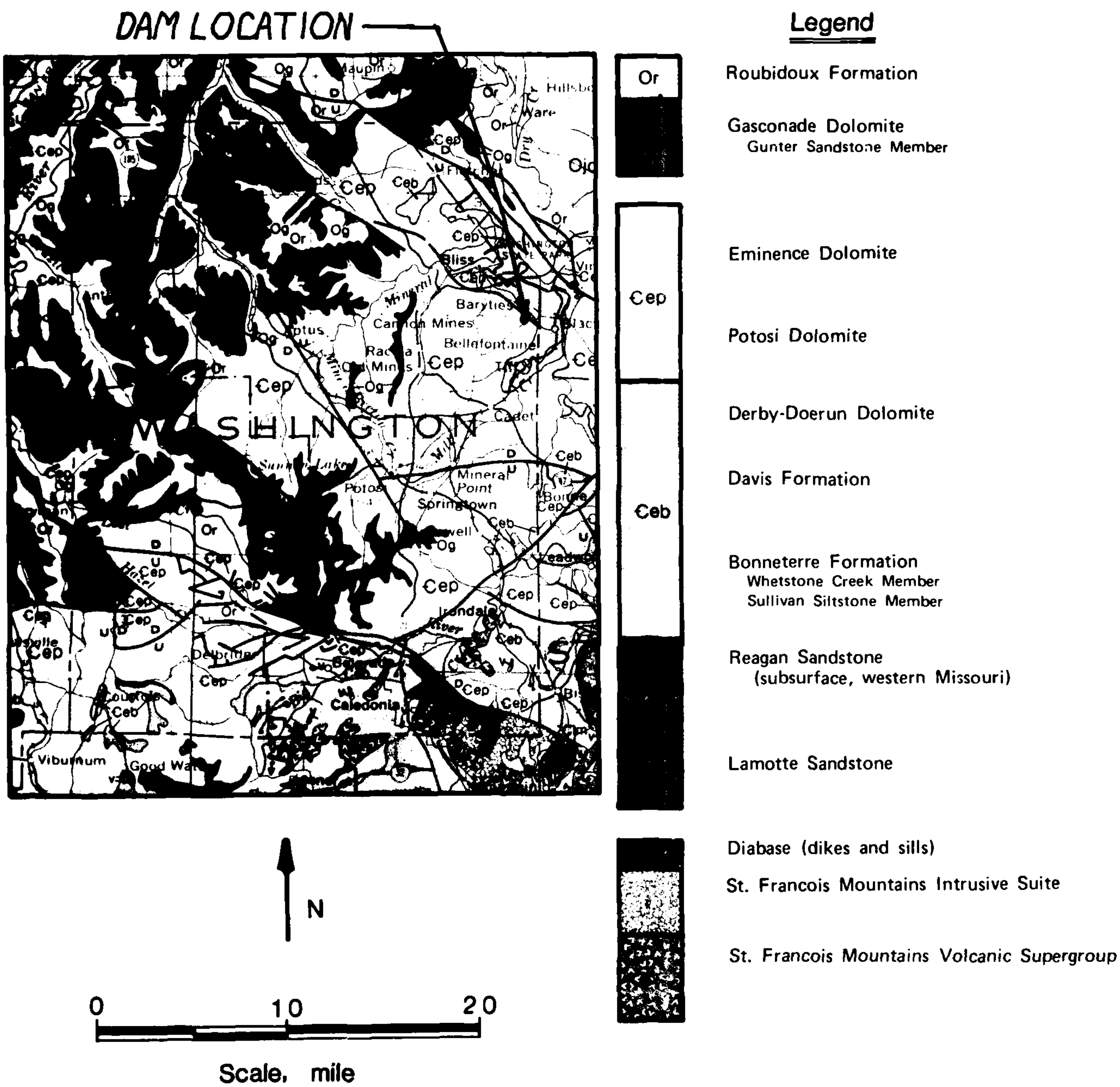


Section A-A
Maximum Dam Section

PLAN AND SECTIONS OF DAM

BLACKWELL MINE DAM

MO. 30709 Fig. 3



REGIONAL GEOLOGIC MAP

BLACKWELL MINE DAM

MO 30709	**Fig. 4**

APPENDIX A

Photographs

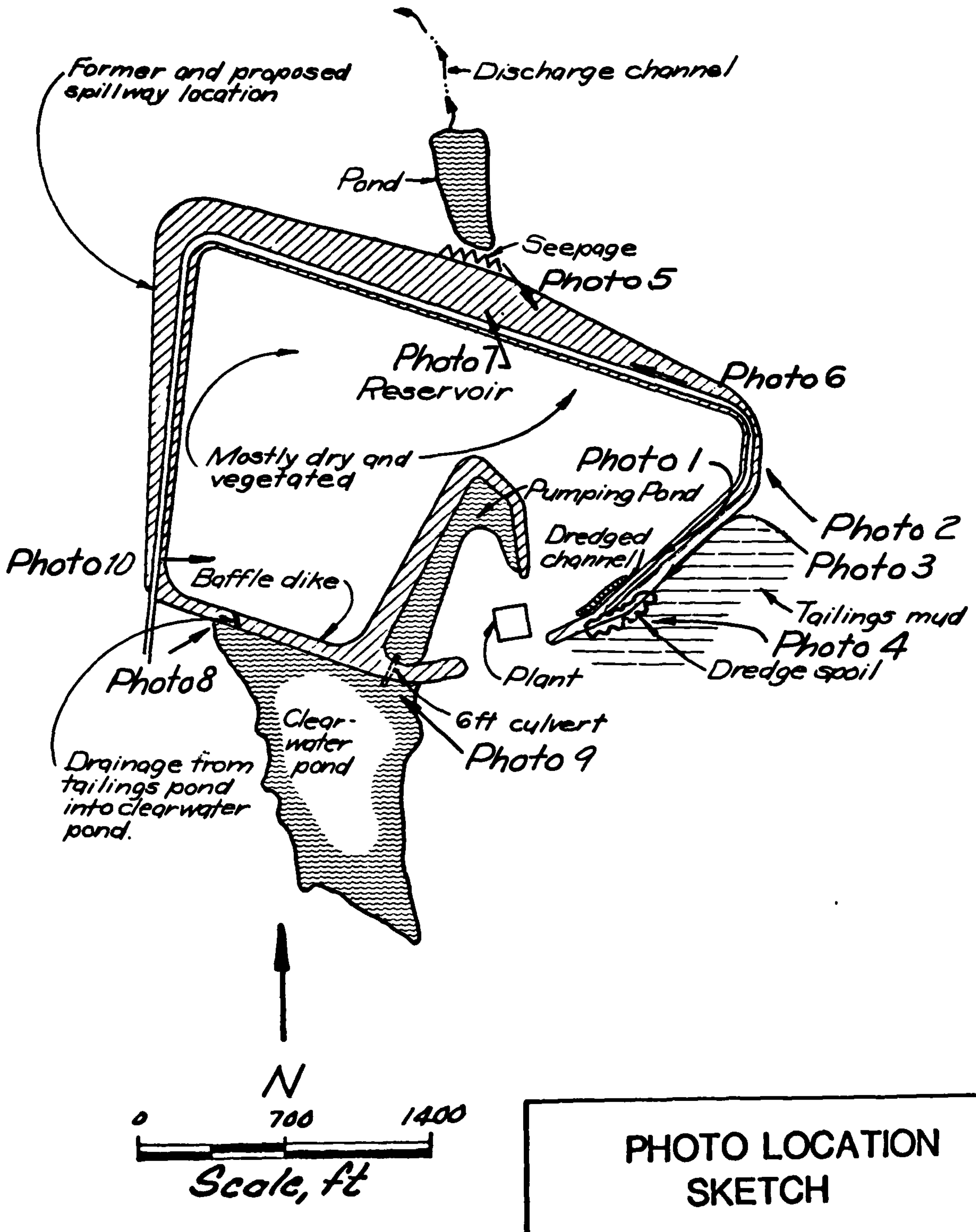


PHOTO LOCATION SKETCH

BLACKWELL MINE DAM

MO 30709	Fig. A-1

1. Dredged channel along east edge of impoundment. Note roadway on main embankment is below tailings level. Plant in background, right. Looking southwest.

2. Area of tailings mud outside of embankment. May be results of overtopping or rainwater washing of dredge spoil. Looking west toward embankment.

3. Dredge spoil along embankment at east edge of impoundment. Looking southwest, reservoir to the right.

4. Toe of dredge spoil along east side of embankment. Note material came to rest at very low angle, approximately 10H:1V. Looking southwest.

5. Bullrock slope cover on face of maximum section. Looking southeast from toe of dam.

6. Steep vegetated downstream face of Blackwell mine dam. Note foreground is exposed "chat". Middle distance covered with bullrock. Looking northwest along dam crest.

7. Seepage into pond at toe of maximum section. Looking northwest from crest of dam.

8. Channel cut through baffle dike separating tailings settlement area from clear water pond. Tailings area in background. Looking north.

9. 6 ft diameter culvert connecting clearwater pond (foreground) with pumping pond. Baffle dike in middle distance, tailings deposition pond in background. Looking northwest.

10. Dried up tailings settlement pond. Looking northeast from crest of baffle dike.

APPENDIX B

Hydraulic/Hydrologic Data and Analyses

APPENDIX B
Hydraulic/Hydrologic Data and Analyses

B.1 Procedures

a. General. The hydraulic/hydrologic analyses were performed using the "HEC-1, Dam Safety Version (1 Apr 80)" computer program. The inflow hydrographs were developed for various precipitation events by applying them to a synthetic unit hydrograph. The inflow hydrographs were subsequently routed through the reservoir and appurtenant structures by the modified Puls reservoir routing option.

b. Precipitation events. The Probable Maximum Precipitation (PMP) and the 1 and 10 percent probability-of-occurrence events were used in the analyses. The total rainfall and corresponding distributions for the 1 and 10 percent probability events were provided by the St. Louis District, Corps of Engineers. The Probable Maximum Precipitation was determined from regional curves prepared by the US Weather Bureau (Hydrometeorological Report Number 33, 1956).

c. Unit hydrograph. The Soil Conservation Services (SCS) Dimensionless Unit Hydrograph method (National Engineering Handbook, Section 4, Hydrology, 1971) was used in the analysis. This method was selected because of its simplicity, applicability to drainage areas less than 10 mi^2, and its easy availability within the HEC-1 computer program.

The watershed lag time was computed using the SCS "curve number method" by an empirical relationship as follows:

$$L = \frac{l^{0.8}(s+l)^{0.7}}{1900\,Y^{0.5}} \quad \text{(Equation 15-4)}$$

where: L = lag in hours
l = hydraulic length of the watershed in feet
$s = \frac{1000}{CN} - 10$ where CN = hydrologic soil curve number
Y = average watershed land slope in percent

This empirical relationship accounts for the soil cover, average watershed slope and hydraulic length.

With the lag time thus computed, another empirical relationship is used to compute the time of concentration as follows:

$$T_c = \frac{L}{0.6} \quad \text{(Equation 15-3)}$$

where: T_c = time of concentration in hours

L = lag in hours.

Subsequent to the computation of the time of concentration, the unit hydrograph duration was estimated utilizing the following relationship:

$$\Delta D = 0.133T_c \qquad \text{(Equation 16-12)}$$

where: ΔD = duration of unit excess rainfall
T_c = time of concentration in hours.

The final interval was selected to provide at least three discharge ordinates prior to the peak discharge ordinate of the unit hydrograph. For this dam, a time interval of 10 minutes was used.

d. Infiltration losses. The infiltration losses were computed by the HEC-1 computer program internally using the SCS curve number method. The curve numbers were established taking into consideration the variables of: (a) antecedent moisture condition, (b) hydrologic soil group classification, (c) degree of development, (d) vegetative cover and (e) present land usage in the watershed.

Antecedent moisture condition III (AMC III) was used for the PMF estimates and AMC II was used for the 1 and 10 percent probability events, in accordance with the guidelines. The remaining variables are defined in the SCS procedure and judgements in their selection were made on the basis of visual field inspection.

e. Starting elevations. Reservoir starting water surface elevations for this dam were set as follows:

(1) 1 and 10 percent probability events - high water mark

(2) Probable Maximum Storm - minimum top of dam

f. Spillway Rating Curve. The basic weir equation was utilized to compute the spillway rating curve. The weir equation is as follows:

$$Q = CLH^{3/2}$$

where Q = discharge in cubic feet per second
L = effective length of spillway in feet
C = coefficient of discharge (2.5 to 3.1)
H = total head over spillway in feet

B.2 Pertinent Data

a. Drainage area. 0.45 mi^2

b. Storm duration. A unit hydrograph was developed by the SCS method option of HEC-1 program. The design storm of 48 hours duration was divided into 10 minute intervals in order to develop the inflow hydrograph.

c. Lag time. 0.80 hrs

d. Hydrologic soil group. C

e. SCS curve numbers.

1. For PMF- AMC III - Curve Number 86
2. For 1 and 10 percent probability-of-occurrence events AMC II - Curve Number 72

f. Storage. Elevation-area data were developed by planimetering areas at various elevation contours on the USGS Tiff 7.5 minute quadrangle map. Storage volume was manually calculated and entered on the $S and $E cards to the HEC-1 program.

g. Outflow over dam crest. As the profile of the dam crest is irregular, flow over the crest was computed according to the "Flow Over Non-Level Dam Crest" supplement to the HEC-1 User's Manual. The crest length-elevation data and hydraulic constants were entered on the $D, $L, and $V cards.

h. Outflow capacity. The outflow rating curve was computed by the intrinsic formula within the HEC-1 program, with pertinent data entered on the $$ cards.

i. Reservoir elevations. For the 50 and 100 percent of the PMF events, the starting reservoir elevation was 760.8 ft, the low area on the dam crest. For the 1 and 10 percent probability-of-occurrence events, the starting reservoir elevation was 758.5 ft, the elevation of the high water line in the reservoir area.

B.3 Results

The results of the analyses as well as the input values to the HEC-1 program follow in this Appendix. Only the results summaries are included, not the intermediate output. Complete copies of the HEC-1 output are available in the project files.

```
************************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  01 APR 80
************************************
                A1      DAM NO. 30709 - GENERAL BARITE MINE, WASHINGTON COUNTY, MISSOURI.
                A2      WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB 79CH009.
                A3      PROBABLE MAXIMUM FLOODS (PMF) ANALYSIS.
                B    288       0      10      -0      -0      -0      -0      -0      -0      -0
                B1     5
                J      1       4       1
                J1   .25     .50     .75    1.00
                K      0    0-IN                                    1
                K1  GENERAL BARITE MINE INFLOW COMPUTATION, PMF RATIO FLOODS.
                M      1       2    0.45                     1.0
                P      0     26.     102     120     130     140
                T                                                  -1     -86             0.34
                W2          0.80
                X     -1    -.05       5
                K      1     DAM                                    1
                K1  GENERAL BARITE MINE DAM PMF FLOOD ROUTINGS.
                Y                              1       1
                Y1     1                                       -760.8
                SS    0.     24.     83.    171.    344.    703.   1312.   1741.   1802.   2904.
                SE  685.    700.    710.    720.    730.    740.    750.    760.   760.8    770.
                SS 760.8             2.8     1.5
                SD 760.8     2.8     1.5
                SL    0.     70.    735.    895.    980.   1560.
                SV 760.8    761.    762.    763.    764.    765.
                K     99
```

Input Data
Various PMF Events
Blackwell Mine Dam
MO 30709

```
**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  01 APR 80
**********************************

RUN  DATE: 06 AUG 80
     TIME: 10.19.06

                    DAM NO. 30709 - GENERAL BARITE MINE, WASHINGTON COUNTY, MISSOURI.
                    WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB 79CH009.
                    PROBABLE MAXIMUM FLOODS (PMF) ANALYSIS.

                                    JOB SPECIFICATION
               NQ     NHR    NMIN    IDAY     IHR    IMIN   METRC    IPLT    IPRT   NSTAN
              288       0      10      -0      -0      -0      -0      -0      -0      -0
                                    JOPER     NWT   LROPT   TRACE
                                        5      -0      -0      -0

                              MULTI-PLAN ANALYSES TO BE PERFORMED
                                   NPLAN= 1 NRTIO= 4 LRTIO= 1
                RTIOS=    .25     .50     .75    1.00

          **********     **********     **********     **********     **********

                                 SUB-AREA RUNOFF COMPUTATION

              GENERAL BARITE MINE INFLOW COMPUTATION, PMF RATIO FLOODS.

                         ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                          Q-IN       0      -0      -0      -0      -0       1      -0      -0

                                        HYDROGRAPH DATA
              IHYDG    IUHG   TAREA    SNAP   TRSDA   TRSPC   RATIO   ISNOW   ISAME   LOCAL
                  1       2     .45     -0.     .45    1.00     -0.     -0      -0      -0

                                         PRECIP DATA
                      SPFE     PMS      R6     R12     R24     R48     R72     R96
                        0.   26.00  102.00  120.00  130.00  140.00     -0.     -0.

                                          LOSS DATA
           LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
              -0     -0.     -0.    1.00     -0.     -0.    1.00   -1.00  -86.00     -0.     .34

              CURVE NO = -86.00  WETNESS =  -1.00  EFFECT CN =  86.00

                                     UNIT HYDROGRAPH DATA
                                   TC= -0.      LAG=   .80

                                        RECESSION DATA
                         STRTQ=   -1.00    ORCSN=   -.09    RTIOR= 9.00

              UNIT HYDROGRAPH 26 END OF PERIOD ORDINATES, TC=   -0.  HOURS, LAG=   .80  VOL= 1.00
           23.      70.     147.     217.     249.     239.     208.     165.     114.      83.
           62.      46.      34.      25.      19.      13.      10.       7.       5.       4.
            3.       2.       2.       1.       1.       0.
```

Input Data
Various PMF Events
Blackwell Mine Dam
MO 30709

UNIT HYDROGRAPH 26 END OF PERIOD ORDINATES, TC= -0. HOURS, LAG= .50 VOL= 1.00

23.	70.	147.	217.	245.	239.	208.	165.	114.	83.
52.	46.	34.	25.	19.	13.	10.	7.	5.	4.
3.	2.	2.	1.	1.	0.				

0

END-OF-PERIOD FLOW

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.10	1	.00	.00	.00	0.	1.02	.10	145	.03	.03	.00	6.
1.01	.20	2	.00	.00	.00	0.	1.02	.20	146	.03	.03	.00	7.
1.01	.30	3	.00	.00	.00	0.	1.02	.30	147	.03	.03	.00	11.
1.01	.40	4	.00	.00	.00	1.	1.02	.40	148	.03	.03	.00	15.
1.01	.50	5	.00	.00	.00	1.	1.02	.50	149	.03	.03	.00	21.
1.01	1.00	6	.00	.00	.00	1.	1.02	1.00	150	.03	.03	.00	26.
1.01	1.10	7	.00	.00	.00	1.	1.02	1.10	151	.03	.03	.00	31.
1.01	1.20	8	.00	.00	.00	1.	1.02	1.20	152	.03	.03	.00	35.
1.01	1.30	9	.00	.00	.00	1.	1.02	1.30	153	.03	.03	.00	38.
1.01	1.40	10	.00	.00	.00	1.	1.02	1.40	154	.03	.03	.00	40.
1.01	1.50	11	.00	.00	.00	1.	1.02	1.50	155	.03	.03	.00	41.
1.01	2.00	12	.00	.00	.00	1.	1.02	2.00	156	.03	.03	.00	42.
1.01	2.10	13	.00	.00	.00	1.	1.02	2.10	157	.03	.03	.00	43.
1.01	2.20	14	.00	.00	.00	1.	1.02	2.20	158	.03	.03	.00	44.
1.01	2.30	15	.00	.00	.00	1.	1.02	2.30	159	.03	.03	.00	44.
1.01	2.40	16	.00	.00	.00	1.	1.02	2.40	160	.03	.03	.00	44.
1.01	2.50	17	.00	.00	.00	1.	1.02	2.50	161	.03	.03	.00	45.
1.01	3.00	18	.00	.00	.00	1.	1.02	3.00	162	.03	.03	.00	45.
1.01	3.10	19	.00	.00	.00	1.	1.02	3.10	163	.03	.03	.00	45.
1.01	3.20	20	.00	.00	.00	1.	1.02	3.20	164	.03	.03	.00	45.
1.01	3.30	21	.00	.00	.00	1.	1.02	3.30	165	.03	.03	.00	45.
1.01	3.40	22	.00	.00	.00	1.	1.02	3.40	166	.03	.03	.00	46.
1.01	3.50	23	.00	.00	.00	1.	1.02	3.50	167	.03	.03	.00	46.
1.01	4.00	24	.00	.00	.00	1.	1.02	4.00	168	.03	.03	.00	46.
1.01	4.10	25	.00	.00	.00	1.	1.02	4.10	169	.03	.03	.00	46.
1.01	4.20	26	.00	.00	.00	1.	1.02	4.20	170	.03	.03	.00	46.
1.01	4.30	27	.00	.00	.00	1.	1.02	4.30	171	.03	.03	.00	46.
1.01	4.40	28	.00	.00	.00	1.	1.02	4.40	172	.03	.03	.00	46.
1.01	4.50	29	.00	.00	.00	1.	1.02	4.50	173	.03	.03	.00	46.
1.01	5.00	30	.00	.00	.00	1.	1.02	5.00	174	.03	.03	.00	46.
1.01	5.10	31	.00	.00	.00	1.	1.02	5.10	175	.03	.03	.00	46.
1.01	5.20	32	.00	.00	.00	1.	1.02	5.20	176	.03	.03	.00	46.
1.01	5.30	33	.00	.00	.00	1.	1.02	5.30	177	.03	.03	.00	46.
1.01	5.40	34	.00	.00	.00	1.	1.02	5.40	178	.03	.03	.00	46.
1.01	5.50	35	.00	.00	.00	1.	1.02	5.50	179	.03	.03	.00	46.
1.01	6.00	36	.00	.00	.00	1.	1.02	6.00	180	.03	.03	.00	46.
1.01	6.10	37	.01	.00	.01	1.	1.02	6.10	181	.13	.12	.01	49.
1.01	6.20	38	.01	.00	.01	2.	1.02	6.20	182	.13	.12	.01	55.
1.01	6.30	39	.01	.00	.01	2.	1.02	6.30	183	.13	.12	.01	69.
1.01	6.40	40	.01	.00	.01	3.	1.02	6.40	184	.13	.12	.01	90.
1.01	6.50	41	.01	.00	.01	3.	1.02	6.50	185	.13	.12	.01	113.
1.01	7.00	42	.01	.00	.01	4.	1.02	7.00	186	.13	.12	.01	136.
1.01	7.10	43	.01	.00	.01	4.	1.02	7.10	187	.13	.12	.01	156.
1.01	7.20	44	.01	.00	.01	5.	1.02	7.20	188	.13	.12	.01	172.
1.01	7.30	45	.01	.00	.01	5.	1.02	7.30	189	.13	.12	.01	181.
1.01	7.40	46	.01	.00	.01	5.	1.02	7.40	190	.13	.12	.01	191.
1.01	7.50	47	.01	.00	.01	5.	1.02	7.50	191	.13	.12	.01	197.
1.01	8.00	48	.01	.00	.01	6.	1.02	8.00	192	.13	.12	.01	202.
1.01	8.10	49	.01	.00	.01	6.	1.02	8.10	193	.13	.12	.01	206.
1.01	8.20	50	.01	.00	.01	6.	1.02	8.20	194	.13	.12	.01	209.
1.01	8.30	51	.01	.00	.01	6.	1.02	8.30	195	.13	.13	.00	211.
1.01	8.40	52	.01	.00	.01	6.	1.02	8.40	196	.13	.13	.00	213.
1.01	8.50	53	.01	.00	.01	6.	1.02	8.50	197	.13	.13	.00	214.
1.01	9.00	54	.01	.00	.01	6.	1.02	9.00	198	.13	.13	.00	215.
1.01	9.10	55	.01	.00	.01	6.	1.02	9.10	199	.13	.13	.00	216.
1.01	9.20	56	.01	.00	.01	6.	1.02	9.20	200	.13	.13	.00	217.

Input Data
Various PMF Events
Blackwell Mine Dam
MO 30709

1.01	8.50	53	.01	.00	.01	6.	1.02	8.50	197	.13	.13	.00	214.	
1.01	9.00	54	.01	.00	.01	6.	1.02	9.00	198	.13	.13	.00	215.	
1.01	9.10	55	.01	.00	.01	6.	1.02	9.10	199	.13	.13	.00	216.	
1.01	9.20	56	.01	.00	.01	6.	1.02	9.20	200	.13	.13	.00	217.	
1.01	9.30	57	.01	.00	.01	6.	1.02	9.30	201	.13	.13	.00	217.	
1.01	9.40	58	.01	.00	.01	6.	1.02	9.40	202	.13	.13	.00	218.	
1.01	9.50	59	.01	.00	.01	6.	1.02	9.50	203	.13	.13	.00	218.	
1.01	10.00	60	.01	.00	.01	6.	1.02	10.00	204	.13	.13	.00	219.	
1.01	10.10	61	.01	.00	.01	6.	1.02	10.10	205	.13	.13	.00	219.	
1.01	10.20	62	.01	.00	.01	6.	1.02	10.20	206	.13	.13	.00	219.	
1.01	10.30	63	.01	.00	.01	6.	1.02	10.30	207	.13	.13	.00	220.	
1.01	10.40	64	.01	.00	.01	6.	1.02	10.40	208	.13	.13	.00	220.	
1.01	10.50	65	.01	.00	.01	6.	1.02	10.50	209	.13	.13	.00	220.	
1.01	11.00	66	.01	.00	.01	6.	1.02	11.00	210	.13	.13	.00	220.	
1.01	11.10	67	.01	.00	.01	6.	1.02	11.10	211	.13	.13	.00	220.	
1.01	11.20	68	.01	.00	.01	6.	1.02	11.20	212	.13	.13	.00	221.	
1.01	11.30	69	.01	.00	.01	6.	1.02	11.30	213	.13	.13	.00	221.	
1.01	11.40	70	.01	.00	.01	6.	1.02	11.40	214	.13	.13	.00	221.	
1.01	11.50	71	.01	.00	.01	7.	1.02	11.50	215	.13	.13	.00	221.	
1.01	12.00	72	.01	.00	.01	7.	1.02	12.00	216	.13	.13	.00	221.	
1.01	12.10	73	.03	.01	.02	7.	1.02	12.10	217	.44	.43	.01	228.	
1.01	12.20	74	.03	.02	.02	8.	1.02	12.20	218	.44	.43	.01	250.	
1.01	12.30	75	.03	.02	.02	10.	1.02	12.30	219	.44	.44	.01	299.	
1.01	12.40	76	.03	.02	.02	12.	1.02	12.40	220	.44	.44	.01	362.	
1.01	12.50	77	.03	.02	.02	15.	1.02	12.50	221	.44	.44	.01	437.	
1.01	13.00	78	.03	.02	.02	18.	1.02	13.00	222	.44	.44	.01	511.	
1.01	13.10	79	.04	.02	.02	21.	1.02	13.10	223	.53	.52	.01	577.	
1.01	13.20	80	.04	.02	.02	24.	1.02	13.20	224	.53	.52	.01	634.	
1.01	13.30	81	.04	.02	.02	26.	1.02	13.30	225	.53	.53	.01	682.	
1.01	13.40	82	.04	.02	.02	29.	1.02	13.40	226	.53	.53	.00	729.	
1.01	13.50	83	.04	.03	.02	32.	1.02	13.50	227	.53	.53	.00	769.	
1.01	14.00	84	.04	.03	.02	34.	1.02	14.00	228	.53	.53	.00	804.	
1.01	14.10	85	.05	.03	.02	36.	1.02	14.10	229	.66	.66	.00	837.	
1.01	14.20	86	.05	.03	.02	39.	1.02	14.20	230	.66	.66	.00	868.	
1.01	14.30	87	.05	.03	.02	42.	1.02	14.30	231	.66	.66	.00	904.	
1.01	14.40	88	.05	.04	.02	44.	1.02	14.40	232	.66	.66	.00	944.	
1.01	14.50	89	.05	.04	.02	48.	1.02	14.50	233	.66	.66	.00	986.	
1.01	15.00	90	.05	.04	.01	51.	1.02	15.00	234	.66	.66	.00	1024.	
1.01	15.10	91	.05	.03	.01	53.	1.02	15.10	235	.60	.60	.00	1055.	
1.01	15.20	92	.08	.06	.02	56.	1.02	15.20	236	1.01	1.00	.00	1086.	
1.01	15.30	93	.14	.11	.03	60.	1.02	15.30	237	1.81	1.81	.01	1141.	
1.01	15.40	94	.35	.28	.07	72.	1.02	15.40	238	4.53	4.52	.01	1318.	
1.01	15.50	95	.10	.08	.02	92.	1.02	15.50	239	1.31	1.31	.00	1635.	
1.01	16.00	96	.06	.05	.01	119.	1.02	16.00	240	.81	.80	.00	2064.	
1.01	16.10	97	.05	.04	.01	143.	1.02	16.10	241	.62	.62	.00	2427.	
1.01	16.20	98	.05	.04	.01	154.	1.02	16.20	242	.62	.62	.00	2578.	
1.01	16.30	99	.05	.04	.01	153.	1.02	16.30	243	.62	.62	.00	2535.	
1.01	16.40	100	.05	.04	.01	143.	1.02	16.40	244	.62	.62	.00	2340.	
1.01	16.50	101	.05	.04	.01	128.	1.02	16.50	245	.62	.62	.00	2076.	
1.01	17.00	102	.05	.04	.01	112.	1.02	17.00	246	.62	.62	.00	1797.	
1.01	17.10	103	.04	.03	.01	101.	1.02	17.10	247	.49	.49	.00	1600.	
1.01	17.20	104	.04	.03	.01	92.	1.02	17.20	248	.49	.49	.00	1454.	
1.01	17.30	105	.04	.03	.00	85.	1.02	17.30	249	.49	.49	.00	1333.	
1.01	17.40	106	.04	.03	.00	79.	1.02	17.40	250	.49	.49	.00	1227.	
1.01	17.50	107	.04	.03	.00	74.	1.02	17.50	251	.49	.49	.00	1139.	
1.01	18.00	108	.04	.03	.00	70.	1.02	18.00	252	.49	.49	.00	1066.	
1.01	18.10	109	.00	.00	.00	66.	1.02	18.10	253	.04	.04	.00	998.	
1.01	18.20	110	.00	.00	.00	61.	1.02	18.20	254	.04	.04	.00	923.	
1.01	18.30	111	.00	.00	.00	55.	1.02	18.30	255	.04	.04	.00	827.	
1.01	18.40	112	.00	.00	.00	47.	1.02	18.40	256	.04	.04	.00	708.	
1.01	18.50	113	.00	.00	.00	39.	1.02	18.50	257	.04	.04	.00	593.	
1.01	19.00	114	.00	.00	.00	31.	1.02	19.00	258	.04	.04	.00	465.	
1.01	19.10	115	.00	.00	.00	24.	1.02	19.10	259	.04	.04	.00	364.	

Input Data
Various PMF Events
Blackwell Mine Dam
MO 30709

1.01	18.20	110	.00	.00	.00	61.	1.02	18.20	254	.04	.04	.00	923.
1.01	18.30	111	.00	.00	.00	55.	1.02	18.30	255	.04	.04	.00	827.
1.01	18.40	112	.00	.00	.00	47.	1.02	18.40	256	.04	.04	.00	708.
1.01	18.50	113	.00	.00	.00	39.	1.02	18.50	257	.04	.04	.00	583.
1.01	19.00	114	.00	.00	.00	31.	1.02	19.00	258	.04	.04	.00	465.
1.01	19.10	115	.00	.00	.00	24.	1.02	19.10	259	.04	.04	.00	364.
1.01	19.20	116	.00	.00	.00	19.	1.02	19.20	260	.04	.04	.00	285.
1.01	19.30	117	.00	.00	.00	15.	1.02	19.30	261	.04	.04	.00	229.
1.01	19.40	118	.00	.00	.00	13.	1.02	19.40	262	.04	.04	.00	187.
1.01	19.50	119	.00	.00	.00	10.	1.02	19.50	263	.04	.04	.00	156.
1.01	20.00	120	.00	.00	.00	9.	1.02	20.00	264	.04	.04	.00	133.
1.01	20.10	121	.00	.00	.00	8.	1.02	20.10	265	.04	.04	.00	117.
1.01	20.20	122	.00	.00	.00	7.	1.02	20.20	266	.04	.04	.00	106.
1.01	20.30	123	.00	.00	.00	7.	1.02	20.30	267	.04	.04	.00	98.
1.01	20.40	124	.00	.00	.00	6.	1.02	20.40	268	.04	.04	.00	91.
1.01	20.50	125	.00	.00	.00	6.	1.02	20.50	269	.04	.04	.00	87.
1.01	21.00	126	.00	.00	.00	6.	1.02	21.00	270	.04	.04	.00	84.
1.01	21.10	127	.00	.00	.00	5.	1.02	21.10	271	.04	.04	.00	81.
1.01	21.20	128	.00	.00	.00	5.	1.02	21.20	272	.04	.04	.00	79.
1.01	21.30	129	.00	.00	.00	5.	1.02	21.30	273	.04	.04	.00	78.
1.01	21.40	130	.00	.00	.00	5.	1.02	21.40	274	.04	.04	.00	77.
1.01	21.50	131	.00	.00	.00	5.	1.02	21.50	275	.04	.04	.00	76.
1.01	22.00	132	.00	.00	.00	5.	1.02	22.00	276	.04	.04	.00	76.
1.01	22.10	133	.00	.00	.00	5.	1.02	22.10	277	.04	.04	.00	75.
1.01	22.20	134	.00	.00	.00	5.	1.02	22.20	278	.04	.04	.00	75.
1.01	22.30	135	.00	.00	.00	5.	1.02	22.30	279	.04	.04	.00	75.
1.01	22.40	136	.00	.00	.00	5.	1.02	22.40	280	.04	.04	.00	75.
1.01	22.50	137	.00	.00	.00	5.	1.02	22.50	281	.04	.04	.00	75.
1.01	23.00	138	.00	.00	.00	5.	1.02	23.00	282	.04	.04	.00	75.
1.01	23.10	139	.00	.00	.00	5.	1.02	23.10	283	.04	.04	.00	75.
1.01	23.20	140	.00	.00	.00	5.	1.02	23.20	284	.04	.04	.00	75.
1.01	23.30	141	.00	.00	.00	5.	1.02	23.30	285	.04	.04	.00	75.
1.01	23.40	142	.00	.00	.00	5.	1.02	23.40	286	.04	.04	.00	75.
1.01	23.50	143	.00	.00	.00	5.	1.02	23.50	287	.04	.04	.00	75.
1.02	0.	144	.00	.00	.00	5.	1.03	0.	288	.04	.04	.00	75.
									SUM	36.40	35.16	1.24	60774.
										(925.)(	893.)(	32.)(	1720.93)

Input Data
Various PMF Events
Blackwell Mine Dam
MO 30709

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS RATIO 1 .10
HYDROGRAPH AT	Q-IN	.45	1	258.
	(	1.17)	(	7.30)(
ROUTED TO	DAM	.45	1	0.
	(	1.17)	(	.00)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	759.50	760.00	760.00
STORAGE	1720.	1802.	1802.
OUTFLOW	0.	0.	0.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.10	760.01	.01	1803.	0.	1.17	48.00	0.

Overtopping Analysis
Blackwell Mine Dam
MO. ID. No. 30709

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIO 1	RATIO 2	RATIO 3	RATIO 4
				RATIOS APPLIED TO FLOWS			
				.25	.50	.75	1.00
HYDROGRAPH AT	U-IN	.45	1	645.	1289.	1934.	2578.
	(	1.17)	(	18.25)(	36.50)(	54.76)(	73.01)(
ROUTED TO	DAM	.45	1	391.	975.	1591.	2195.
	(	1.17)	(	11.06)(	27.62)(	45.05)(	62.24)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	760.80	760.80	760.80
STORAGE	1802.	1802.	1802.
OUTFLOW	0.	0.	0.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.25	761.64	.84	1903.	391.	48.00	41.17	0.
.50	761.98	1.18	1944.	975.	48.00	40.83	0.
.75	762.22	1.42	1972.	1591.	48.00	40.93	0.
1.00	762.41	1.61	1995.	2198.	48.00	40.83	0.

Output Summary
Various PMF Events
Blackwell Mine Dam
MO 30709