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NATIONAL DAM SAFETY PROGRAM. KEYES BRANCH MINE DAM (MO 30386), --ETC(U)
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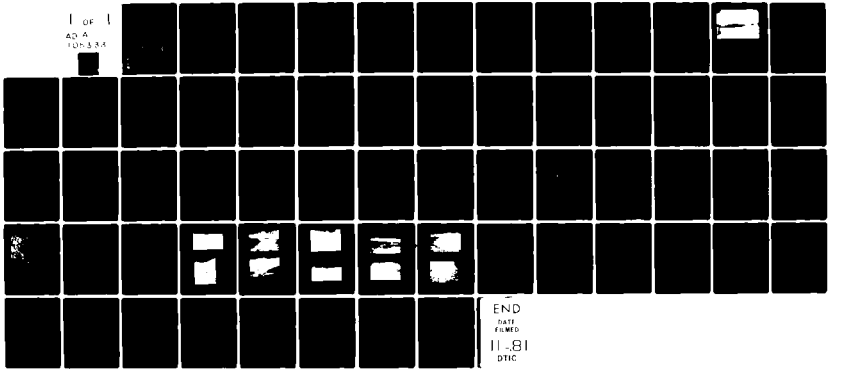

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AD A105233

KEYES BRANCH MINE DAM
WASHINGTON COUNTY, MISSOURI
MO 30386

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY INSPECTION

United States Army
Corps of Engineers
...Serving the Army
...Serving the Nation

St. Louis District

PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI

AUGUST 1980

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REPORT DOCUMENTATION PAGE

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Dam Safety, Lake, Dam Inspection, Private Dams

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: Keyes Branch Mine Dam (MO 30386)

This report presents the results of field inspection and evaluation of the Keyes Branch Mine Dam. It was prepared under the National Program of Inspection of Non-Federal Dams.

SIGNED 12 SEP 1980

SUBMITTED BY: _____ _____
Chief, Engineering Division Date

SIGNED 12 SEP 1980

APPROVED BY: _____ _____
Colonel, CE, District Engineer Date

KEYES BRANCH DAM

County, Missouri

Missouri Inventory No. 30386

Phase I Inspection Report

National Dam Safety Program

Prepared by

Woodward-Clyde Consultants

Chicago, Illinois

Under Direction of

St Louis District, Corps of Engineers

for

Governor of Missouri

August 1980

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	Keyes Branch Mine Dam
State Located	Missouri
County Located	Washington
Stream	Unnamed Tributary of Keyes Branch Creek
Date of Inspections	15 May 1980; 5 June 1980

Keyes Branch Mine Dam, Identification Number 30386, was inspected by Richard Berggreen (engineering geologist), James Burnett (geotechnical engineer), Jean-Yves Perez (project manager and geotechnical engineer), and Sean Tseng (hydrologist).

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 are considered to 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.

Based on the criteria in the guidelines, the dam is judged to be in the significant hazard classification. The estimated damage zone extends approximately 10 mi downstream. The apparently occupied structures downstream from the dam appear to be above potential flood levels. Damage and loss of life would likely be restricted to traffic on state highways and railroads which cross the creek. The closest state road is approximately 1.6 mi downstream.

Keyes Branch Mine Dam is in the intermediate size classification based on its maximum height of 57 ft, and on its maximum reservoir storage volume of 1400 ac-ft.

Our inspection and evaluation indicate the dam to be in a fair to good condition. A slump-type landslide on the downstream face of the embankment, where sliding had been described earlier by the Missouri Geological Survey, suggests continuing instability at this location.

The erosion potential of the spillway walls and discharge channel appears to be significant. Mining and processing operations at the facility have been discontinued as of December 1979 and no plans were formed by the owner for any future maintenance or inspections of the dam. In light of the discontinued operations and the erosion potential of the spillway facilities, deterioration sufficient to pose a hazard to the stability of the dam could occur in the future without being noticed.

As a result of the erosion potential of the spillway, it was calculated that discharge through the spillway of more than 170 ft^3/s or discharge velocity greater than 3.5 ft/sec will significantly erode the spillway to a degree such that this discharge will have the same effects as overtopping the embankment. Based on this analysis, the spillway cannot safely pass a flood of greater than 23 percent of the PMF without effectively overtopping the dam. The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic considerations that are reasonably possible in the region. A flood with 1 percent probability-of-occurrence will safely pass the spillway.

Based on our inspection of the Keyes Branch Mine Dam, it is recommended that further study be conducted without undue delay under the guidance of an engineer experienced in the design and construction of dams, to evaluate, as a minimum, the following topics:

1. What spillway capacity should be provided, and in what manner, taking into consideration the high potential erodibility of the embankment materials in the event of overtopping.

2. Potential for erosion during period of heavy flow within the spillway and adjacent portion of the embankment, including erosion mitigating options.

3. Potential for erosion and lateral migration in the discharge channel, including erosion mitigating options.

It is recommended that an inspection and monitoring program be initiated for this facility. This program should include:

1. Inspection of erosion in spillway to evaluate deterioration of the coarse tailings dike on the south side of the spillway;

2. Inspection of lateral and headward erosion in the discharge channel to evaluate potential for undermining the toe of the dam by migration of the discharge channel;

3. Monitoring seepage in the discharge channel and at the toe of the dam to identify changes in the amount of flow and turbidity of the seepage water; and

4. Evaluation of alternatives for an effective, practical warning system to alert downstream residents and traffic on the highways and railroads which cross the drainage if an unsafe condition should develop.

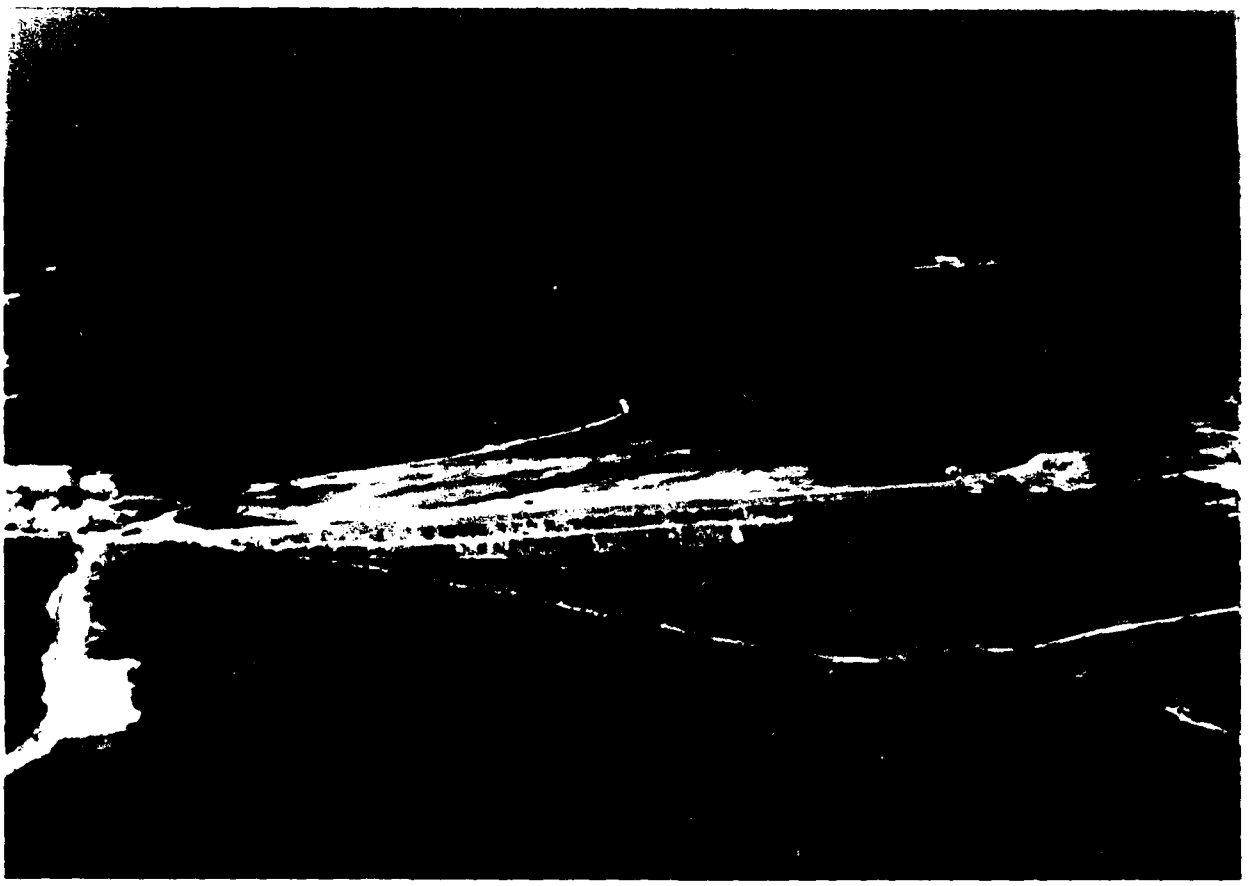
In view of the slide which occurred in the interval between two inspection visits, it is recommended that an analysis be made of the static and seismic stability of the existing structure. An engineering analysis should also be made to identify and design erosion control alternatives for the spillway and discharge channel. This analysis should be conducted by an engineer experienced in the design and construction of dams.

It is suggested that the owner takes action on these recommendations in the near future to preclude deterioration which could lead to the development of hazardous conditions at this facility.

WOODWARD-CLYDE CONSULTANTS

Richard G. Berggreen
Registered Geologist

Jean-Yves Perez, PE
Vice President



OVERVIEW

KEYES BRANCH MINE DAM

MISSOURI INVENTORY NO. MO 30386

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
KEYES BRANCH MINE DAM - MISSOURI ID. No. 30386

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
KEYES BRANCH MINE DAM, MISSOURI ID. No. 30386

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 Keyes Branch Mine Dam, Missouri Inventory Number 30386.

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 (SLD). 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.** The Keyes Branch Mine Dam is a tailings dam. The construction of Keyes Branch Mine Dam, as described by Mr Joe Rossier of Milchem, Inc. is somewhat atypical of barite tailings dams in this area. The majority of dams are constructed as a single tier, having a constant slope from crest to toe. The Keyes Branch tiered Dam is a 3 tiered dam. The resulting profile (Fig 3a) is wider and flatter than is typical for tailings dams in this area.

The uppermost tier is constructed of "chat", the gravel-sized waste produced during the milling of the ore (Photo 1). The middle and lower tiers are primarily chat, but have a veneer of "bullrock", large (6 in. to 2 ft) waste rock, placed on the downstream face (Photo 2). This bullrock veneer is quite clayey and may act as an impermeable blanket on the downstream face, allowing seepage pressures to build up behind the face. The flat steps between tiers allow precipitation to enter the dam more readily than on single tier dams.

The material impounded behind the dam consists of silt, sand, and clay produced by washing the barite ore. This fine-grained waste is sluiced into the impoundment where the suspended material is deposited. The resulting sediments are typical of recent lacustrine clay deposits. Where the tailings have been continuously submerged, they have a very soft consistency and high water contents. A stiff crust has formed where the tailings have dried out; however, below the crust the material remains very soft.

The spillway, located at the left abutment, consists of a broad, flat-bottomed notch at the junction of the abutment and dam (Photo 3). The spillway is approximately 70 ft wide at the level of the top of the embankment. The crest of the spillway is approximately 3.2 ft below the elevation of the low point on the top of the embankment. No low level outlet was found. No control structures were found for regulating higher flows.

b. **Location.** The dam is located on a tributary of Keyes Branch Creek, approximately 2 mi northeast of the town of Potosi off Missouri Highway E in Washington County, Missouri, Section 6, T37N, R3E, and Section 31, T38N, R3E; see Fig. 1. The dam location is on the USGS Potosi 7.5 minute quadrangle sheet.

c. **Size classification.** The dam is classified intermediate size based on its 57 ft height and 1400 ac-ft storage capacity.

d. **Hazard classification.** The St Louis District, Corps of Engineers has classified this dam as a significant hazard dam; we concur with this classification. The estimated damage zone extends approximately 10 mi downstream of the dam. Located within this zone are Missouri State Route E and State Route 47, several crossings of the Missouri-Pacific Railroad, and several gravel roads.

e. **Ownership.** We understand the dam is owned by Milchem Inc, Mineral Point, Missouri, 63660. Correspondence should be addressed to the attention of Mr Joe Rossier.

f. **Purpose of dam.** The Keyes Branch Mine Dam was constructed to impound fine barite tailings produced by the washing of barite ore mined in the vicinity. Water impounded by the dam was recycled from the reservoir and used in the barite processing operation.

g. **Design and construction history.** According to information obtained from Mr Joe Rossier of Milchem, Inc, a starter dam was constructed on the site in 1972. This was further documented in a letter report from the Missouri Geological Survey (Appendix C). A typical cross section of the present configuration of the dam and of the probable configuration of the starter dam is included as Fig. 3a. An engineering design of the starter dam was prepared by Mr Bill Devitt, but consisted of only a general sketch drawing. No provision was made for construction inspection.

The starter dam was constructed of stoney red clay borrowed from the reservoir area and was approximately 30 ft high, 20 ft wide across the crest, with a 5-ft deep cut-off trench.

The main dam was constructed between 1975 and 1979. During this time coarse tailings, ranging from sand to medium gravel size, were dumped along the embankment. The embankment face was stepped upstream to form a

3-tiered embankment. Large rock, to approximately 2 ft diameter, was placed on the downstream face of the lower two tiers. Fine tailings of sand silt and clay size, were sluiced into the impoundment area from the processing plant located on the right abutment.

Mining and processing operations were terminated in December 1979. No work has been done on the dam construction since then, nor is any further work anticipated.

h. **Normal operating procedure.** No operating records were found. Overflow passes over the uncontrolled spillway at the left abutment.

1.3 Pertinent Data

a. **Drainage area:** approximately .32 mi^2 (Fig. 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	1073 ft^3/s
Total spillway capacity at maximum pool elevation	1073 ft^3/s

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

Top of dam	1005.6
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
Toe of dam at maximum section	948.7
Maximum tailwater	N/A

d. **Reservoir.**

Length of maximum pool	Approximately 2000 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	Approximately 1400 (includes tailings)

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

Top of dam	Approximately 65
Maximum pool	Approximately 65
Flood control pool	N/A
Recreation pool	N/A
Spillway crest	Approximately 60.5

g. **Dam.**

Type	Tailings
Length	Approximately 1700 ft
Height	56.9 ft (maximum section)
Crest width	Approximately 12 ft (typical)
Side slopes	Downstream 3H to 1V; Upstream unknown
Zoning	Stoney clay starter dam overlain by coarse tailings (see Fig. 3a)
Impervious core	Unknown (probably none)

Cutoff	5-ft deep trench
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	Unlined notch cut at left abutment
Length of weir	Approximately 70 ft
Crest elevation	1002.4 ft MSL
Gates	None
Upstream channel	None
Downstream channel	Unlined channel through tailings and residual soil

j. **Regulating outlets.** None

SECTION 2
ENGINEERING DATA

2.1 Design

A general sketch drawing of a starter dam was prepared by Mr Bill Devitt. However, it did not contain specifications on materials or construction inspection. A typical cross section of the starter dam was obtained from the owner's files (Milchem Inc, Potosi, Missouri) and is shown in Fig. 3a.

2.2 Construction

The starter dam was constructed in 1972. No records were found of construction inspection of the materials used in the starter dam. A letter report prepared by the Missouri Geological Survey, dated Sept 1975, describing the condition of the dam shortly after barite processing operations began, is presented in Appendix C.

2.3 Operation

No operating records were available. Inspection indicates the main dam was constructed of coarse tailings (approximately 3/4 in. maximum particle size) trucked from the processing plant and end-dumped onto the embankment. No records are available on the compaction or actual gradation of the material in the embankment.

Fine tailings mud was carried by flume from the plant on the right abutment, and discharged near the right abutment, at the back of the coarse tailings embankment. A baffle dike composed of coarse tailings extends nearly across the southwestern fourth of the impoundment area. This dike restricts, somewhat, the fine tailings to the northeastern three-fourths of the reservoir and allows the pumping of water for plant operations from the southwestern fourth of the reservoir. See Figure A1, Appendix A for a sketch of the operations layout.

2.4 Evaluation

a. **Availability.** There are no engineering data available other than the general sketch drawing of the starter dam, and the letter report by the Missouri Geological Survey (Fig. 3a and Appendix C).

b. **Adequacy.** The engineering data available is insufficient to evaluate the adequacy of the design of this dam.

Seepage and stability analyses comparable to the requirements of the guidelines are not on record. This is a deficiency which should be rectified. These seepage and stability 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.** Not applicable.

2.5 Project Geology

The dam site lies on the northern flank of the Ozark structural dome. The regional dip is to the north. The bedrock in the area consists of Cambrian age Eminence and Potosi dolomite formations (Fig. 4). The Potosi Formation is a medium- to fine-grained, light gray dolomite and typically contains an abundance of quartz druse, characteristic of chert bearing formations. The Eminence Formation conformably overlies the Potosi Formation, is similar in appearance but contains less quartz and chert.

The soil at the dam site is a dark red-brown, very sticky, plastic residual clay (CH), characteristicly developed on the Potosi Formation. It is locally overlain by a thin (2-5 ft) loess profile of clayey silt (ML). The soils are mapped on the Missouri General Soils Map as Union-Goss-Gasconade-Peridge Association.

The Cabanne Fault, an east-west trending branch of the Big River Fault system, is mapped approximately 2 mi south of the dam. The fault is mapped as north side down and is within the Potosi and Eminence Formations at the surface. The Aptus Fault, a northwest-southeast trending branch of the Big River Fault system is

mapped approximately 4 mi west of the site. The Aptus fault is mapped as southwest side down, and is mapped within the Potosi and Eminence Formations at the surface. The faults are likely Paleozoic in age, and are not considered to be in a seismically active area. The faults are not considered to pose a significant hazard to the dam.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. **General.** The field inspection was conducted on 15 May 1980; a supplemental inspection was conducted 5 June 1980. These inspections indicated the dam was in a fair to good condition.

b. **Dam.** The initial inspection indicated the dam was in good condition. However, on the supplemental visit, a slump-type landslide was noted on the lowest tier of the downstream face of the dam, at approximately station 5+00 to 6+50 measured from the right end of the dam. The slump thickness is apparently less than 5 ft, and the height about 15 to 20 ft. The slide is limited to the "bullrock" slope cover, (6 to 24 in. coarse tailings placed on slope.) Slip on the slide is approximately 5 to 10 ft.

No extensive vegetation is growing on the embankment. No substantial erosion was noted on the face of the embankment. No animal burrows were noted on the face of the embankment.

A moderately large wet area, approximately 50 ft square, with some standing water, was noted at the toe of the dam in the former drainage channel. No single source of seepage, however, could be identified. Total seepage was estimated at approximately 10 gal/min at the time of the inspection. The seepage water was clear and carried no soil.

Some seepage was also noted in the discharge channel downstream from the spillway at the contact between the underlying residual soil and the tailings or waste. This seepage also contributed to minor sloughing along the walls of the discharge channel. The rate of seepage was estimated at less than 1 gal/min at the time of the inspection. The seepage water was clear.

The materials comprising the bulk of the dam consist of coarse tailings or "chat". This material (sandy gravel and gravelly sand, GW-SW) appears quite cohesionless and would likely be severely eroded should the dam be overtopped (Photo 1).

c. **Appurtenant structures.**

1. Spillway. The spillway at the Keyes Branch Mine Dam consists of a broad, flat-bottomed notch at the left abutment (Photo 3). The floor of the spillway appears to be underlain by residual soil and weathered bedrock. The right side (south side) of the spillway consists of coarse tailings (Fig. 3b).

The highly plastic, stony red clay residual soil and weathered bedrock will likely be slightly to moderately erodible. The tailings portion of the spillway wall will likely be easily eroded during periods of high flow. The flat-bottomed shape of the spillway indicates runoff through the spillway will be in contact with the easily erodible coarse tailings. Erosion of these tailings could lead to undermining of the main dam embankment. Therefore, this portion of the existing spillway may require lining or rip-rap to prevent extensive erosion of the spillway.

d. **Reservoir area.** The reservoir area at the time of the inspection was nearly filled with fine tailings carried by flume to the impoundment (Photo 8). The tailings near the discharge end of the flume are quite sandy and are firm enough to walk on. Farther from the flume, the material is quite silty and clayey, water-saturated and very soft. The southwestern part of the reservoir is water covered due to the baffle dike which restricts most of the tailings to the northeastern portion of the impoundment.

The slopes surrounding the reservoir are quite flat, estimated to be less than 5 horizontal to 1 vertical. No indication was found of potentially unstable slopes surrounding the reservoir.

Much of the area around the reservoir is pockmarked with small prospect or development pits 3 to 5 ft in diameter. The majority of these pits have been nearly filled with soil or slopewash debris. They should reduce or delay surface runoff into the reservoir during periods of heavy precipitation.

e. **Downstream channel.** The downstream channel below the spillway is a relatively narrow erosion channel, 6 to 8 ft wide at the bottom, cut into residual soil and tailings (Photo 4). These materials appear to be moderately to easily erodible. Seepage occuring at the contact between the tailings and soil has further softened the material and increased its erodibility. The channel walls are approximately 1.5 horizontal to 1 vertical in the tailings, and steeper than 1 horizontal to 1 vertical in the residual soil. High flow through the channel could cause erosion of the walls and result in lateral channel migration downhill toward the toe of the dam. The upper reaches of the channel should be widened and lined or rip-rapped to protect the channel walls from erosion.

3.2 Evaluation

The visual inspection of the dam identified a slump type landslide on the downstream face of the dam. This slump occurred in the 3-week interval between the 2 visits to this dam. Although this slump does not appear to pose an immediate hazard to the dam, it did occur where an earlier failure was described by the Missouri Geological Survey (See Appendix C). This record of continued instability suggests additional work is necessary to evaluate the causes of these failures.

The erosion resistance of the spillway and discharge channel appears to be inadequate to carry significant runoff. Substantial erosion could result in migration of the discharge channel and possibly result in erosion at the toe of the dam.

Seepage in the discharge channel and at the toe of the dam did not appear to constitute a hazard to the dam at the time of the inspection. However, the seepage should be monitored to evaluate any increase in discharge or turbidity of the seepage water .

SECTION 4
OPERATIONAL PROCEDURES

4.1 Procedures

Mining operations were begun at the Keyes Branch Mine in early 1975.

Mining and processing operations were discontinued in December 1979. According to Mr Robert Politte, a mine employee at the site, there are no plans to resume operations in the future. The spillway is uncontrolled. No operating procedures currently exist at this structure.

4.2 Maintenance of Dam

No maintenance program was available as the facility is inactive and no future activity is planned.

4.3 Maintenance of Operating Facilities

Not applicable.

4.4 Description of Any Warning System in Effect

As the facility is inactive, no warning system is in effect.

4.5 Evaluation

There are no operating facilities or warning procedures in effect at this structure.

There is no known plan for scheduled inspection or monitoring of the dam by the owner in the future. In light of the erodability of the embankment and of portions of the spillway and discharge channel, the condition of the dam and its appurtenant structures may deteriorate with time without being noticed.

SECTION 5
HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. **Design data.** No hydrologic or hydraulic design information was available for evaluation of the dam or the reservoir. Dimensions of the dam and spillway were surveyed 26 May 1980, measured on the date of the visual inspections, or estimated from topographic mapping. The topographic map used was the USGS Potosi 7-1/2 minute quadrangle sheet.

b. **Experience data.** No recorded precipitation, runoff, discharge or pool stage data were available for this reservoir or dam. There are no stream gaging stations in the drainage basin.

c. **Visual observations.** The spillway constructed at this dam consists of a broad flat weir cut into the left abutment. The soil appears moderately erodible. The erosion potential of the tailings dike adjacent to the spillway is high. On the date of the inspection there were no conditions observed that would indicate a reduced spillway capacity during a flood occurrence. The discharge channel drops steeply and the possibility of supercritical flows in the discharge channel cannot be ruled out.

d. **Overtopping potential.** One of the primary considerations in the evaluation of the Keyes Branch Mine Dam is assessment of the potential for overtopping and consequent failure by erosion of the embankment. Since the spillway of this dam is composed of erodible materials, and substantial erosion of the spillway could result in damage to the embankment, the potential consequences of significant spillway discharges are substantially the same as the overtopping of the dam embankment. Hydraulic considerations of the material erodibility and of the spillway geometry suggest that flows below a velocity of 3.5 ft/s or a discharge of less than 170 ft^3/s will not result in substantial spillway erosion. For the purpose of determining the overtopping potential of this dam, spillway discharge of greater than 170 ft^3/s second is considered to produce the effects of overtopping.

Hydrologic analysis of the tailings dam using the data and method as inclosed and described in Appendix B, Hydrology/Hydraulics Data and Analyses, indicate that a flood of greater than 23 percent of the Probable Maximum Flood (PMF) will effectively overtop the dam. The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

A flood with 1 percent chance of occurrence will be contained within the spillway without overtopping the dam.

The following data were computed for various flood events, assuming no erosion of the spillway or embankment:

Precipitation Event	Maximum Depth of Overtopping ft	Maximum Lake Elevation ft (msl)	Maximum Outflow ft^3/s	Duration of Overtop hr
10% Prob	0	1002.9	50	0
1% Prob	0	1003.2	90	0
23% PMF	0	1003.6 (effective top of dam)	165	0
50% PMF	0	1004.6	490	0
100% PMF	0.4	1006.0	1360	1.3

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. **Visual observations.** The field inspection identified a slump-type slide on the south end of the downstream face of the dam embankment. The slide appears to be limited to the coarse rock layer placed as slope erosion protection (2- to 5-ft thick) and does not appear to constitute an immediate hazard to the stability of the dam.

A letter report dated September 23, 1975, by the Missouri Geological Survey (Appendix C), describes a backslope rotational slide which also occurred at the south end of the dam. This slide occurred shortly after barite mining operations had begun. Fine tailings mud had not been deposited along the entire length of the starter dam and leakage was described as high along the entire length of the dam. Slime resembling barite mud was observed for some 500 ft in the stream channel below the dam. There was evidence that water had percolated through the starter dam and transported some fine material downstream. The report recommended that material pushed onto the slide be removed; the toe of the dam be buttressed by a free draining berm of rock; and that mud be spread by flume along the entire crest of the dam to aid in sealing the gravel. There is no report describing whether these recommendations were carried out. However, there was no evidence of significant seepage or barite slimes downstream during the visual inspection recently completed.

The seepage noted at the toe of the dam at the time of the inspection did not appear to pose a hazard to the stability of the dam.

The spillway and discharge channel are judged to be in poor condition due to the potential for erosion during periods of high flow. Seepage in the discharge channel has softened the material and probably increased the erodibility of

the soil. Lateral and headward erosion of the discharge channel could result in erosion of the toe of the dam or the spillway and reduce the structural stability of the embankment.

b. **Design and construction data.** No design or construction data relating to structural stability were found.

c. **Operating records.** No appurtenant structures requiring operation exist at this dam. Seepage and stability analyses comparable to the requirements of the guidelines are not on record. This is a deficiency which should be corrected to meet the recommended guidelines.

d. **Post construction changes.** Based on aerial photo interpretation of the site area, the most significant post construction change in the vicinity of the dam is the land clearing and mining operations which have been conducted on the slopes around the resevoir area. This will likely increase the runoff and siltation below the cleared and mined areas. Much of the mined area, however, drains into Keyes Branch Creek below the dam. No other significant post construction changes are known or apparent.

e. **Seismic stability.** The dam is located in Seismic Zone 2, to which the guidelines assign a moderate damage potential. Since no static stability analysis of the dam is available for review, the seismic stability cannot be evaluated. However, the saturated and very soft condition of the tailings in the reservoir and the granular nature of the dam suggest substantial 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 Keyes Branch Dam appears to be in fair to good condition. The effect of the observed slide on the stability of the dam needs to be evaluated. The erosion potential of the dam, if overtopped, and the erodibility of the spillway and discharge channel are deficiencies which should be corrected to increase the long term stability of the dam.

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. The lack of these analyses 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 promptly.

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 undue delay are described in Section 7.2b. 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 several general options which may be considered to reduce the possibility of dam failure. Some of these options are:

1. Remove the dam, or breach it to prevent storage of water.

2. Increase the height of 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 by the probable maximum flood without failure.

5. Provide a highly reliable flood warning system (generally does not prevent damage but avoids loss of life).

b. **Recommendations.** Based on our inspection of the Keyes Branch Mine Dam, it is recommended that further study be conducted without undue delay under the guidance of an engineer experienced in design and construction of dams to evaluate, as a minimum, the following topics:

1. What spillway capacity should be provided, and in what manner, taking into consideration the high potential erodibility of the embankment materials in the event of overtopping.

2. Potential for erosion during period of heavy flow within the spillway and adjacent portion of the embankment, including erosion mitigating options.

3. Potential for erosion and lateral migration in the discharge channel, including erosion mitigating options.

c. **Operation and maintenance procedures.** In view of the discontinued operations at this site and the erodibility of the spillway and discharge channel, the potential for deterioration of the stability of the dam indicates a program of periodic inspections should be designed and implemented for this facility. Any deterioration of the dam conditions should be called to the attention of an engineer experienced in design and construction of dams. This program should include:

1. A monitoring program to periodically check the condition of the face of the dam, with special regard to the south end where small slope failure has been noted in the past and at present.

2. Monitor seepage to identify changes in the amount of seepage flow or turbidity (soil) in the seepage water.

3. Inspect the spillway and discharge channel for evidence of substantial erosion which could pose a hazard to the embankment stability.

REFERENCES

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

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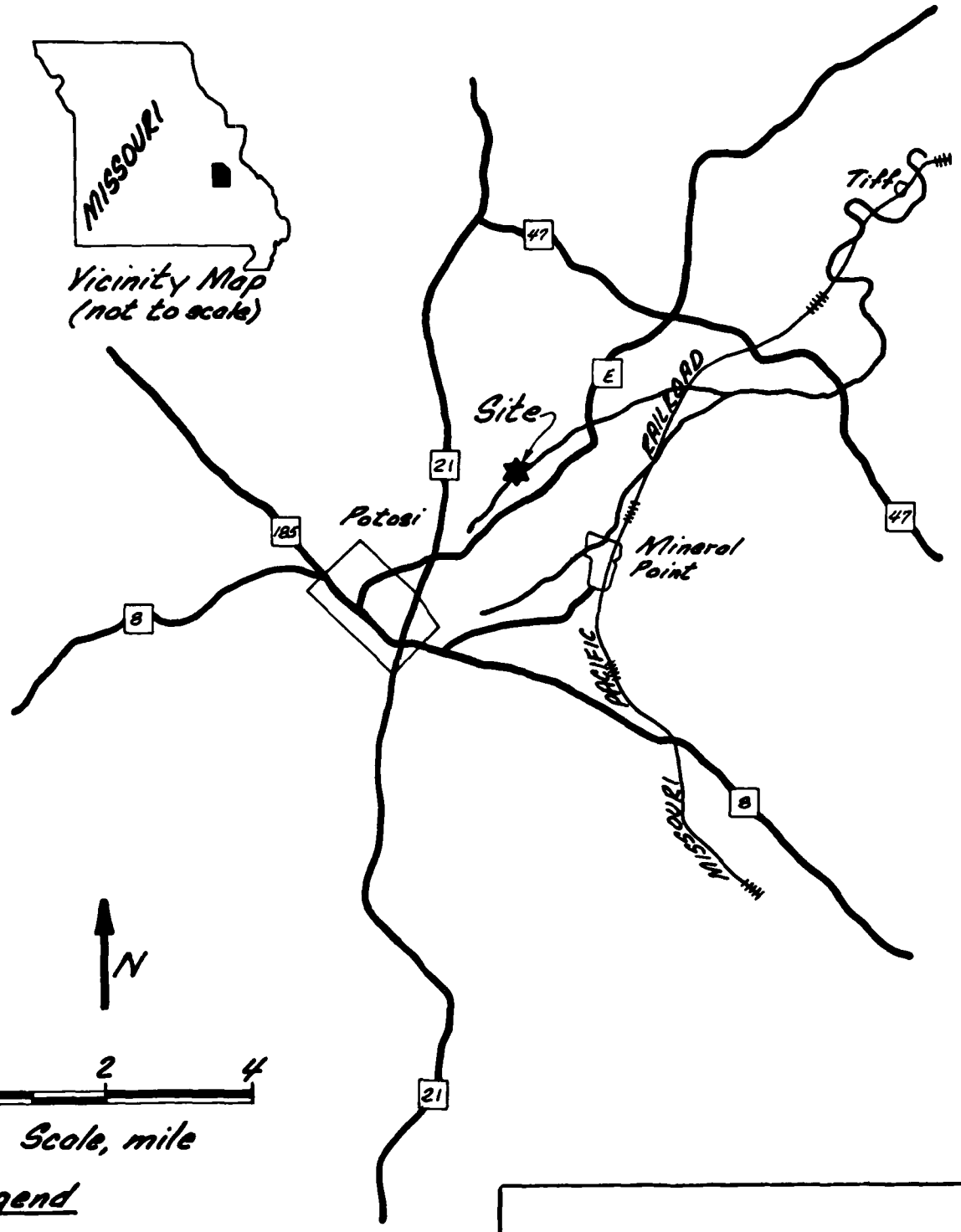
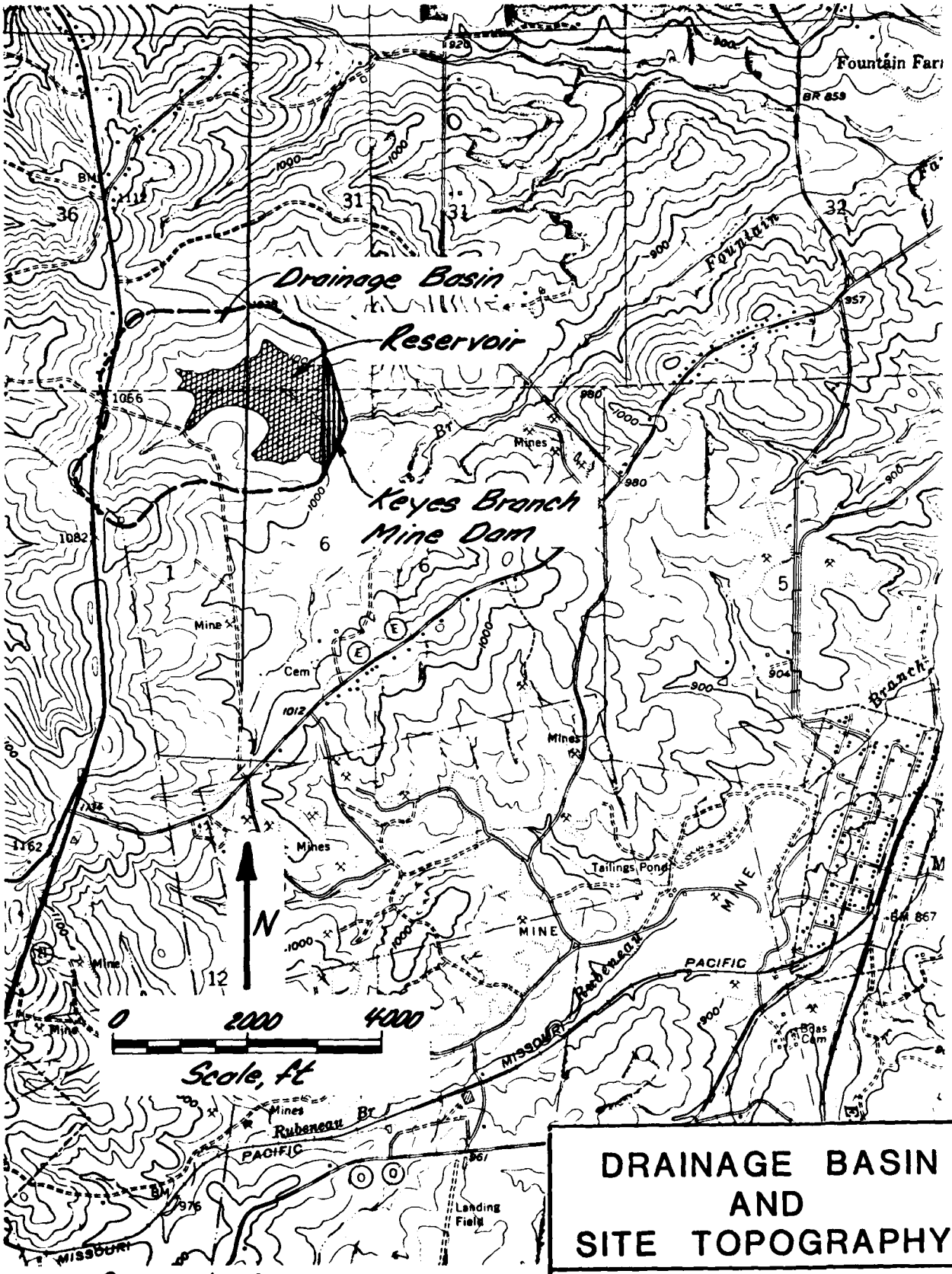
US Soil Conservation Service, 1971, "National Engineering Handbook," Section 4, Hydrology, 1971.



SITE LOCATION MAP	
KEYES BRANCH MINE DAM	
MO. 30386	Fig. 1

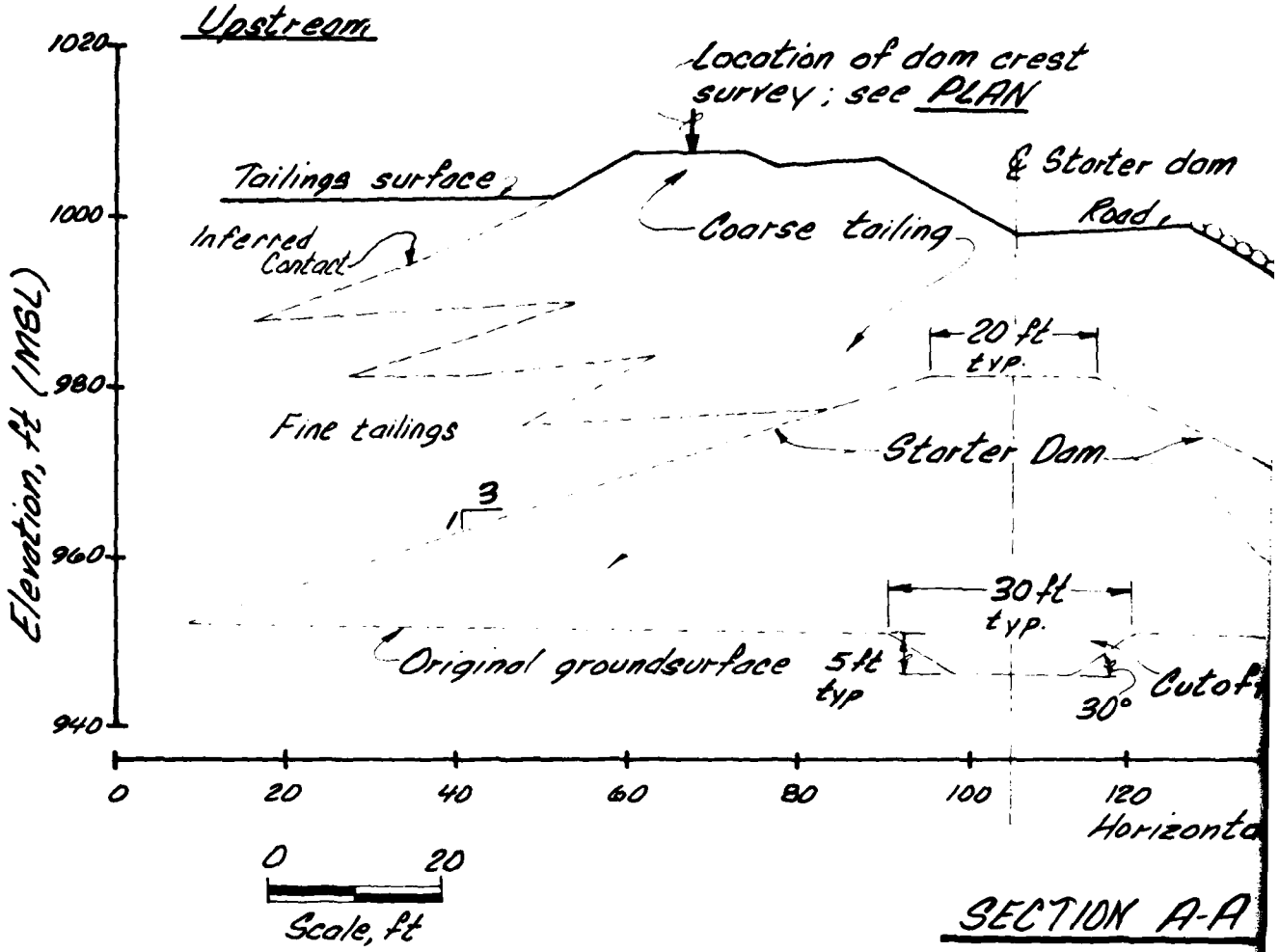


Topography from USGS POTOSI and MINERAL POINT 7.5 minute Quadrangle maps.

DRAINAGE BASIN AND SITE TOPOGRAPHY

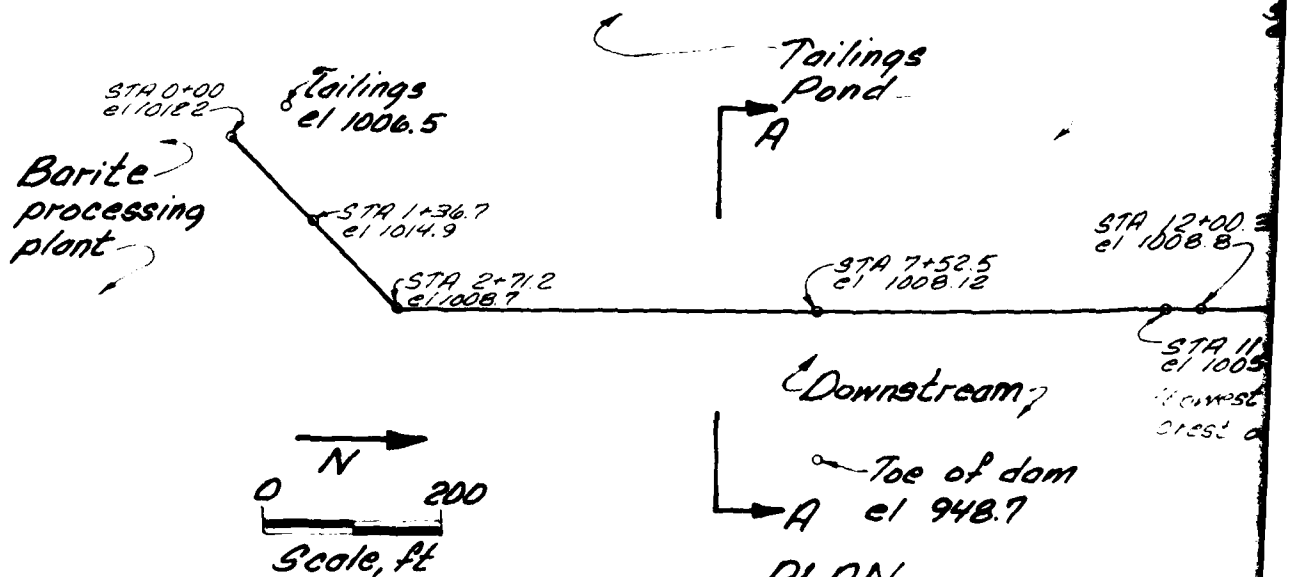
KEYES BRANCH MINE DAM

MO. 30386 | Fig. 2



SECTION A-A

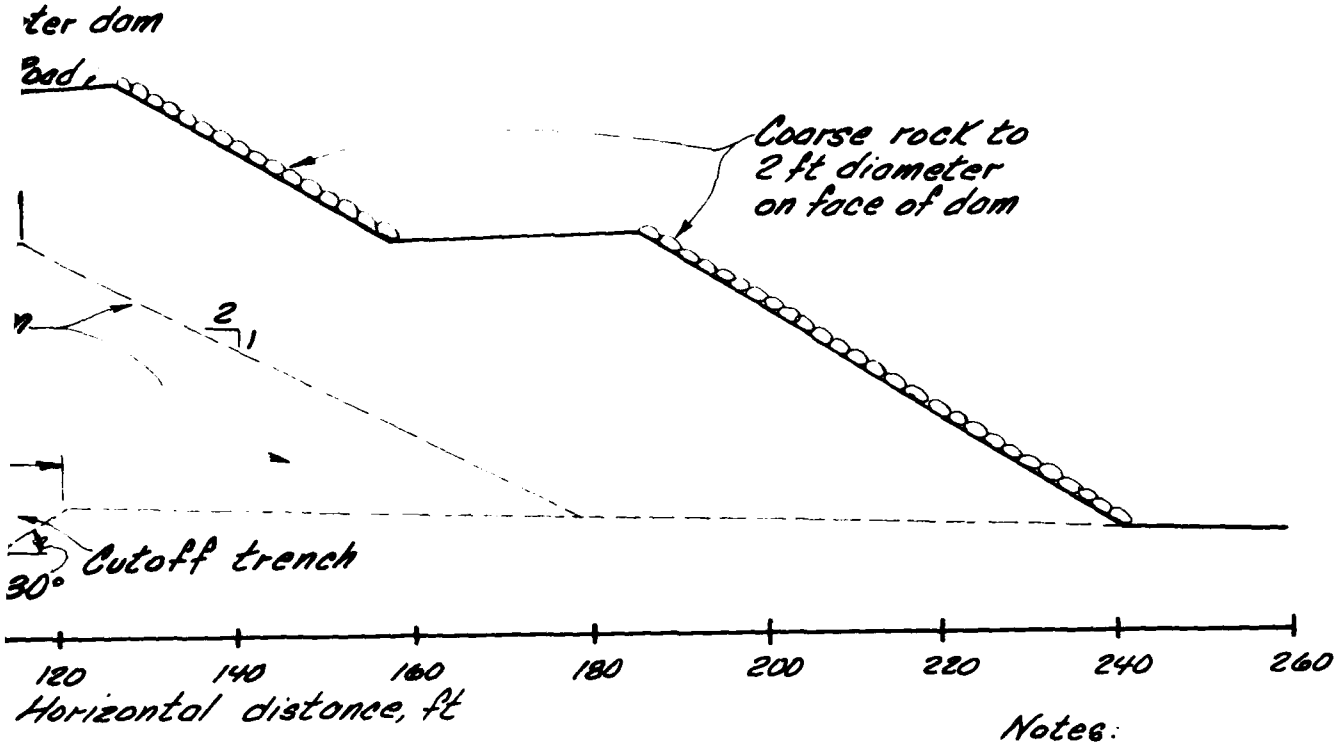
MAXIMUM CROSS SECTION (STA



PLAN

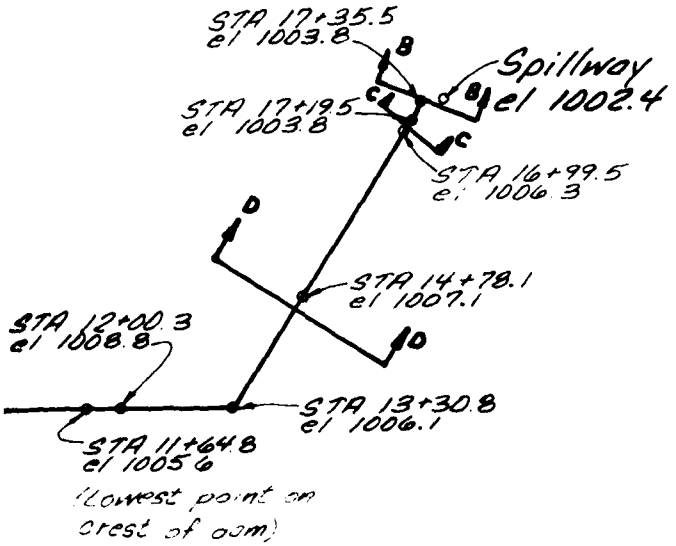
SURVEYED ELEVATION OF DAM CREST, KEYES BRANCH MINE DAM

Downstream



ION A-A

TION (STA 7+52.5) LOOKING NORTH

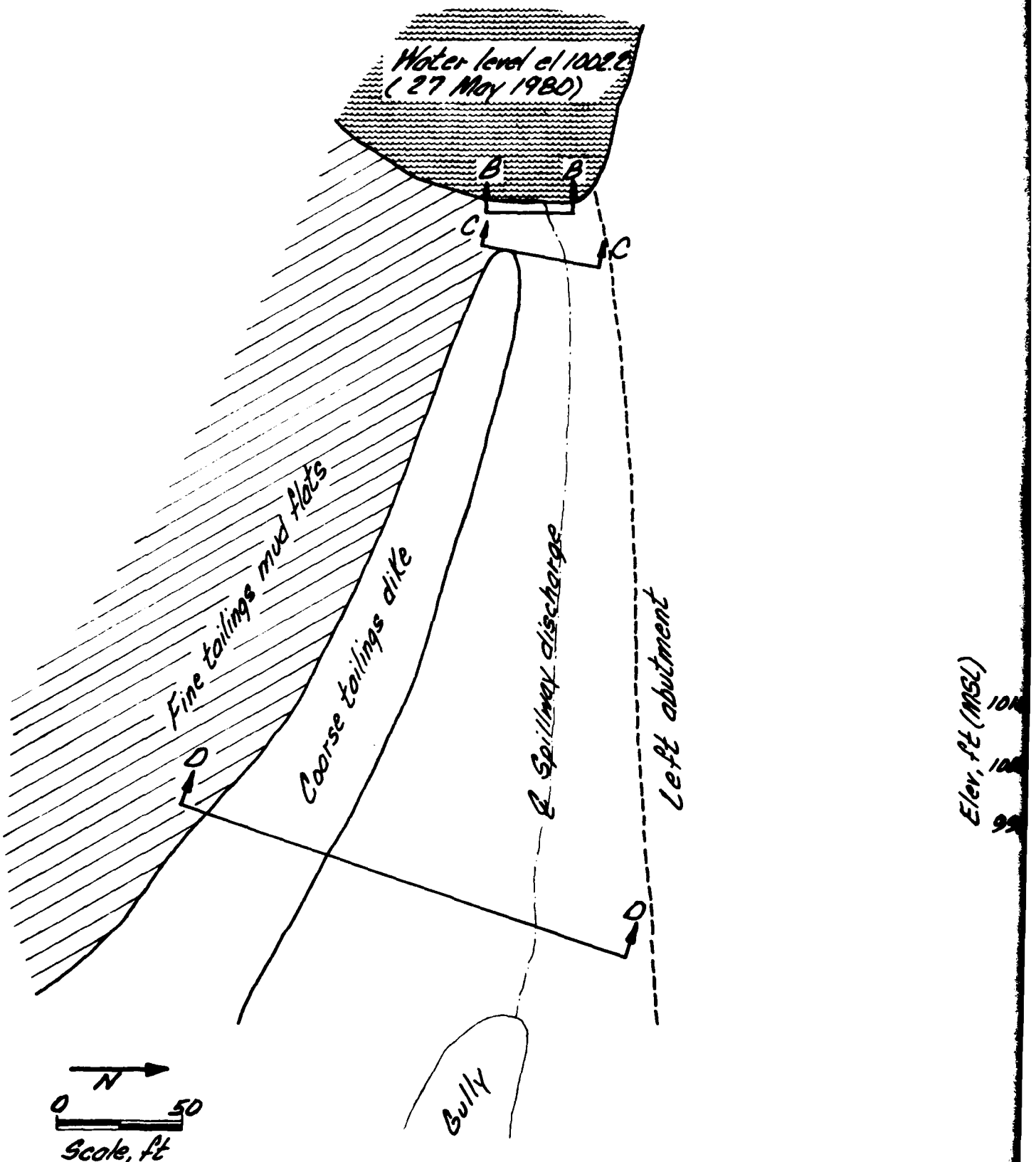


Notes:

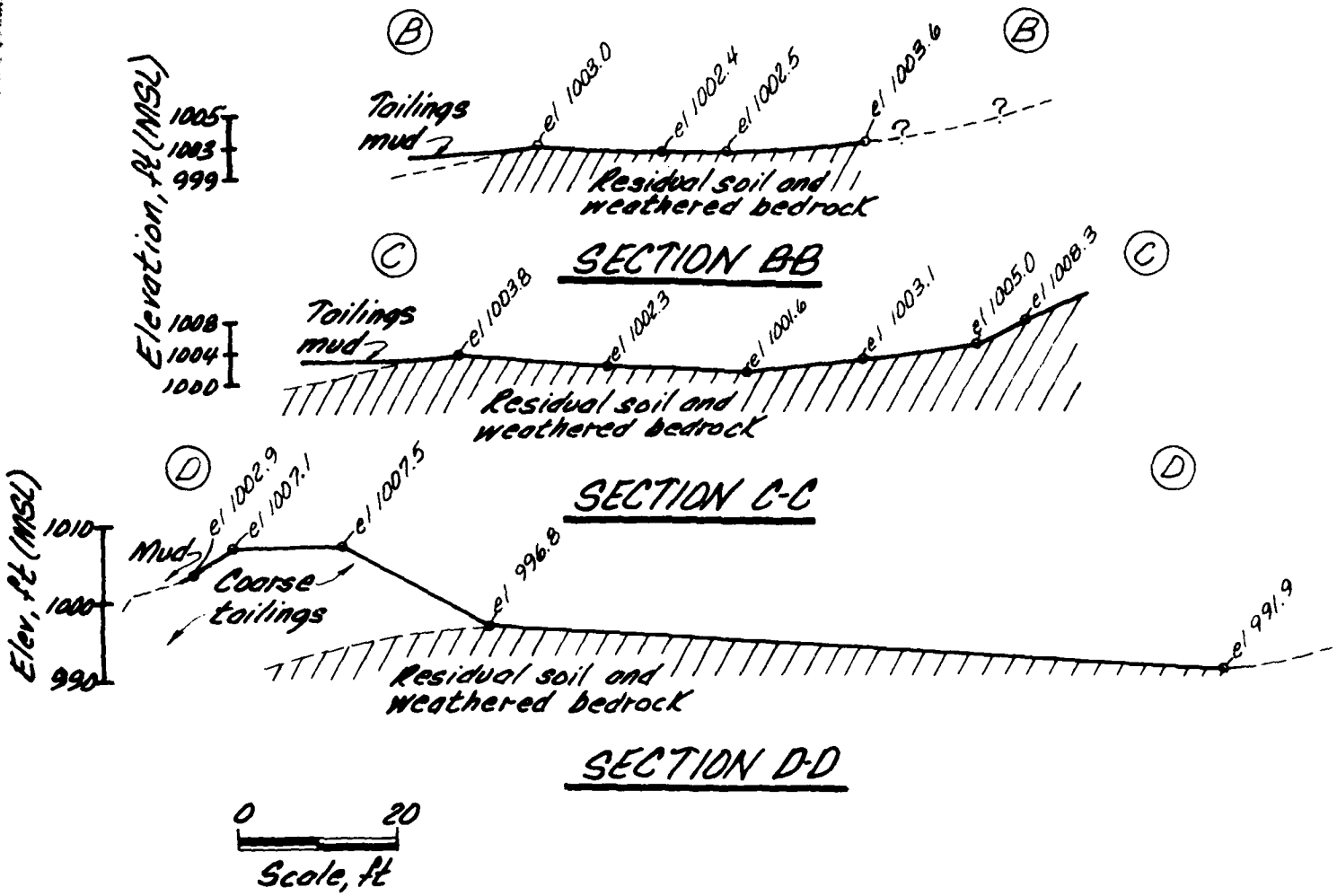
1. Information on starter dam provided by Mr Joe Rossier, Milchem Inc.:
   - Location within main dam as shown
   - Max height 30 ft
   - Width at base: 150 ft (typ)
   - Constructed of Clayey soil borrowed from pond area
   - Compaction by construction equipment
   - No drains
2. No chimney or blanket drain
3. See Fig. 2 Appendix 2, for spillway plan and cross-sections
4. Existing dam profile from survey 26 May 1980

CROSS-SECTION AND SURVEYED CREST ELEVATIONS	
KEYES BRANCH MINE DAM	
MO. 30386	Fig. 3a

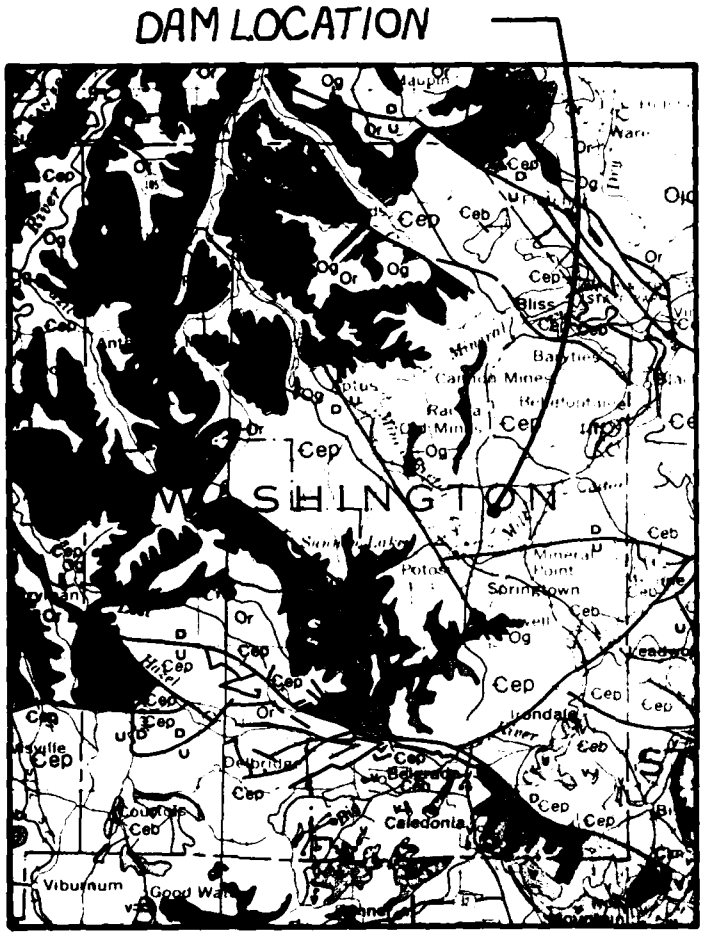
CREST,



PLAN OF SPILLWAY



CROSS-SECTION AND PLAN OF SPILLWAY	
KEYES BRANCH MINE DAM	
MO. 30386	Fig. 36



Legend

- Or — Roubidoux Formation
- Gasconade Dolomite
  - Gunter Sandstone Member
- Cep — Eminence Dolomite
- Potosi Dolomite
- Derby-Doerun Dolomite
- Ceb — Davis Formation
- Bonneterre Formation
  - Whetstone Creek Member
  - Sullivan Siltstone Member
- Reagan Sandstone (subsurface, western Missouri)
- Lamotte Sandstone
- Diabase (dikes and sills)
- St. Francois Mountains Intrusive Suite
- St. Francois Mountains Volcanic Supergroup

REGIONAL GEOLOGIC MAP

KEYES BRANCH MINE DAM

MO 30386	FIG 4

APPENDIX A

Photographs

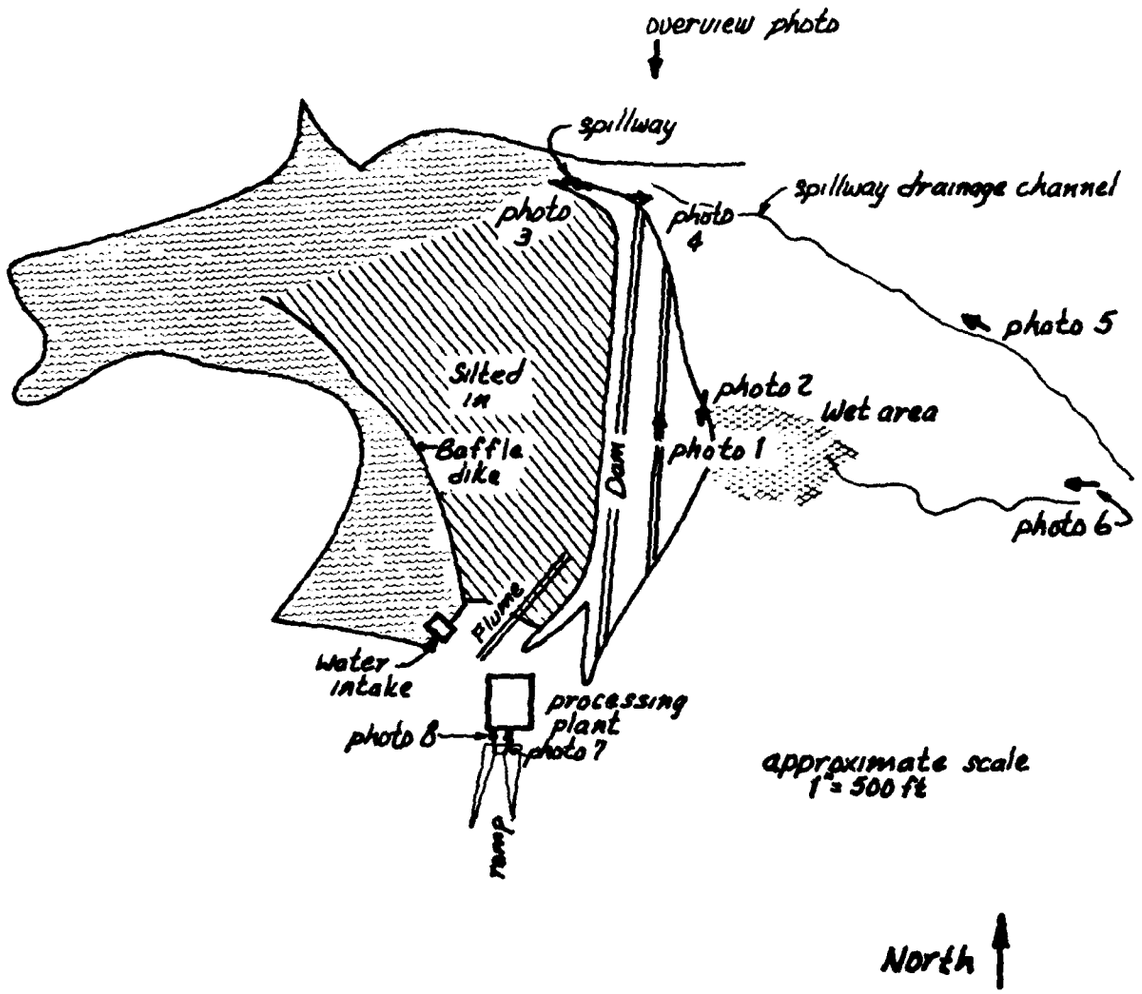


PHOTO LOCATION SKETCH	
KEYES BRANCH MINE DAM	
MO. 30386	Fig. A-1

1. Downstream face of dam looking North toward spillway

2. Rock cover on face of dam looking South

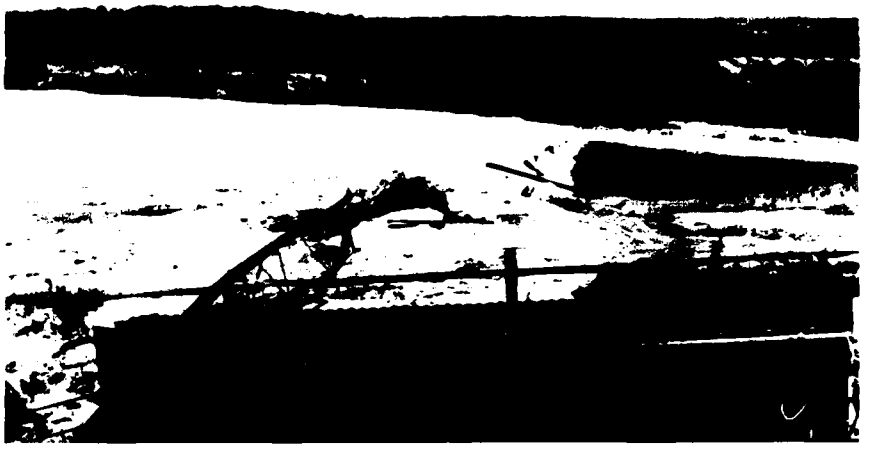
NOTE: Marshy area at toe of dam.

3. Spillway at left abutment, looking upstream.

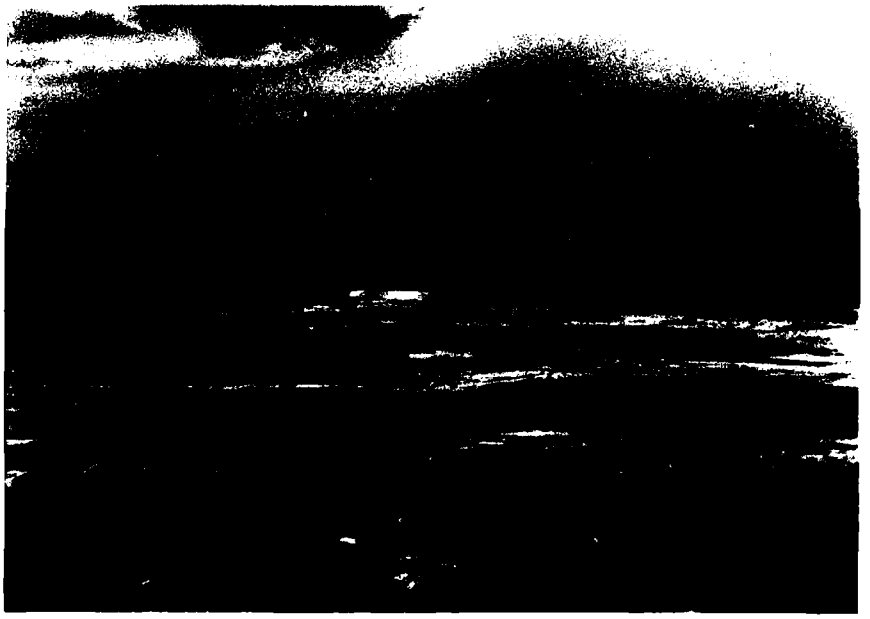
4. Eroded discharge channel below spillway looking downstream.

5. Erosion downstream on discharge channel looking West, upstream.

6. View of area downstream of dam, looking West. Dam in background.

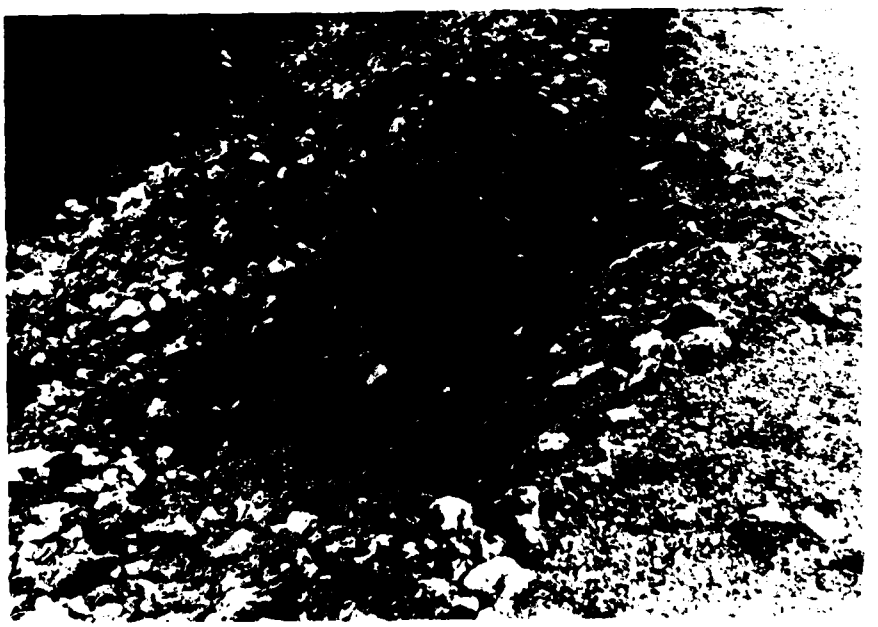


7. Discharge flume from processing plant looking Northeast toward Dam.



8. Filled reservoir area looking North-Northeast from processing plant.

9. Shallow slope failure on lowest tier of downstream face of dam. Looking north.



10. Head scarp of slope failure on downstream face of dam. Note failure consists predominantly of bullrock slope cover. Looking south.

APPENDIX B

Hydraulic/Hydrologic Data and Analyses

APPENDIX B

Hydraulic/Hydrologic Analyses

B.1 Procedures

a. **General.** The hydraulic/hydrologic analyses were performed using the "HEC-1, Dam Safety Version (1 Apr 80)" computer program. Inflow hydrographs were developed by applying various precipitation events to a synthetic unit hydrographs. The inflow hydrographs, thus obtained, were then routed through the reservoir and appurtenant structures by the modified Puls reservoir routing method used in the HEC-1 program to determine overtopping potential.

b. **Precipitation events.** Various percentages including 100 percent of the Probable Maximum Precipitation (PMP) and the 1 and 10 percent probability-of-occurrence events were used in the analyses. The PMP was determined from regional charts prepared by the US Weather Bureau (1956). The 1 and 10 percent probability-of-occurrence events were provided by SLD.

c. **Unit hydrograph.** The Soil Conservation Service (SCS) unit hydrograph (SCS, 1971) for a storm duration of 48 hrs was used to develop the inflow hydrograph. The unit hydrograph was divided into 10 min increments.

d. **Infiltration losses.** The SCS curve number (CN) method was used to compute infiltration losses. Curve numbers were selected on the basis of antecedent moisture conditions in accordance with the guidelines, present land usage and hydrologic soil group of the soils in the drainage basin. Where more than one soil group was present, the group giving the highest CN was used for the entire basin. If the soil group was not available, group D was assumed.

e. **Lag time.** Lag time was computed by the SCS method (SCS, 1971).

B.2 Pertinent Data

a. **Drainage area:** 0.32 mi^2

b. **Lag time:** - 0.34 hrs

c. **Hydrologic soil group:** C

d. **SCS curve numbers.**

1. For PMF: 87 (AMC III)
2. For 1 and 10 percent probability-of-occurrence events: 73 (AMCII)

e. **Storage.** Elevation-area data were developed by planimetering areas at various elevation contours on the USGS Potosi 7.5-minute quadrangle map. The data were entered on the $A and $E cards so that the HEC-1 program could compute storage volumes.

f. **Outflow capacity.** The elevation-discharge relationship was developed from cross-sections of the spillway and downstream channel using the HEC-2 backwater profile program and entered on the Y4 and Y5 cards for the HEC-1 program.

g. **Outflow over crest.** As the profile of the dam crest is irregular, flow over the crest cannot be determined by conventional weir formulas. Crest length-elevation data and hydraulic constants for the crest were entered on $D, $L and $V cards.

h. **Reservoir elevations.** For all fractions of the PMF, the starting reservoir elevation was the spillway crest elevation of 1002.4 ft. For the 1 and 10 percent probability-of-occurrence events, the starting reservoir elevation was 1002.4 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 file.

PMF ANALYSIS

```
**********
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION  JULY 1978
  LAST MODIFICATION  01 APR 80
**********
     1                A1       KEYES BRANCH TAILINGS DAM NO. 30386, WASHINGTON COUNTY, MISSOURI.
     2                A2       WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB 79H009.
     3                A3       PROBABLE MAXIMUM FLOODS (PMF) ANALYSIS
     4                B      288       0         9        -0       -0       -0       -0       -0       -0       -0
     5                B1       5
     6                J        1         4         1
     7                J1     .25       .50       .75      1.00
     8                K        0  INFLOW                                                    1
     9                K1  KEYES BRANCH DAM NO. 30386: MULTI-RATIO PMF RUNOFF COMPUTATIONS.
    10                M        1         2      0.32                  1                   1
    11                P                 26       102       123       130
    12                T                                                                  -1       -87              .22
    13                W2              0.34
    14                X      -10      -0.1       2.0
    15                M        1       DAM                                               1
    16                K1  KEYES BRANCH DAM NO. 30386: PMP CAPACITY AND OVERTOPPING ANALYSIS.
    17                Y                                            1        1
    18                Y1       1                                                  -1002.4
    19                SA     0.0       1.8       5.4      12.9      22.9      36.5      56.7      60.9      74.3
    20                SE    940.      950.      960.      970.      980.      990.     1000.    1002.4    1010.
    21                SS1002.4      42.2       2.9       1.5
    22                SQ1009.8       2.8       1.9
    23                SL      0.      16.0      110.      790.      900.     1500.     1540.     1670.     1720.
    24                SV1003.0    1003.8    1006.0    1007.5    1008.0    1010.0    1012.0    1014.0    1014.9
    25                K       99
```

Input Data
Various PMF Events
Keyes Branch Mine Dam
MO 30386

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

RUN  DATE: 31 JUL 80
     TIME: 10.31.53
```

KEYES BRANCH TAILINGS DAM NO. 30386, WASHINGTON COUNTY, MISSOURI.
WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB 79H009.
PROBABLE MAXIMUM FLOODS (PMF) ANALYSIS

JOB SPECIFICATION

NO	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	MSTAN
298	0	5	-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

KEYES BRANCH DAM NO. 30386 MULTI-RATIO PMF RUNOFF COMPUTATIONS.

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

HYDROGRAPH DATA

IHYDO	HUNO	AREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
1	2	.32	-0.	.32	1.00	-0.	-0	1	-0

PRECIP DATA

SPFE	PMS	R6	R12	R24	R48	R72	R96
-0.	26.00	102.00	120.00	130.00	-0.	-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	-87.00	-0.	.22

CURVE NO = -87.00 HETNESS = -1.00 EFFECT CN = 87.00

UNIT HYDROGRAPH DATA
TC= -0. LAG= .34

RECESSION DATA
STRTQ= -10.00 QRCSN= -.10 RTIOR= 2.00

UNIT HYDROGRAPH 22 END-OF-PERIOD ORDINATES, TC= -0. HOURS, LAG= .34 VOL= 1.00

57.	149.	303.	394.	401.	345.	261.	173.	120.	86.
59.	42.	29.	21.	14.	10.	7.	5.	4.	3.

Input Data
Various PMF Events
Keyes Branch Mine Dam
MO 30386

1.01	.05	1	.01	.00	.01	3.	1.01	12.05	145	.22	.21	.01	167.
1.01	.10	2	.01	.00	.01	3.	1.01	12.10	146	.22	.21	.01	184.
1.01	.15	3	.01	.00	.01	4.	1.01	12.15	147	.22	.21	.01	230.
1.01	.20	4	.01	.00	.01	5.	1.01	12.20	148	.22	.21	.01	290.
1.01	.25	5	.01	.00	.01	6.	1.01	12.25	149	.22	.21	.01	351.
1.01	.30	6	.01	.00	.01	7.	1.01	12.30	150	.22	.22	.01	403.
1.01	.35	7	.01	.00	.01	8.	1.01	12.35	151	.22	.22	.01	443.
1.01	.40	8	.01	.00	.01	8.	1.01	12.40	152	.22	.22	.01	470.
1.01	.45	9	.01	.00	.01	9.	1.01	12.45	153	.22	.22	.00	489.
1.01	.50	10	.01	.00	.01	9.	1.01	12.50	154	.22	.22	.00	502.
1.01	.55	11	.01	.00	.01	9.	1.01	12.55	155	.22	.22	.00	512.
1.01	1.00	12	.01	.00	.01	9.	1.01	13.00	156	.22	.22	.00	519.
1.01	1.05	13	.01	.00	.01	9.	1.01	13.05	157	.27	.26	.00	526.
1.01	1.10	14	.01	.00	.01	9.	1.01	13.10	158	.27	.26	.00	537.
1.01	1.15	15	.01	.00	.01	9.	1.01	13.15	159	.27	.26	.00	552.
1.01	1.20	16	.01	.00	.01	9.	1.01	13.20	160	.27	.26	.00	572.
1.01	1.25	17	.01	.00	.01	9.	1.01	13.25	161	.27	.26	.00	591.
1.01	1.30	18	.01	.00	.01	9.	1.01	13.30	162	.27	.26	.00	607.
1.01	1.35	19	.01	.00	.01	9.	1.01	13.35	163	.27	.26	.00	620.
1.01	1.40	20	.01	.00	.01	9.	1.01	13.40	164	.27	.26	.00	628.
1.01	1.45	21	.01	.00	.01	9.	1.01	13.45	165	.27	.26	.00	634.
1.01	1.50	22	.01	.00	.01	9.	1.01	13.50	166	.27	.26	.00	638.
1.01	1.55	23	.01	.00	.01	9.	1.01	13.55	167	.27	.26	.00	641.
1.01	2.00	24	.01	.00	.01	9.	1.01	14.00	168	.27	.26	.00	644.
1.01	2.05	25	.01	.00	.01	9.	1.01	14.05	169	.33	.33	.00	649.
1.01	2.10	26	.01	.00	.01	9.	1.01	14.10	170	.33	.33	.00	659.
1.01	2.15	27	.01	.00	.01	9.	1.01	14.15	171	.33	.33	.00	680.
1.01	2.20	28	.01	.00	.01	10.	1.01	14.20	172	.33	.33	.00	707.
1.01	2.25	29	.01	.00	.01	10.	1.01	14.25	173	.33	.33	.00	734.
1.01	2.30	30	.01	.00	.01	10.	1.01	14.30	174	.33	.33	.00	757.
1.01	2.35	31	.01	.01	.01	11.	1.01	14.35	175	.33	.33	.00	775.
1.01	2.40	32	.01	.01	.01	11.	1.01	14.40	176	.33	.33	.00	787.
1.01	2.45	33	.01	.01	.01	12.	1.01	14.45	177	.33	.33	.00	795.
1.01	2.50	34	.01	.01	.01	12.	1.01	14.50	178	.33	.33	.00	801.
1.01	2.55	35	.01	.01	.01	12.	1.01	14.55	179	.33	.33	.00	805.
1.01	3.00	36	.01	.01	.01	13.	1.01	15.00	180	.33	.33	.00	809.
1.01	3.05	37	.01	.01	.01	13.	1.01	15.05	181	.20	.20	.00	804.
1.01	3.10	38	.01	.01	.01	14.	1.01	15.10	182	.40	.40	.00	796.
1.01	3.15	39	.01	.01	.01	14.	1.01	15.15	183	.40	.40	.00	788.
1.01	3.20	40	.01	.01	.01	14.	1.01	15.20	184	.60	.60	.00	804.
1.01	3.25	41	.01	.01	.01	15.	1.01	15.25	185	.71	.70	.00	871.
1.01	3.30	42	.01	.01	.01	15.	1.01	15.30	186	1.71	1.71	.01	1030.
1.01	3.35	43	.01	.01	.01	15.	1.01	15.35	187	2.82	2.81	.01	1377.
1.01	3.40	44	.01	.01	.01	16.	1.01	15.40	188	1.11	1.11	.00	1916.
1.01	3.45	45	.01	.01	.01	16.	1.01	15.45	189	.71	.70	.00	2501.
1.01	3.50	46	.01	.01	.01	16.	1.01	15.50	190	.60	.60	.00	2859.
1.01	3.55	47	.01	.01	.01	17.	1.01	15.55	191	.40	.40	.00	2900.
1.01	4.00	48	.01	.01	.01	17.	1.01	16.00	192	.40	.40	.00	2689.
1.01	4.05	49	.01	.01	.01	17.	1.01	16.05	193	.31	.31	.00	2331.
1.01	4.10	50	.01	.01	.01	17.	1.01	16.10	194	.31	.31	.00	1949.
1.01	4.15	51	.01	.01	.01	18.	1.01	16.15	195	.31	.31	.00	1642.
1.01	4.20	52	.01	.01	.01	18.	1.01	16.20	196	.31	.31	.00	1402.
1.01	4.25	53	.01	.01	.01	18.	1.01	16.25	197	.31	.31	.00	1219.
1.01	4.30	54	.01	.01	.01	19.	1.01	16.30	198	.31	.31	.00	1082.
1.01	4.35	55	.01	.01	.01	19.	1.01	16.35	199	.31	.31	.00	986.
1.01	4.40	56	.01	.01	.01	19.	1.01	16.40	200	.31	.31	.00	920.
1.01	4.45	57	.01	.01	.01	19.	1.01	16.45	201	.31	.31	.00	874.
1.01	4.50	58	.01	.01	.01	20.	1.01	16.50	202	.31	.31	.00	841.
1.01	4.55	59	.01	.01	.01	20.	1.01	16.55	203	.31	.31	.00	819.
1.01	5.00	60	.01	.01	.01	20.	1.01	17.00	204	.31	.31	.00	803.
1.01	5.05	61	.01	.01	.01	20.	1.01	17.05	205	.26	.26	.00	789.

Input Data
Various PMF Events
Keyes Branch Mine Da
MO 30386

1.01	5.30	66	.01	.01	.01	21.	1.01	17.30	210	.24	.24	.00	658.
1.01	5.35	67	.01	.01	.01	21.	1.01	17.35	211	.24	.24	.00	640.
1.01	5.40	68	.01	.01	.01	22.	1.01	17.40	212	.24	.24	.00	628.
1.01	5.45	69	.01	.01	.01	22.	1.01	17.45	213	.24	.24	.00	620.
1.01	5.50	70	.01	.01	.01	22.	1.01	17.50	214	.24	.24	.00	614.
1.01	5.55	71	.01	.01	.01	22.	1.01	17.55	215	.24	.24	.00	610.
1.01	6.00	72	.01	.01	.01	22.	1.01	18.00	216	.24	.24	.00	607.
1.01	6.05	73	.07	.04	.02	24.	1.01	18.05	217	.02	.02	.00	599.
1.01	6.10	74	.07	.04	.02	29.	1.01	18.10	218	.02	.02	.00	581.
1.01	6.15	75	.07	.05	.02	40.	1.01	18.15	219	.02	.02	.00	493.
1.01	6.20	76	.07	.05	.02	54.	1.01	18.20	220	.02	.02	.00	409.
1.01	6.25	77	.07	.05	.02	68.	1.01	18.25	221	.02	.02	.00	316.
1.01	6.30	78	.07	.05	.02	81.	1.01	18.30	222	.02	.02	.00	277.
1.01	6.35	79	.07	.05	.02	92.	1.01	18.35	223	.02	.02	.00	259.
1.01	6.40	80	.07	.05	.02	100.	1.01	18.40	224	.02	.02	.00	241.
1.01	6.45	81	.07	.05	.01	106.	1.01	18.45	225	.02	.02	.00	225.
1.01	6.50	82	.07	.05	.01	111.	1.01	18.50	226	.02	.02	.00	210.
1.01	6.55	83	.07	.05	.01	115.	1.01	18.55	227	.02	.02	.00	196.
1.01	7.00	84	.07	.05	.01	118.	1.01	19.00	228	.02	.02	.00	183.
1.01	7.05	85	.07	.05	.01	121.	1.01	19.05	229	.02	.02	.00	171.
1.01	7.10	86	.07	.05	.01	123.	1.01	19.10	230	.02	.02	.00	159.
1.01	7.15	87	.07	.05	.01	125.	1.01	19.15	231	.02	.02	.00	149.
1.01	7.20	88	.07	.05	.01	127.	1.01	19.20	232	.02	.02	.00	139.
1.01	7.25	89	.07	.05	.01	129.	1.01	19.25	233	.02	.02	.00	129.
1.01	7.30	90	.07	.06	.01	130.	1.01	19.30	234	.02	.02	.00	121.
1.01	7.35	91	.07	.06	.01	132.	1.01	19.35	235	.02	.02	.00	113.
1.01	7.40	92	.07	.06	.01	133.	1.01	19.40	236	.02	.02	.00	105.
1.01	7.45	93	.07	.06	.01	134.	1.01	19.45	237	.02	.02	.00	98.
1.01	7.50	94	.07	.06	.01	135.	1.01	19.50	238	.02	.02	.00	91.
1.01	7.55	95	.07	.06	.01	136.	1.01	19.55	239	.02	.02	.00	85.
1.01	8.00	96	.07	.06	.01	137.	1.01	20.00	240	.02	.02	.00	80.
1.01	8.05	97	.07	.06	.01	138.	1.01	20.05	241	.02	.02	.00	74.
1.01	8.10	98	.07	.06	.01	139.	1.01	20.10	242	.02	.02	.00	69.
1.01	8.15	99	.07	.06	.01	140.	1.01	20.15	243	.02	.02	.00	65.
1.01	8.20	100	.07	.06	.01	140.	1.01	20.20	244	.02	.02	.00	60.
1.01	8.25	101	.07	.06	.01	141.	1.01	20.25	245	.02	.02	.00	56.
1.01	8.30	102	.07	.06	.01	142.	1.01	20.30	246	.02	.02	.00	54.
1.01	8.35	103	.07	.06	.01	142.	1.01	20.35	247	.02	.02	.00	54.
1.01	8.40	104	.07	.06	.01	143.	1.01	20.40	248	.02	.02	.00	54.
1.01	8.45	105	.07	.06	.01	144.	1.01	20.45	249	.02	.02	.00	54.
1.01	8.50	106	.07	.06	.01	144.	1.01	20.50	250	.02	.02	.00	54.
1.01	8.55	107	.07	.06	.01	145.	1.01	20.55	251	.02	.02	.00	54.
1.01	9.00	108	.07	.06	.01	145.	1.01	21.00	252	.02	.02	.00	54.
1.01	9.05	109	.07	.06	.01	146.	1.01	21.05	253	.02	.02	.00	54.
1.01	9.10	110	.07	.06	.01	146.	1.01	21.10	254	.02	.02	.00	54.
1.01	9.15	111	.07	.06	.01	147.	1.01	21.15	255	.02	.02	.00	54.
1.01	9.20	112	.07	.06	.00	147.	1.01	21.20	256	.02	.02	.00	54.
1.01	9.25	113	.07	.06	.00	147.	1.01	21.25	257	.02	.02	.00	54.
1.01	9.30	114	.07	.06	.00	148.	1.01	21.30	258	.02	.02	.00	54.
1.01	9.35	115	.07	.06	.00	148.	1.01	21.35	259	.02	.02	.00	54.
1.01	9.40	116	.07	.06	.00	148.	1.01	21.40	260	.02	.02	.00	54.
1.01	9.45	117	.07	.06	.00	149.	1.01	21.45	261	.02	.02	.00	54.
1.01	9.50	118	.07	.06	.00	149.	1.01	21.50	262	.02	.02	.00	54.
1.01	9.55	119	.07	.06	.00	149.	1.01	21.55	263	.02	.02	.00	54.
1.01	10.00	120	.07	.06	.00	150.	1.01	22.00	264	.02	.02	.00	54.
1.01	10.05	121	.07	.06	.00	150.	1.01	22.05	265	.02	.02	.00	54.
1.01	10.10	122	.07	.06	.00	150.	1.01	22.10	266	.02	.02	.00	54.
1.01	10.15	123	.07	.06	.00	151.	1.01	22.15	267	.02	.02	.00	54.
1.01	10.20	124	.07	.06	.00	151.	1.01	22.20	268	.02	.02	.00	54.
1.01	10.25	125	.07	.06	.00	151.	1.01	22.25	269	.02	.02	.00	54.
1.01	10.30	126	.07	.06	.00	151.	1.01	22.30	270	.02	.02	.00	54.
1.01	10.35	127	.07	.06	.00	152.	1.01	22.35	271	.02	.02	.00	54.

Input Data
Various PMF Events
Keyes Branch Mine D
MO 30386

1.01	10.55	131	.07	.05	.00	152.	1.01	22.55	275	.02	.02	.00	54.
1.01	11.00	132	.07	.06	.00	153.	1.01	23.00	276	.02	.02	.00	54.
1.01	11.05	133	.07	.06	.00	153.	1.01	23.05	277	.02	.02	.00	54.
1.01	11.10	134	.07	.06	.00	153.	1.01	23.10	278	.02	.02	.00	54.
1.01	11.15	135	.07	.06	.00	153.	1.01	23.15	279	.02	.02	.00	54.
1.01	11.20	136	.07	.06	.00	153.	1.01	23.20	280	.02	.02	.00	54.
1.01	11.25	137	.07	.06	.00	153.	1.01	23.25	281	.02	.02	.00	54.
1.01	11.30	139	.07	.06	.00	154.	1.01	23.30	282	.02	.02	.00	54.
1.01	11.35	139	.07	.05	.00	154.	1.01	23.35	283	.02	.02	.00	54.
1.01	11.40	140	.07	.06	.00	154.	1.01	23.40	284	.02	.02	.00	54.
1.01	11.45	141	.07	.06	.00	154.	1.01	23.45	285	.02	.02	.00	54.
1.01	11.50	142	.07	.06	.00	154.	1.01	23.50	286	.02	.02	.00	54.
1.01	11.55	143	.07	.06	.00	154.	1.01	23.55	287	.02	.02	.00	54.
1.01	12.00	144	.07	.06	.00	154.	1.02	0.	288	.02	.02	.00	54.
								SUM	33.80	32.45	1.35	81639.	
									(859.1(	824.1(	34.1(	2311.76(	

		PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
	CFS	2900.	891.	283.	283.	81592.
	CMS	82.	25.	8.	8.	2310.
	INCHES		25.90	32.94	32.94	32.94
	MM		657.89	836.74	836.74	836.74
	AC-FT		442.	562.	562.	562.
	THOUS CU M		545.	693.	693.	693.

Input Data
Various PMF Events
Keyes Branch Mine Dam
MO 30386

HYDROGRAPH AT STAINFLOW FOR PLAN 1, RTIO 1

1.	1.	1.	1.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	2.	3.
3.	3.	3.	3.	3.	3.	3.	3.	3.	4.
4.	4.	4.	4.	4.	4.	4.	4.	4.	4.
4.	4.	5.	5.	5.	5.	5.	5.	5.	5.
5.	5.	5.	5.	5.	5.	5.	5.	5.	6.
6.	6.	6.	7.	10.	13.	17.	20.	23.	25.
26.	28.	29.	29.	30.	31.	31.	32.	32.	33.
33.	33.	34.	34.	34.	34.	34.	35.	35.	35.
35.	35.	36.	36.	36.	36.	36.	36.	36.	37.
37.	37.	37.	37.	37.	37.	37.	37.	37.	37.
38.	38.	38.	38.	38.	38.	38.	38.	38.	38.
38.	38.	38.	38.	38.	38.	38.	38.	38.	38.
39.	39.	39.	39.	40.	46.	58.	72.	89.	101.
111.	117.	122.	126.	128.	130.	132.	134.	136.	143.
148.	152.	155.	157.	158.	160.	160.	161.	162.	165.
170.	177.	183.	189.	194.	197.	199.	200.	201.	202.
201.	199.	197.	202.	218.	258.	344.	479.	629.	719.
725.	672.	603.	487.	411.	350.	304.	270.	247.	230.
219.	210.	205.	201.	197.	193.	186.	178.	171.	164.
158.	157.	155.	154.	153.	152.	149.	140.	124.	101.
79.	69.	65.	60.	56.	53.	49.	46.	43.	40.
37.	35.	32.	30.	28.	26.	24.	23.	21.	20.
19.	17.	16.	15.	14.	13.	13.	13.	13.	13.
13.	13.	13.	13.	13.	13.	13.	13.	13.	13.
13.	13.	13.	13.	13.	13.	13.	13.	13.	13.
13.	13.	13.	13.	13.	13.	13.	13.	13.	13.
13.	13.	13.	13.	13.	13.	13.	13.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	725.	223.	71.	71.	20398.
CMS	21.	6.	2.	2.	578.

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 .25	RATIO 2 .50	RATIO 3 .75	RATIO 4 1.00
HYDROGRAPH AT	INFLOW	.32	1	725.	1450.	2175.	2900.
		(.83)		(20.53)	(41.06)	(61.59)	(82.12)
ROUTED TO	DAM	.32	1	185.	490.	893.	1358.
		(.83)		(5.23)	(13.86)	(25.30)	(38.44)

Output Summary
Various PMF Events
Keys Branch Mine Dam
MO 30386

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1		INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
	ELEVATION	1002.40	1002.40	1005.60
	STORAGE	1192.	1192.	1395.
	OUTFLOW	0.	0.	1075.

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	1003.68	0.	1271.	185.	0.	17.25	0.
.50	1004.59	0.	1329.	490.	0.	16.58	0.
.75	1005.34	0.	1377.	893.	0.	16.42	0.
1.00	1005.96	.36	1418.	1358.	1.33	16.33	0.

Output Summary
Various PMF Events
Keys Branch Mine Dam
MO 30386

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	1002.40	1002.40	1003.60
STORAGE	1192.	1192.	1266.
OUTFLOW	0.	0.	167.

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
.22	1003.55	0.	1263.	156.	0.	17.33	0.
.23	1003.59	0.	1265.	165.	0.	17.33	0.
.24	1003.63	.03	1268.	175.	1.83	17.25	0.
.25	1003.68	.08	1271.	185.	2.33	17.25	0.

PMF Over Topping
Analysis, Assuming Erosion
Of Spillway at + 170 cfs
Discharge.
Keys Branch Mine Dam
MO 30386

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1		INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
	ELEVATION	1002.40	1002.40	1005.60
	STORAGE	1192.	1192.	1395.
	OUTFLOW	0.	0.	1075.

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
.85	1005.60	0.	1395.	1073.	0.	16.42	0.
.90	1005.72	.12	1403.	1166.	.67	16.42	0.
.95	1005.84	.24	1411.	1260.	1.00	16.33	0.
1.00	1005.96	.36	1418.	1358.	1.33	16.33	0.

PMF Over Topping
Analysis. Assuming
No Spillway Erosion
Keys Branch Mine Dam
MO 30386

APPENDIX C

Letter Report on Melchem-Keyes Branch Tailings
Pond From Missouri Geological Survey

(for file only)

2B

ENGINEERING GEOLOGIC REPORT ON THE MILCHEM-KEYES BRANCH-TAILINGS POND

Washington County, Mo.

LOCATION: NW¼, Sec. 6, T. 37 N., R. 3 E., Potosi Quadrangle.

The tailings pond is underlain by Potosi dolomite. However, bedrock is not exposed within the region. The starter dam is constructed of stony red clay intermixed with yellow brown clay.

The starter dam is 30 feet in height and has a crest width of 20 feet. The dam was built by Bloomsdale Excavating Company. There was an engineering design constructed by a Bill Devitt. However, the plan was of little use since it was a general sketch drawing. No provision was made for engineering construction inspection.

The dam was constructed some 3 years ago. Barite operations have just recently begun. Mud is being deposited along the south edge of the starter dam. Mud has not been deposited along the entire length of the structure. Thus, leakage was rather high where gravel is exposed to water. In addition, there seems to be considerable leakage throughout the entire starter dam. However, no free running water is evident with one single and particularly important exception.

A backslope slide has occurred on the southern end of the dam. This slide apparently is related to the pipe that was placed in the structure during construction. The slide is located where one of the drainageways was present in the original valley. The slide was rotational in nature with the toe bulging as the result of movement of the red clay. Slime resembling barite mud is present downstream in the stream channel for some 500 feet. There is evidence that water had percolated through the starter dam for some time and washing fine textured materials from the valley bottom downstream in the stream channel. Repairs were made by pushing dirt up on top of the slide. This has increased pore water pressure and will further weaken the dam.

RECOMMENDATIONS:

All of the material pushed up on the slides should be removed. The toe of the dam should be buttressed by a free draining berm of rock. Recommendations are also made that the mud be spread by flume along the entire crest with the dam. This would aid in sealing the gravels.

Dr. J. Hadley Williams, Chief
Applied Engineering & Urban Geology
Missouri Geological Survey
September 23, 1975