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NATIONAL DAM SAFETY PROGRAM. BOCO MO DAM (MO 10893), MISSOURI --ETC(U)
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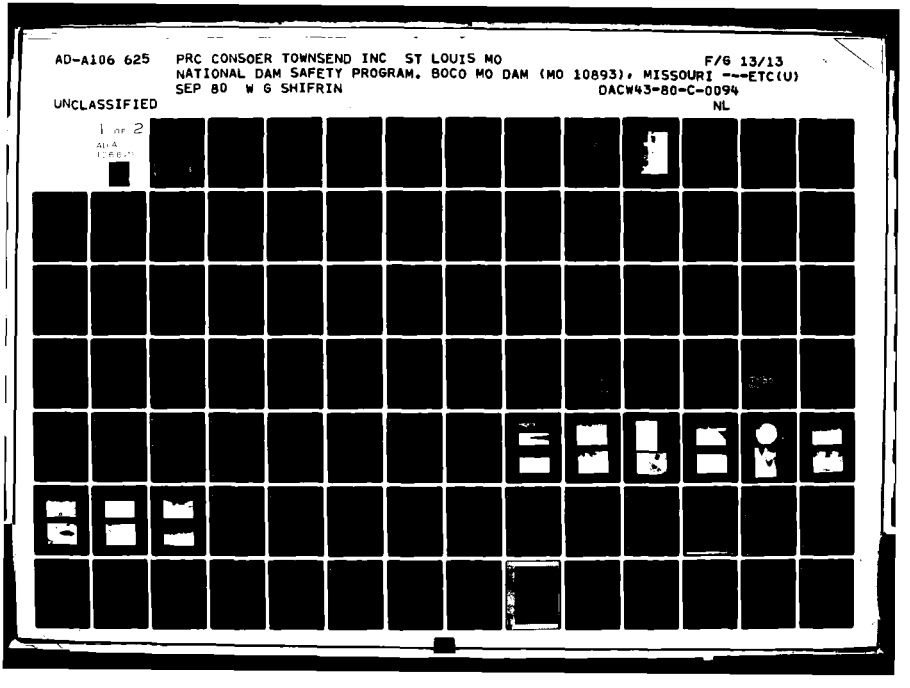

MISSOURI · KANSAS CITY RIVER BASIN

BOCO MO DAM
BOONE COUNTY, MISSOURI
MO. 10893

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

United States Army
Corps of Engineers
...Serving the Army
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St. Louis District

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

FOR: STATE OF MISSOURI

SEPTEMBER, 1980

UNCLASSIFIED

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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: BoCo Mo Dam (Mo. 10893) Phase I Inspection Report

This report presents the results of field inspection and evaluation of the BoCo Mo Dam (Mo. 10893).

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

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

1) Spillway will not pass 50 percent of the Probable Maximum Flood
2) Overtopping could result in dam failure
3) Dam failure significantly increases the hazard to loss of life downstream

SUBMITTED BY: SIGNED
Chief, Engineering Division

07 OCT 1980
Date

APPROVED BY: SIGNED
Colonel, CE, District Engineer

08 OCT 1980
Date

A

BoCo Mo DAM
BOONE COUNTY, MISSOURI

MISSOURI INVENTORY NO. 10893

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

PREPARED BY
CONSOER, TOWNSEND AND ASSOCIATES, LTD.
ST. LOUIS, MISSOURI
AND
PRC ENGINEERING CONSULTANTS, INC.
ENGLEWOOD, COLORADO
A JOINT VENTURE

UNDER DIRECTION OF
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
FOR
GOVERNOR OF MISSOURI

SEPTEMBER 1980

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam: BoCo Mo Dam, Missouri Inv. No. 10893
State Located: Missouri
County Located: Boone
Stream: The Slacks Branch of Perche Creek
Date of Inspection: June 2, 1980

Assessment of General Condition

BoCo Mo Dam was inspected by the engineering firms of Consoer, Townsend and Associates, Ltd. and PRC Engineering Consultants, Inc. (A Joint Venture) of St. Louis, Missouri according to the U. S. Army Corps of Engineers "Engineer Regulation No. 1110-2-106" and additional guidelines furnished by the St. Louis District of the Corps of Engineers. Based upon the criteria in the guidelines, the dam is in the high hazard potential classification, which means that loss of life and appreciable property damage could occur in the event of failure of the dam. Within the estimated damage zone of four miles downstream of the dam are three dwellings, one building, two barns, and one trailer all of which may be subjected to flooding, with possible damage and/or destruction, and possible loss of life. BoCo Mo Dam is in the intermediate size classification since it is less than 40 feet in height but impounds more than 1,000 acre-feet of water.

Our inspection and evaluation indicates that the spillway system of BoCo Mo Dam does not meet the criteria set forth in the guidelines for a dam having the above size and hazard potential. BoCo Mo Dam, an intermediate size dam with a high hazard potential, is required

by the guidelines to be able to pass the Probable Maximum Flood without an occurrence of overtopping the dam. It was determined that the reservoir/spillway system can accommodate approximately 35 percent of the Probable Maximum Flood before overtopping of the dam occurs. Our evaluation also indicates that the reservoir/spillway system will accommodate the one-percent chance flood (100-year flood) without overtopping the dam.

The Probable Maximum Flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region.

BoCo Mo Dam and its appurtenant structures appear to be in a poor condition due to the seepage observed to the left of the service spillway outlet, which is considered to be a major deficiency, and the other deficiencies described below. The seepage is apparently occurring along the service spillway conduit due to the fact that rust colored sediment was observed in the discharge. This indicates a potential danger to the safety of both the dam and the service spillway.

Other deficiencies noted by the inspection team were as follows: two areas of possible seepage; cracks on the downstream and upstream slopes; wave erosion on the upstream berm; two areas of erosion downstream of the toe; damage to the embankment slopes due to grazing livestock and inadequate vegetative protection; problems associated with the service spillway consisting of the corrosion along the conduit and in the intake structure; the distortion of the conduit and the beads of water observed on the inside of the conduit; a need for periodic inspection by a qualified engineer; and a lack of maintenance schedule. The lack of seepage and stability analyses on record is also a deficiency that should be corrected.

It is recommended that the owner should take action to investigate the cause of seepage occurring along the service spillway and other suspected seepage areas and implement necessary corrective measures. Other deficiencies in the dam mentioned above should also be corrected without delay.

Walter G. Shifrin, P.E.

Overview of BoCo Mo Dam

NATIONAL DAM SAFETY PROGRAM

BoCo Mo DAM, I.D. No. 10893

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NATIONAL DAM SAFETY PROGRAM

BoCo Mo DAM, Missouri Inv. No. 10893

SECTION 1: PROJECT INFORMATION

1.1 General

a. Authority

The Dam Inspection Act, Public Law 92-367 of August, 1972, authorizes the Secretary of the Army, through the Corps of Engineers, to initiate a national program of dam inspections. Inspection for BoCo Mo Dam was carried out under Contract DACW 43-80-C-0094 between the Department of the Army, St. Louis District, Corps of Engineers, and the engineering firms of Consoer, Townsend & Associates, Ltd., and PRC Engineering Consultants, Inc. (A Joint Venture), of St. Louis, Missouri.

b. Purpose of Inspection

The visual inspection of BoCo Mo Dam was made on June 2, 1980. The purpose of the inspection was to make a general assessment regarding the structural integrity and operational adequacy of the dam embankment and its appurtenant structures.

c. Scope of Report

This report summarizes available pertinent data relating to the project, provides an account of visual observations made during the field inspection, gives an assessment of hydrologic and hydraulic conditions at the site, presents an assessment of the

structural adequacy of the various project features and evaluates the general condition of the dam with respect to safety.

Subsurface investigations, laboratory testing and detailed analyses were not within the scope of this study. No warranty as to the absolute safety of the project features is implied by the conclusions presented in this report.

It should be noted that in this report reference to left or right abutments is viewed as looking downstream. Where left abutment or left side of the dam is used in this report, this also refers to the southeast abutment or side, and right abutment or right side to the northwest abutment or side.

d. Evaluation Criteria

The inspection and evaluation of the dam is performed in accordance with the U.S. Army Corps of Engineers "Engineer Regulation No. 1110-2-106" and additional guidelines furnished by the St. Louis District office of the Corps of Engineers for Phase 1 Dam Inspection.

1.2 Description of the Project

a. Description of Dam and Appurtenances

The following description is based upon observations and measurements made during the visual inspection and from telephonic conversations with Mr. Kenneth Mertens of Mertens Construction Company of Fulton, Missouri and Mr. Bill Crockett of Williams and Works Engineering Firm of Columbia, Missouri. Mertens Construction Company constructed the dam. Williams and Works did the planning, the preliminary design of the dam, and some of the surveying at the damsite. No final design drawings for the dam or appurtenant structures were available and the design engineer for the project is unknown.

The dam is a homogeneous, rolled earthfill structure with a straight alignment between earth abutments. Photos 1 through 3 show views of the embankment. The top of dam is 16-feet wide, 912 feet long, and was found approximately level from the left abutment/embankment contact to the service spillway, located approximately 475 feet to the right of the left abutment. From this point, the top of dam slopes slightly upward to the right side of the embankment and the difference in elevation between the lowest and the highest points is approximately 1.5 feet (see Plate 2). The minimum elevation of the top of dam is approximately 705 feet above mean sea level (M.S.L.). The maximum structural height of the dam is 38.5 feet. The upstream and downstream slopes were measured as 1 vertical to 2 horizontal (1V to 2H). A berm exists on the upstream slope of the dam at an elevation of 696.5 feet above M.S.L. The width of the berm varied from 8 feet on the left side to 19 feet on the right side. According to Mr. Mertens, a 12- to 14-foot wide core trench was excavated into bedrock under the embankment.

The dam has two spillways; one is the service spillway, which is a drop inlet type of structure, and the other is the emergency spillway, comprising an overflow section formed into the right side of the dam. The service spillway basically consists of a horizontal inlet opening (with a crest level about 8.5 feet below the minimum elevation of the top of dam), a drop of approximately 28 feet to the invert of the steel conduit, and about 185 feet of steel conduit running slightly askew through the embankment on a 1.0 to 1.5 percent slope. A steel trashrack-cattleguard sits atop the inlet opening. The combination trashrack-cattleguard consists of steel bars welded to a 5-1/2 foot diameter steel plate at the top and a 14-foot diameter ring at the bottom; it is anchored in place atop the inlet with a collar of dumped concrete around the bottom ring (see Photo 7).

The construction of the drop portion of the inlet can be divided into two parts, an upper segment and a lower segment. The upper segment approximates a cloverleaf shape (see Photo 7) and appears to be assembled from four 10-foot long semi-cylindrical sections of used, riveted boilerplate, welded together along the 10-foot vertical edges (according to Mr. Mertens, the material used in constructing the spillway was not used boilerplate but old railroad tank cars). The drop inlet structure has a maximum horizontal outside dimension of approximately 14 feet and stands with its bottom edge formed into a concrete floor. The upper segment therefore reaches from the normal water level down to the concrete floor, 10 feet below the normal water level. The lower segment is oval to about circular in shape and appears to be assembled from two or more lengths of semi-or partially-cylindrical sections of used, riveted, railroad tank car welded together to form a cylinder which is about 10 feet deep and approximately 7 feet across a diameter (see Photo 9). The top of this cylindrical enclosure is encased into the above mentioned concrete floor and the bottom appears to be weld-fitted to the top of the conduit. Therefore, this lower segment reaches from the concrete floor down to the top of the steel conduit, 11 feet below the concrete floor. The steel conduit is 80 inches in diameter and also appears to be constructed from used, riveted railroad tank cars. The conduit is laid through the approximate center of the embankment on a line 20° right skew from the normal to the dam axis and outlets into a 40- by 90-foot pool area at the toe of the embankment (see Photos 8 and 13).

The emergency spillway is an overflow section off the right side of the dam (see Photo 11). The waterway at the crest is trapezoidal in shape with a 390-foot top width, a 118-foot bottom width, and a depth of just over 3 feet. The invert elevation of the spillway crest is 1.6 feet lower than the minimum top of dam and 6.9 feet higher than the crest of the service spillway. The emergency crest was found approximately 8.3 feet higher than the reservoir water level on the day of inspection. Downstream of the crest, the defined discharge channel disappears into a very flat

configuration until a natural gully is intercepted, 100 to 150 feet downstream (see Photo 12). The axis of the spillway crest angles from the axis of the dam in an upstream direction (see Plate 2).

A low level outlet was provided for BoCo Mo Dam. The outlet consists of an 8-inch diameter steel pipe which passes through the embankment and is controlled by an 8-inch Walworth gate valve located at the downstream end of the pipe. The valve is located 12 feet to the right of the service spillway outlet (see Photo 8). The valve is housed in a 4.8-foot diameter riveted steel encasement which is itself enclosed in a 6.8-foot diameter riveted steel encasement. The two encasements are connected together by a steel plate. The 4.8-foot diameter encasement has a circular steel plate cover which is hinged at one point on the perimeter (see Photo 14).

b. Location

BoCo Mo Dam is located in Boone County of the State of Missouri on the Slacks Branch of Perche Creek which flows into the Missouri River. The dam is located approximately 6 miles north of Columbia and 1.5 miles west of the small community of Hinton. The dam is located in the northeast quarter of Section 10 of Range 13 West, Township 49 North as shown on the Browns, Missouri Quadrangle (7.5 minute series) sheet.

c. Size Classification

The BoCo Mo Dam reservoir impoundment is less than 50,000 acre-feet but more than 1,000 acre-feet which would classify it as an "intermediate" size dam. The maximum height of the dam is less than 40 feet and greater than 25 feet which classifies it classified as a "small" size dam. The size classification is determined by either the storage or height, whichever gives the larger size category. Therefore, the size classification is determined to fall within the "intermediate" category, according to the "Engineer

Regulation No. 1110-2-106, Appendix D" by the U.S. Department of the Army, Office of the Chief Engineer.

d. Hazard Classification

The dam has been classified as having a "high" hazard potential in the National Inventory of Dams, on the basis that in the event of failure of the dam or its appurtenances, excessive damage could occur to downstream property, together with the possibility of the loss of life. From a visual inspection of the downstream area, our findings concur with this classification. Within the estimated damage zone, which extends approximately four miles downstream of the dam, are three dwellings, one building, two barns, and one trailer (see Photos 17 and 18).

e. Ownership

BoCo Mo Dam is privately owned by Mr. Gordon Burnam. The mailing address is Mr. Gordon Burnam, P.O. Box U, Columbia, Missouri, 65205.

f. Purpose of Dam

The dam was constructed so that its reservoir could be used for recreational purposes.

g. Design and Construction History

According to Mr. Don Nicolson of Williams and Works Engineering Firm, Columbia, Missouri, their firm was responsible for much of the surveying work (i.e., centerline control stakes, offset stakes, etc.) for BoCo Mo Dam. Williams and Works also gave recommendations for the size of the core trench and emergency spillway. Mr. Nicolson also stated that their firm did not do the actual design for the dam and that he believed it was done as a "moon lighting" project. The name of the actual design engineer is not known.

BoCo Mo Dam was constructed by Mertens Construction Company of Fulton, Missouri between April and June, 1973. According to Mr. Bill Crockett of Williams and Works Engineering Firm, the dam has a volume of approximately 80,000 cubic yards. Mr. Crockett also stated that no plans or specifications were prepared for the dam.

h. Normal Operational Procedures

Normal procedure is to allow the reservoir to remain as full as possible while the water level is controlled by rainfall, runoff, evaporation and the elevation of the service spillway crest.

1.3 Pertinent Data

a. Drainage Area (square miles):. 3.18

b. Discharge at Damsite

Estimated experienced maximum flood (cfs):	Unknown
Estimated ungated spillway capacity with reservoir at top of dam elevation (cfs):	2206

c. Elevation (Feet above MSL)

Top of dam (minimum):.	705 (Assumed)*
Spillway crest:	
Service Spillway	696.5
Emergency Spillway	703.4
Normal Pool:	696.5
Maximum Experienced Pool:.	Unknown
Observed Pool:	695.1

d. Reservoir

Length of pool with water surface at top of dam elevation (feet):.	6,700

e. Storage (Acre-Feet)

Top of dam (minimum):.	1,861
Spillway crest:	
Service Spillway	854
Emergency Spillway	1,628
Normal Pool:	854
Maximum Experienced Pool	Unknown
Observed Pool:	759

* No exact elevation is known for the top of dam, therefore an assumed elevation was estimated from the Browns, Missouri U.S.G.S. Quadrangle sheet. All other elevations were determined from the assumed top of dam elevation and field measurements.

f. Reservoir Surfaces (Acres)

Top of dam (minimum):	153
Spillway crest:	
Service Spillway	86
Emergency Spillway	140
Normal Pool:	86
Maximum Experienced Pool:	Unknown
Observed Pool:	79

g. Dam

Type:	Rolled, earthfill
Length:	912 feet
Structural Height:	38.5 feet
Hydraulic Height:	38.5 feet
Top width:	16 feet
Side slopes:	
Downstream	1V to 2H
Upstream	1V to 2H (from top of dam to the berm)
Zoning:	Homogeneous
Impervious core:	NA
Cutoff:	A core trench with a 12 to 14 foot bottom width excavated to bedrock (According to Mr. Mertens.)
Grout curtain:	No
Volume:	80,000 cu.yds. (According to Mr. Crockett)

h. Diversion and Regulating Tunnel. . . . None

i. Spillway

Type:

Service Spillway	Drop inlet, uncontrolled
Emergency Spillway	Earthcut channel, uncontrolled

Length of crest:

Service Spillway	44 feet
Emergency Spillway	118 feet

Crest Elevation (feet above MSL):

Service Spillway	696.5
Emergency Spillway	703.4

j. Regulating Outlets

Type:	8-inch diameter low-level outlet
Location:	12 feet to the right of the service spillway
Length:	Unknown
Closure:	8-inch Walworth gate valve
Maximum Capacity:	Unknown

SECTION 2: ENGINEERING DATA

2.1 Design

No design data were available for BoCo Mo Dam. In addition, no "as-built" plans were available. The only information available was a letter from J. Hadley Williams of the Missouri Geological Survey, explaining the geologic suitability for the site. The letter is dated November 8, 1972 and is presented in this report as Plates 7 through 9.

2.2 Construction

No data are available concerning the construction of the dam and appurtenant structures. The following information about the construction of the dam and appurtenant structures was obtained from telephone conversations with Mr. Mertens and Mr. Crockett. The compaction of the embankment was achieved by the use of a sheepsfoot roller. No compaction tests were performed; however, it is believed that good compaction of the embankment material was achieved. The material used for the embankment was a good clay with no boulders. The core trench was excavated to bedrock. The material for the service spillway was obtained from used railroad tank cars and the service spillway was founded on the compacted embankment.

2.3 Operation

There were no operations records which could be made available to the inspection team for this dam.

2.4 Evaluation

a. Availability

The availability of engineering data is poor and consists only of a letter from the Department of Natural Resources Geologic Division, dated November 8, 1972, pertaining to the Geologic suitability of the site, along with state Geologic Maps, U.S.G.S. Quadrangle sheets, and a soil survey by the Soil Conservation Service for Boone County.

b. Adequacy

The conclusions presented in this report are based on field measurements, the available engineering data, past performance and present condition of the dam. The available data, including the field measurements taken by the field inspection team, are considered adequate to evaluate the hydraulic and hydrologic capabilities of the dam. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

c. Validity

The only pertinent and valid engineering data available was the letter by J. Hadley Williams pertaining to the geologic site suitability. The report was basically written for an original damsite some 500 to 600 feet downstream of the present damsite. Mr. Williams recommended that the dam be moved upstream, which it was. The report also stated that sinkholes in the Burlington Limestone bedrock were present near the original damsite. This was verified by the observation of two sinkholes 300 feet downstream of the dam (see Photo 16).

SECTION 3: VISUAL INSPECTION

3.1 Findings

a. General

A visual inspection of the BoCo Mo Dam was made on June 2, 1980. The following persons were present during the inspection:

Name	Affiliation	Disciplines
Mark Haynes, P.E.	PRC Engineering Consultants, Inc.	Project Engineer, Soils and Mechanical
Jerry Kenny	PRC Engineering Consultants, Inc.	Hydraulics and Hydrology
Ken Bullard, P.E.	PRC Engineering Consultants, Inc.	Hydraulics and Hydrology
Robert McLaughlin, P.E.	PRC Engineering Consultants, Inc.	Civil
Razi Quraishi, R.P.G.	PRC Engineering Consultants, Inc.	Geology
Kevin Blume	Consoer, Townsend & Assoc., Ltd.	Civil and Structural

Specific observations are discussed below.

b. Dam

The overall condition of the dam appears to be poor due to the several items of concern discussed below.

The top of dam supports a dirt access road. Tire tracks caused by vehicular traffic across the dam were observed. No tire ruts or depressions, which are generally associated with vehicular traffic across earthen structures, were seen. Evidence of a gravel surface placed on the top of dam at one time was observed. No depressions indicating a settlement of the dam were observed. The difference in elevation between the right side and the left side of the dam did not appear to be due to an instability of the embankment. The dam was most likely constructed in this way. No significant deviation in horizontal alignment was apparent. Minor surface shrinkage cracks were observed, however, no major cracking was observed on the top of dam. No evidence of the dam ever being overtopped was observed.

The upstream slope of the dam has no riprap protection. Consequently, some erosion has occurred on the upstream side of the berm due to wave action. The portion of the slope above the water surface and the berm itself have a tall grass cover. The grass cover is not dense enough to adequately protect the slope from surface runoff. Some minor erosion due to surface runoff was observed; however, no large erosion gullies were noted. Considerable damage to the surface of the embankment slopes has been caused by grazing livestock. Small 6-inch diameter depressions and shallow surface sloughs due to the livestock activity were observed. Longitudinal and transverse cracks were observed over most of the slope. The cracks were noncontinuous and some were measured up to 8 inches deep, 1/2-inch wide, and 6-feet long. No bulges or depressions were observed on the slope.

The downstream slope of the dam has the same problems as the upstream slope with the tall but inadequate grass cover, the minor surface runoff erosion, the damage caused by the grazing livestock and the longitudinal and transverse cracks as described above (see Photo 5). Flowing seepage and two areas of probable seepage were observed in three different locations. The flowing seepage was observed a few feet to the left of the service spillway outlet (see Photo 6). The rate of flow was estimated at less than 1 gallon per minute (gpm). The discharge did not appear to be transporting soil particles. It is unknown whether the seepage was through the embankment or along the spillway pipe. A boggy area measuring approximately 70 feet long was observed to the left of the service spillway discharge channel and downstream of the toe of the dam (see Photo 3). No measurable flowing seepage was observed in this area. The second area of probable seepage was observed approximately 100 feet to the right of the service spillway and downstream of the toe. In this area, boggy ground and standing water were observed. It appeared that the presence of water in this area is fairly recent because the area contained fairly sparse vegetation generally associated with moist, boggy areas and only small cattails were observed. No measurable flowing seepage was observed in this area. No bulges or depressions were apparent on the slope. No trees were observed on the embankment. Two erosion gullies were observed downstream of the embankment one on each side of the dam (see Photos 3 and 4). The largest gully is located on the right side of the dam. It measured approximately 5 to 6 feet deep and 6 feet wide.

Both abutments slope gently upward from the top of dam. No instabilities or seepage were observed on either abutment. Erosion gullies were observed on the right upstream side of the abutment near the reservoir. The erosion did not appear to affect the safety of the dam or abutment.

No rodent activity was apparent on either the embankment or the abutments.

c. Project Geology and Soils

(1) Project Geology

The damsite is located on the Slacks Branch of Perche Creek in the Dissected Till Plains Section of the central Lowland Physiographic Province. Loess-mantled Kansas drift covers the surface of most of the Dissected Till Plains Section. This section is distinguished from the Young Drift Section to the north and from the Till Plains on the east by the stage it has reached in the post-glacial erosion cycle. Broadly generalized, this section is a nearly flat till plain, submature to mature in its erosion cycle.

The topography at the damsite is rolling to hilly with strip mining stockpiles in the vicinity of the damsite. Elevation of the ground surface ranges from 800 feet above M.S.L. (one mile east of the site) to about 700 feet above M.S.L. at BoCo Mo Dam. The reservoir slopes are generally 10^{o} to 20^{o} from horizontal. The area near the damsite is covered with slope wash deposits of glacial-fluvial and loess origin consisting of yellowish brown to gray, silty clay with brown shale fragments.

The regional bedrock geology beneath the glacial outwash deposit in the damsite, shown on the Geologic Map of Missouri (1979) (see Plate 4), consists of Pennsylvanian age rocks of the Marmaton-Cherokee Group (cyclic deposits of shale, limestone, and sandstone), Mississippian age Burlington Limestone (cherty, grayish brown, sandy limestone), Devonian age rocks of the Sulphur Springs Group (Glen Park Limestone, Grassy Creek Shale) and Ordovician rocks consisting of St. Peter Sandstone and Powell Dolomite. The predominent bedrock underlying glacial-fluvial deposits in the vicinity of the damsite are the coal beds and the Burlington Limestone. Two sinkholes with moderately progressive solution activity were observed nearly 300 feet downstream from the dam (see Photo 16). No outcropping of bedrock was seen at the damsite. The inlet and outlet areas of the Slacks Branch contain Quaternary alluvium.

No faults have been identified in the vicinity of the damsite, The closest trace of a fault to the damsite is the Fox Hollow Fault nearly 20 miles south of the site. The Fox Hollow Fault had its last movement in post-Mississippian time. Thus, the fault appears to have no effect on the dam.

BoCo Mo Dam consists of a homogeneous earthfill embankment, a cloverleaf shaped drop inlet service spillway with a metal outlet pipe located near the midsection of the embankment and an emergency spillway located at the right abutment end of the embankment.

No boring logs or construction reports were available which would indicate foundation conditions encountered during the construction. Based on conversations with the construction contractor, Mr. Mertens, the embankment rests on bedrock which may be of Burlington Limestone of Mississippian age. The cloverleaf shaped drop inlet service spillway and the outlet pipe rests on the compacted embankment, according to Mr. Mertens. The emergency spillway was cut into the compacted embankment fill.

(2) Project Soils

According to the "Soil Survey for Boone County, Missouri" published by the Soil Conservation Service in 1962, the common soils in the general area of the dam belong to the White Oak Land:Lindley - Hatton association. The Boone County soil maps show the soil at the damsite consisting of a narrow strip of the Westerville silt loam along the creek channel with the Mandeville silt loam, the Lindley loam, and the Lindley clay loam laying on both sides of the Westerville silt loam. These soils are basically formed from glacial till, alluvium, and weathered limestone. The Lindley soil is generally quite susceptible to erosion. If the Lindley soil type was used in the embankment, the potential of failure of the embankment would be increased due to erosion during overtopping.

Materials removed from the upstream and downstream slopes of the embankment appeared to be a mottled, yellowish brown and gray, silty clay with some fine to medium sand. Based upon the Unified Soil Classification System, the soil would probably be classified as a CL. This soil type generally has the following characteristics: an impervious soil with a coefficient of permeability less than 1.0 foot per year, medium shear strength, and a high resistance to piping.

d. Appurtenant Structures

(1) Service Spillway

The service spillway conduit has apparently been in place for several years and the following observations were noted. The combination trashrack-cattleguard is set over the inlet opening with its bottom edge partially held in place by dumped, unvibrated concrete. There is no protective coating present and rust reaction is happening over the entire structure (see Photo 7). The upper segment of the inlet drop structure is approximately 10 feet high with its bottom edge held fast by the concrete floor; the vertical edges of the semi-cylindrical sections appear to be welded together to form seams. Since this upper segment acts as a retaining structure for 10 feet of fill, the seams are somewhat bowed out of vertical and are severely corroded; it looks as though the outside surfaces are covered by what appears to be an epoxy coating except at the edges; here from welding, cutting, etc. the epoxy coating is slightly peeled back (see Photo 10). The crest of the inlet was approximately 1.5 feet higher than the reservoir water level on the day of the inspection, therefore no flow through the conduit was observed. The lower segment of the drop inlet structure extends from the concrete floor to a point approximatly 11 feet down where it is apparently welded to the top of the conduit (see Photo 9). The shape of this part aproaches a circular cylinder, however, it is difficult to determine the exact shape or condition of this segment. (It appears circular on top and oval on the bottom). The conduit

itself carries the flow under the embankment to the downstream channel. The inside of the conduit exhibited a fair degree of corrosion and sweating (i.e., beads of water resting on the top area of the conduit surface), but as previously mentioned, there was no flow in the conduit; however, there was a pool of water at the outlet end, perhaps supplied by the various potential seepage spots nearby (see Photo 8). The flowing seepage mentioned in Section 3.1b, immediately adjacent to the conduit outlet (see Photos 6 and 8), was discharging a rust colored sediment, albeit at the rate of less than one gallon per minute. Although the outlet of the pipe appears round, the view of the perimeter from deep inside the pipe, looking out, is that of an oval or bowed shape for a partial length of the pipe, i.e. for that portion under the top of dam. No debris was accumulated in or around the trashrack-cattleguard structure.

(2) Emergency Spillway

The emergency spillway, located just off the right side of the dam, has a crest and flat V-shaped discharge channel, both of which have little or no grass cover protection or other surface erosion control measures. The slope of the discharge channel is approximately 9 percent and it has a clay surface (see Photos 11 and 12). There was also some erosion noted in the emergency spillway approach area.

(3) Outlet Works

The 8-inch low level outlet is in an operable condition. The gate valve was operated on the day of the inspection, and it operated freely. The entire system appeared to operate as originally intended. The gate stem of the valve was bent at an angle of approximately 20^{o} from vertical. This did not appear to hamper the operation of the valve. No leakage through the valve or seepage along the pipe were observed. Some minor surface rusting was observed on the gate stem and the hand wheel. The intake of the system was not located due to the water level of the reservoir.

e. Reservoir Area

The reservoir water surface elevation at the time of the inspection was 695.1 feet above M.S.L.

The surface area of the reservoir at normal water level is about 86 acres. The rim appears to be stable with no severe erosion problems. A localized erosional slump approximately 20-feet wide and 5-feet high was observed just upstream of the dam on the left abutment. Erosional gullies due to the surface runoff were observed upstream of the dam in the right abutment area. Some minor erosion due to wave action was observed along the shoreline. The erosional problems do not appear to be detrimental to the stability of the reservoir or the embankment. The land around the reservoir slopes gently to the rim and is grass and/or tree covered. There are a few homes built in close proximity to the reservoir (see Photo 15).

f. Downstream Channel

The downstream channel is well defined. The channel has a bottom width of about 5 feet and has side slopes of 1V to 2.5H on the right and 1V to 5H on the left. The channel is approximately 2 feet deep, but is obstructed with trees (see Photo 13). The floodplain outside of the channel is fairly wide near the damsite and is grass covered with some trees.

3.2 Evaluation

The visual inspection revealed the following condition which was felt to pose a threat to the safety of the structure and would warrant prompt attention.

The flowing seepage observed to the left of the service spillway outlet poses a potential danger to the structural integrity of the dam and the service spillway. The source of the seepage is unknown, however, it appears that the water is flowing along the outside of the conduit of the service spillway. The evidence which points to this conclusion is the sweating condition on inside of the conduit and the

rust colored sediment observed in the discharge. The rust colored sediment indicates that possibly the outside of the conduit is undergoing some deterioration due to corrosion. Holes could develop in the conduit due to the corrosion; in which case, fill material could wash into the pipe due to the seepage, or the flow through the conduit would erode the material exposed by the holes. Such progressive erosion, if it occurs, could cause collapse of the embankment material around the conduit leading to its eventual failure.

The following conditions were observed which could affect the safety of the dam.

1. The two probable seepage areas observed downstream of the toe could have an adverse effect on the stability and safety of the embankment. If the rate of seepage were to increase, it is possible that the seepage could transport soil particles which would cause piping of the embankment material. This condition could lead to the eventual failure of the embankment.

2. The wave erosion on the upstream berm and the areas of surface runoff erosion downstream of the toe do not appear to affect the structural stability of the dam in their present condition. However, continual erosion due to wave action can only be detrimental to the stability of the dam. The erosion downstream of the toe of the dam, if allowed to continue, could encroach upon the toe and endanger the safety of the dam.

3. It is unknown whether the cracks observed on the upstream and downstream slopes are indicative of shrinkage, slope movement or foundation settlement. However, judging from their extent and location, the cracks were probably caused by shrinkage.

4. The damage to the downstream and upstream slopes due to the grazing livestock and to the lack of an adequate grass protection against surface runoff does not adversely affect the stability of the dam in its present condition.

5. The corrosion due to the lack of protective covering occurring along the seams of the cloverleaf portion of the drop inlet section and along the outlet conduit, plus the corrosion potentially occurring on the walls of the fill side of the drop inlet structure could lessen the structural integrity of the spillway to such a degree that it could not retain the presently imposed fill. This condition, if it eventually occurred, would cause at least a partial obstruction, if not a full closure of the service spillway.

6. The distortion of the shape of the conduit seems to be taking place under the maximum section of the dam. The weight of the embankment could have a crushing effect upon the conduit, especially if the used tank cars were originally designed to take tension forces but not compression forces. Since the conduit has been in place for about 7 years, it would seem that this condition could only progressively worsen in the future causing damage to both the conduit and the embankment.

It was also noted that there was no flow entering the inlet to the service spillway but there were boggy and seepage areas along the toe of the dam, sweating on the inside top of the conduit, and a 90-foot by 40-foot outlet pool (see Photo 13) on the day of the inspection.

7. No accumulation of debris was observed in or around the trashrack-cattleguard structure on the day of the inspection. Nevertheless, floating debris could accumulate in the future, which could hamper the normal operation of the spillway.

8. The gate valve for the low level outlet appeared to operate properly and no major problems with the drain were observed. However, the condition of the pipe through the dam is unknown and deterioration of the pipe could cause considerable damage to the dam. Since the pipe carries full reservoir pressure, a failure of the pipe could result in internal erosion (piping) of the dam.

SECTION 4: OPERATIONAL PROCEDURES

4.1 Procedures

BoCo Mo Dam was constructed to impound water for recreational use, however, it is also used for livestock watering. There are no specific operational procedures for the dam and reservoir.

4.2 Maintenance of Dam

The dam and appurtenant structures are maintained by workmen hired by the owner, Mr. Gordon Burnam. Cattle are allowed to graze on the slopes of the dam and, consequently, damage to slopes has occurred. However, the cattle appear to keep the vegetation from growing too tall. Several areas of erosion were observed.

4.3 Maintenance of Operating Facilities

The only operable facility at the damsite is the 8-inch low level gate valve. The 8-inch low level valve was tested on the day of inspection and found to be in good working order.

4.4 Description of Any Warning System in Effect

The inspection team is not aware of any existing warning system for this dam consisting of any electrical warning systems or manual warning notification plans.

4.5 Evaluation

Operational procedures are non-existent, and the maintenance of the dam appears to be less than adequate. The remedial measures outlined in Section 7 should be undertaken to improve the condition of the dam.

SECTION 5: HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. Design Data

The watershed area of the BoCo Mo Dam upstream from the dam axis consists of approximately 2,035 acres. The watershed area consists mostly of pasture and range land with some wooded areas. Land gradients in the watershed average roughly 1 percent. The BoCo Mo Dam Reservoir is located on the Slacks Branch of Perche Creek. The reservoir is about 3.4 miles upstream from the confluence of Slacks Branch tributary and the Perche Creek. The watershed measures approximately 3 miles at its longest arm. A drainage map showing the watershed and the downstream hazard zone is presented on Plates 1A and 1B in Appendix B.

Evaluation of the hydraulic and hydrologic features of BoCo Mo Dam was based upon criteria set forth in the Corps of Engineers' "Engineer Regulation No. 1110-2-106" and additional guidance provided by the St. Louis District of the Corps of Engineers. The Probable Maximum Flood (PMF) was calculated from the Probable Maximum Precipitation (PMP) using the methods outlined in the U.S. Weather Bureau Publication, Hydrometeorological Report No. 33. The probable maximum storm duration was set at 48 hours, and the storm rainfall distribution was based upon criteria given in the Corps of Engineers' EM 1110-2-1411 (Standard Project Storm). The Soil Conservation Service (SCS) method was used for deriving the unit hydrograph, utilizing the Corps of Engineers' computer program HEC-1 (Dam Safety Version). The unit hydrograph parameters are presented in Appendix B. The SCS method also was used for determining the loss rate. The hydrologic soil group of the watershed was determined by use of published soil maps. The hydrologic soil group of the watershed and the SCS curve number are presented in Appendix B. The curve number, unit hydrograph parameters, the PMP index rainfall and the percentages for various durations were the

direct input to the HEC-1 (Dam Safety Version) computer program used to obtain the PMF hydrograph. The computed peak inflows of the PMF and one-half of the PMF are 16,400 cfs and 8,200 cfs, respectively.

Both the PMF and the one-half PMF inflow hydrographs were routed through the reservoir by the Modified Puls Method also utilizing the HEC-1 (Dam Safety Version) computer program. A storm of 50 percent of the PMF preceded the PMF and a storm of 25 percent of the PMF preceded the one-half PMF, each by four days. The reservoir was assumed at the mean annual high water level at the beginning of the antecedent storm. The mean annual high water level for BoCo Mo Lake was estimated to be at the crest of the service spillway. The antecedent 50 percent PMF storm, when routed through the reservoir, will leave the reservoir at approximately the same elevation as the crest of the service spillway (see Appendix B) at the end of the four day period. Thus, the reservoir was assumed at the crest level of the service spillway at the start of the routing computation for the PMF, one-half of the PMF and other PMF ratio floods. The peak outflow discharges for the PMF and one-half of the PMF are 15,178 and 5,970 cfs, respectively. Both the PMF and one-half of the PMF when routed through the reservoir resulted in overtopping of the dam.

The sizes of physical features, utilized to develop the stage-outflow relation for the spillway and overtopping of the dam, were taken from field notes and sketches prepared during the field inspection. The reservoir elevation-area data were obtained from the U.S.G.S. Browns, Missouri Quadrangle topographic map (7.5 minute series). The reservoir elevation-area curve and the spillway and overtop rating curve are presented as Plates 2 and 3, respectively, in Appendix B.

From the standpoint of dam safety, the hydrologic design of a dam must aim at avoiding overtopping. Overtopping is especially dangerous for an earth dam because of its erodable characteristics. The safe hydrologic design of an embankment dam requires a spillway discharge capability combined with an embankment height that can handle a very large and exceedingly rare flood without

overtopping.

The Corps of Engineers designs dams to safely pass the Probable Maximum Flood that could be generated from the dam's watershed. This is the generally accepted criterion for major dams throughout the world and is the standard for dam safety where overtopping would pose any threat to human life. Accordingly, the hydrologic requirement for safety for this dam is the capability to pass the Probable Maximum Flood without overtopping.

b. Experience Data

No records of reservoir stage or spillway discharge are maintained for this site. Nevertheless, there was no evidence of the dam ever having been overtopped.

c. Visual Observations

Observations made of the spillways during the visual inspection are discussed in Section 3.1d and evaluated in Section 3.2. The trashrack-cattleguard structure over the service spillway inlet appeared sufficiently adequate to prevent clogging of the pipe by floating debris.

d. Overtopping Potential

As indicated in Section 5.1a, both the Probable Maximum Flood and one-half of the Probable Maximum Flood when routed through the reservoir, resulted in overtopping of the dam. The peak outflow discharges for the PMF and one-half of the PMF are 15,178 and 5,970 cfs, respectively. The maximum capacity of the spillway just before overtopping of the dam is 2206 cfs. The PMF overtopped the dam by 2.39 feet and one-half of the PMF overtopped the dam by 1.02 feet. The total duration of flow over the lowest point on the top of dam is 5.75 hours during the PMF and 3 hours during the occurrence of one-half of the PMF. The spillway/reservoir system of BoCo Mo Dam is capable of accommodating a flood equal to approximately 35 percent of the PMF just before overtopping the dam. The reser-

voir/spillway system of BoCo Mo Dam will accommodate the one-percent chance flood (100-year flood) without overtopping. Due to the lack of adequate vegetative cover and the high flow velocities, the silty clay soil in the emergency spillway may be susceptible to erosion. The downstream slope of the embankment may also be susceptible to erosion during overtopping of the dam.

The failure of the dam could cause extensive damage to the property downstream of the dam and possible loss of life. The estimated damage zone extends approximately four miles downstream of the dam. There are three dwellings, one building, two barns, and one trailer within the damage zone.

SECTION 6: STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations

There were no major signs of settlement or distress observed on the embankment or foundation during the visual inspection. The flowing seepage and the two areas of probable seepage observed in the three different locations downstream of the toe could be detrimental to the stability of the embankment. Nevertheless, the seepage did not appear to constitute an unsafe condition at this time. It was not apparent whether the cracks on the upstream and downstream slopes were due to shrinkage, slope movement, or foundation settlement. Judging from their extent and location, the cracks were probably caused by shrinkage. Nevertheless, further investigation of the cracks is warranted. The erosional problems due to wave action and surface runoff on the upstream berm and downstream of the toe, respectively, and the damage to the downstream and upstream slope due to grazing livestock and inadequate grass cover do not endanger the structural integrity of the embankment in their present condition. Nevertheless, continual aggravation could only have an adverse effect on the stability of the embankment. In the absence of seepage and stability analyses, no quantitative evaluation of the structural stability can be made.

Due to the corrosion taking place both along the conduit and at the intake structure, the distortion of the conduit under the center of the embankment, and the apparent seepage path along the outside of the conduit, the service spillway could not be considered as structurally stable.

The low level outlet did not exhibit signs of structural instability.

b. Design and Construction Data

No design computations pertaining to the embankment were uncovered during the report preparation phase. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available. No embankment or foundation soil parameters were available for carrying out a conventional stability analysis on the embankment. No construction data or specifications relating to the degree of embankment compaction were available for use in a stability analysis.

c. Operating Records

No operating records are available relating to the stability of the dam or appurtenant structures. The water level on the day of inspection was 17 inches below the crest of the service spillway, and it is assumed that the reservoir remains close to full at all times. The low level drain is in operable condition and was operated on the day of the inspection.

d. Post Construction Changes

No post construction changes to the embankment are known to exist which will affect the structural stability of the dam.

e. Seismic Stability

The dam is located in Seismic Zone 1 (see Plate 6), as defined in "Recommended Guidelines for Safety Inspection of Dams", prepared by the Corps of Engineers, and will not require a seismic stability analysis. An earthquake of the magnitude which would be expected in Seismic Zone 1 will not cause significant distress to a well designed and constructed earth dam. Available literature

indicates that no active faults exist near the vicinity of the damsite.

SECTION 7: ASSESSMENT/REMEDIAL MEASURES

7.1 Dam Assessment

The assessment of the general condition of the dam is based upon available data and the visual inspection. Detailed investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

It should be realized that the reported condition of the dam is based upon observations of field conditions at the time of the inspection along with data available to the inspection team.

It is also important to realize that the condition of a dam depends upon 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 continued care and inspection can there be assurance that an unsafe condition would be detected.

a. Safety

The spillway capacity of BoCo Mo Dam is found to be "Seriously Inadequate". The spillway/reservoir system will accommodate about 35 percent of the PMF without overtopping the dam. The safety of the embankment will be in jeopardy if the dam is overtopped. The embankment itself would be susceptible to erosion due to the high velocity of flow on its downstream slope which could lead to an eventual failure of the dam. The present erosion downstream of the toe of the dam, if left unattended, would be further eroded in the event the dam is overtopped which would further jeopardize the safety of the dam.

The dam and appurtenant structures appear to be in a poor condition and a quantitative evaluation of the safety of the embankment could not be made in view of the absence of seepage and stability analyses. The present embankment and appurtenant structures, however, appear to have performed satisfactorily since their construction without any apparent failures. There was no evidence observed of the dam ever being overtopped. The safety of the dam can be improved if the deficiencies described in Section 3.2 and 6.1a are properly corrected as described in Section 7.2b.

b. Adequacy of Information

Pertinent information relating to the design of the dam and appurtenant structures is completely lacking. The conclusions presented in this report are based on field measurements, past performance, and the present condition of the dam. Information on the design hydrology, hydraulic design, and the operation and maintenance of the dam, as well as seepage and stability analyses was not available for review. Lack of seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" is considered a deficiency.

c. Urgency

The items recommended in paragraph 7.2a and the first item in paragraph 7.2b should be pursued on a high priority basis. The remaining remedial measures recommended in Paragraph 7.2 should be accomplished within a reasonable period of time.

d. Necessity for Phase II Inspection

Based upon results of the Phase I inspection, and assuming that the remedial measures recommended in Paragraph 7.2 are undertaken, a Phase II inspection is not felt to be necessary.

7.2 Remedial Measures

a. Alternatives

There are several general options which may be considered to reduce the possibility of dam failure or to diminish the harmful aspects of such a failure. Some of these options are:

1. Increase the spillway capacity to pass the PMF without overtopping the dam.

2. Increase the height of the dam in order to pass the PMF without overtopping the dam; an investigation should also include studying the effects on the structural stability of the present embankment. The overtopping depth during the occurrence of the PMF, stated in Section 5.1d, is not the required or recommended increase in the height of the dam.

3. A combination of 1 and 2 above.

b. O & M Procedures

1. Further investigation of the flowing seepage should be undertaken to determine the cause and the seriousness of the seepage. The area should also be monitored to determine if the seepage is transporting embankment material. The investigation should be carried out under the direction of a qualified professional engineer.

2. The two areas of probable seepage should be monitored to detect any changes in turbidity, location, or quantity. Any changes should be reported and investigated further.

3. The observed cracking on the upstream and downstream slopes should be further investigated to ensure that it is not symptomatic of distress in the slopes or foundation. Large cracks should be properly repaired.

4. The wave erosion on the upstream berm and the two areas of erosion due to surface runoff downstream of the toe should be properly repaired and adequately protected from further damage.

5. The damage to the downstream and upstream slopes due to the grazing livestock and to the lack of an adequate grass cover should be properly repaired and adequately protected from further damage. The grazing livestock should be prevented access to the embankment. The vegetation on the slopes should be maintained periodically and large vegetation, such as bushes and trees, should be prevented from growing on the slope.

6. The corrosion of the upper segment of the inlet structure should be closely watched and monitored to detect any potential problems associated with this condition; also the interior of the spillway conduit should be watched and monitored on a periodic basis for a worsening of the distorted section of the conduit which could indicate a failure of the conduit and the "beading" condition on the upper surfaces of the conduit interior which indicates possible seepage along the pipe. Any worsening of these conditions should be investigated further in greater detail by a qualified engineer. Repairs should be made when deemed necessary.

7. The gate valve for the low level outlet should be properly maintained as recommended by the valve manufacturer and operated periodically. The area around the pipe should also be monitored to detect any potential problems which when detected should be investigated and properly repaired.

8. The trashrack-cattleguard structure should be maintained free of any accumulation of debris.

9. Seepage and stability analyses should be performed by a professional engineer experienced in the design and construction of earth dams.

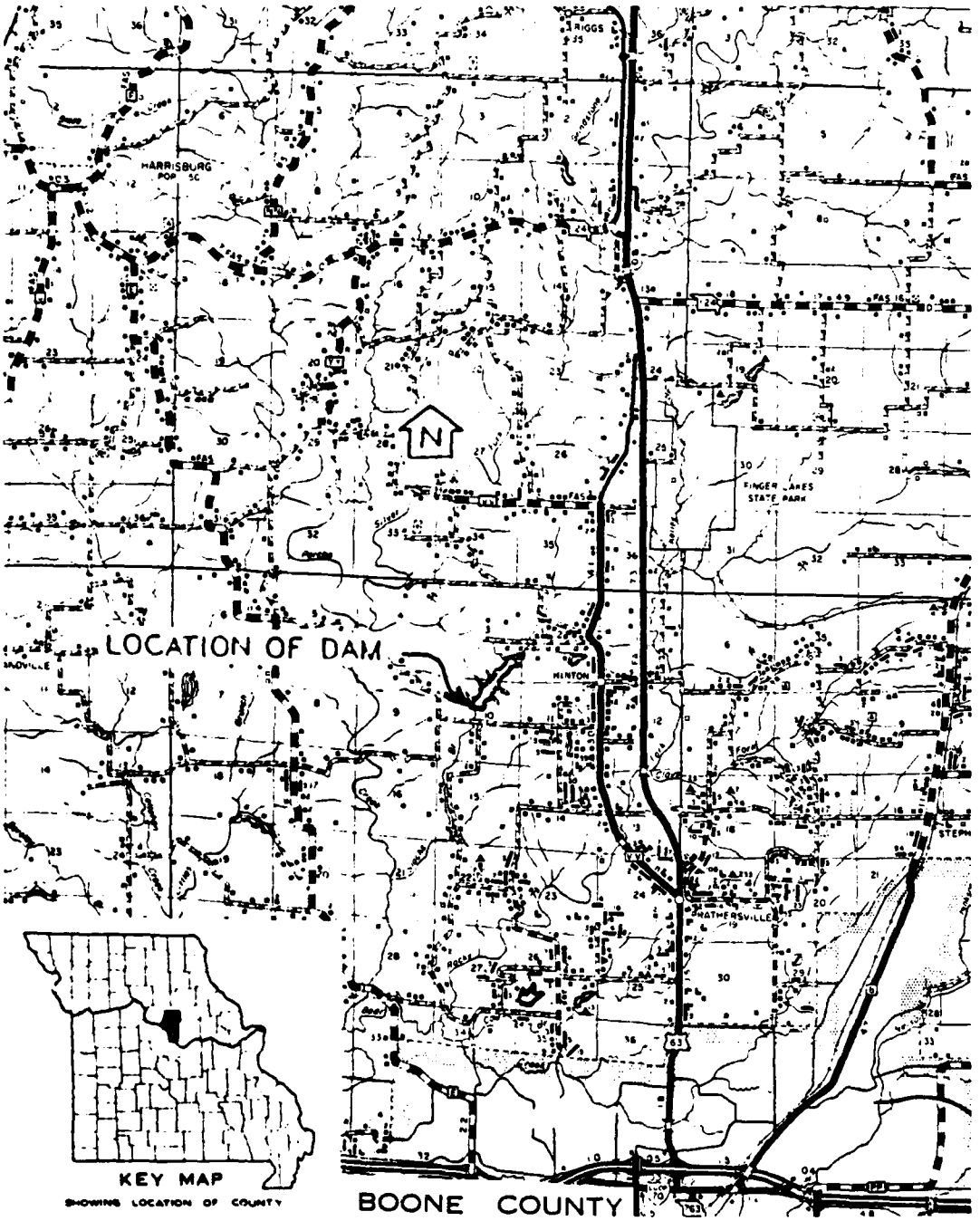
10. The owner should initiate the following programs:

    (a) Periodic inspection of the dam by a professional engineer experienced in the design and construction of earthen dams.

    (b) Set up a maintenance schedule and log all visits to the dam for operation, repairs and maintenance.

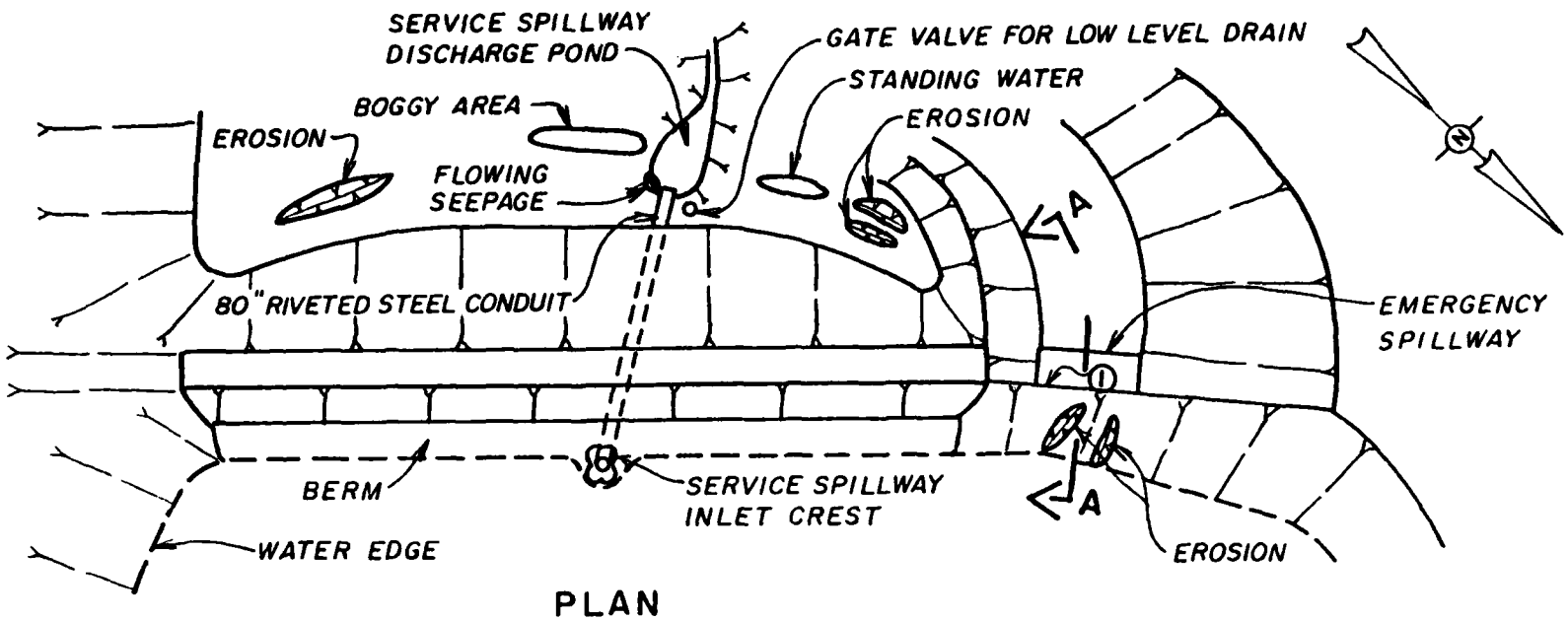
PLATES

PLATE 1

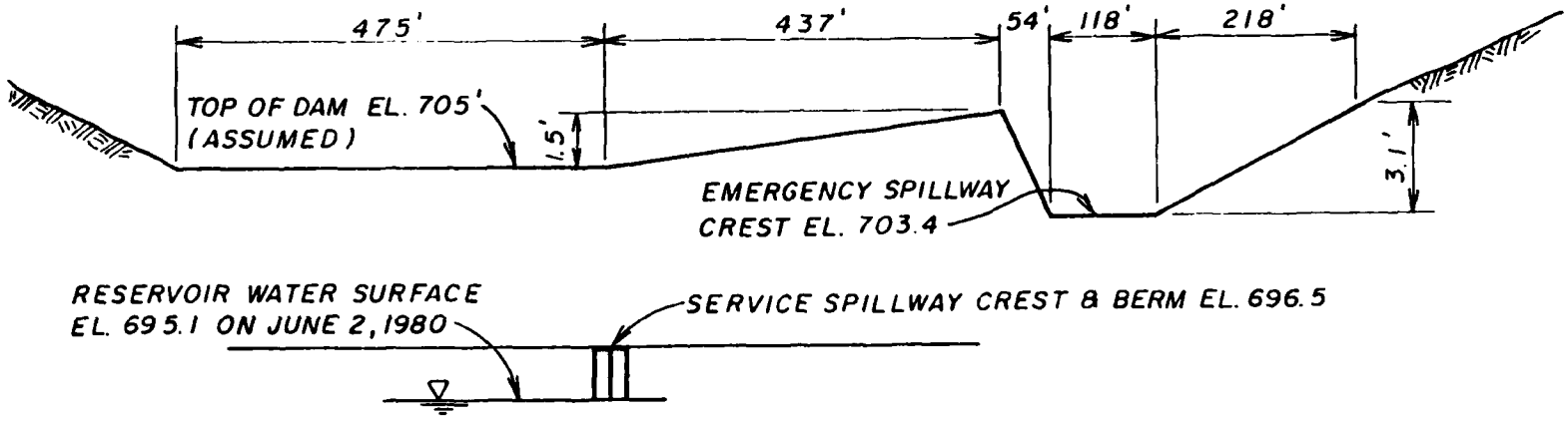


LOCATION MAP - BOCO MO DAM

MO. 10893



PLAN

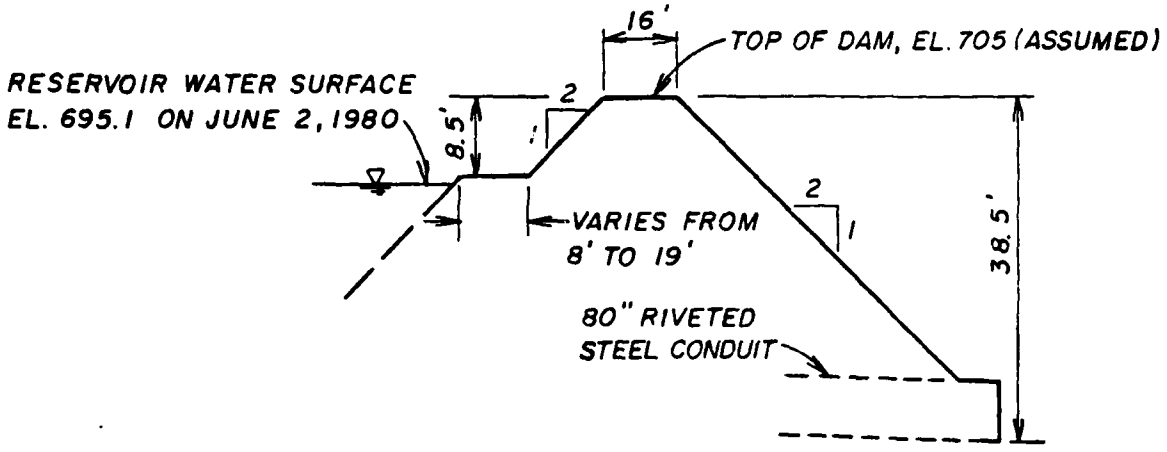


ELEVATION

SCALE:
HORIZ. 1" = 200'
VERT. NO SCALE

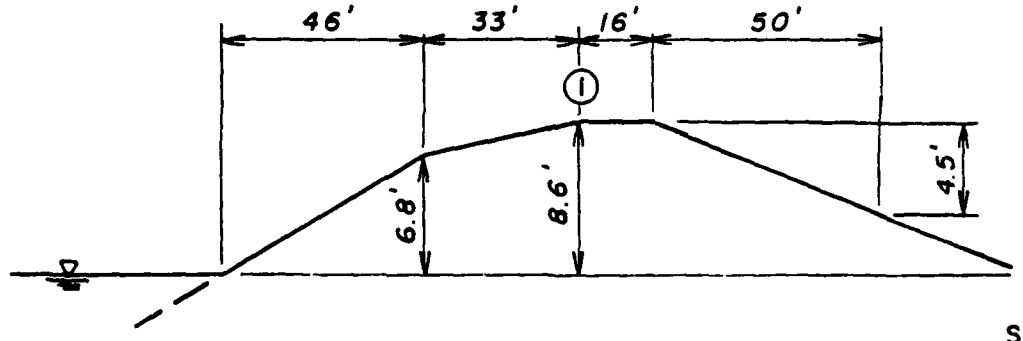
BOCO MO DAM (MO. 10893)
PLAN AND ELEVATION
(SHEET 1 OF 2)

PLATE 2



MAXIMUM SECTION

SCALE:
HORIZ. 1"=40'
VERT. 1"=20'



SCALE:
HORIZ. 1"=40'
VERT. 1"=10'

SECTION A-A

EMERGENCY SPILLWAY PROFILE

(1) *REFERENCE POINT SHEET 1 OF 2*

BOCO MO DAM (MO. 10893)
MAXIMUM SECTION OF EMBANKMENT
AND EMERGENCY SPILLWAY PROFILE
(SHEET 2 OF 2)

PLATE 4

SCALE

10 0 10 20 30 40 Miles

⊕ LOCATION OF DAM

NOTE: LEGEND OF THIS DAM IS ON PLATE 5

REFERENCE:

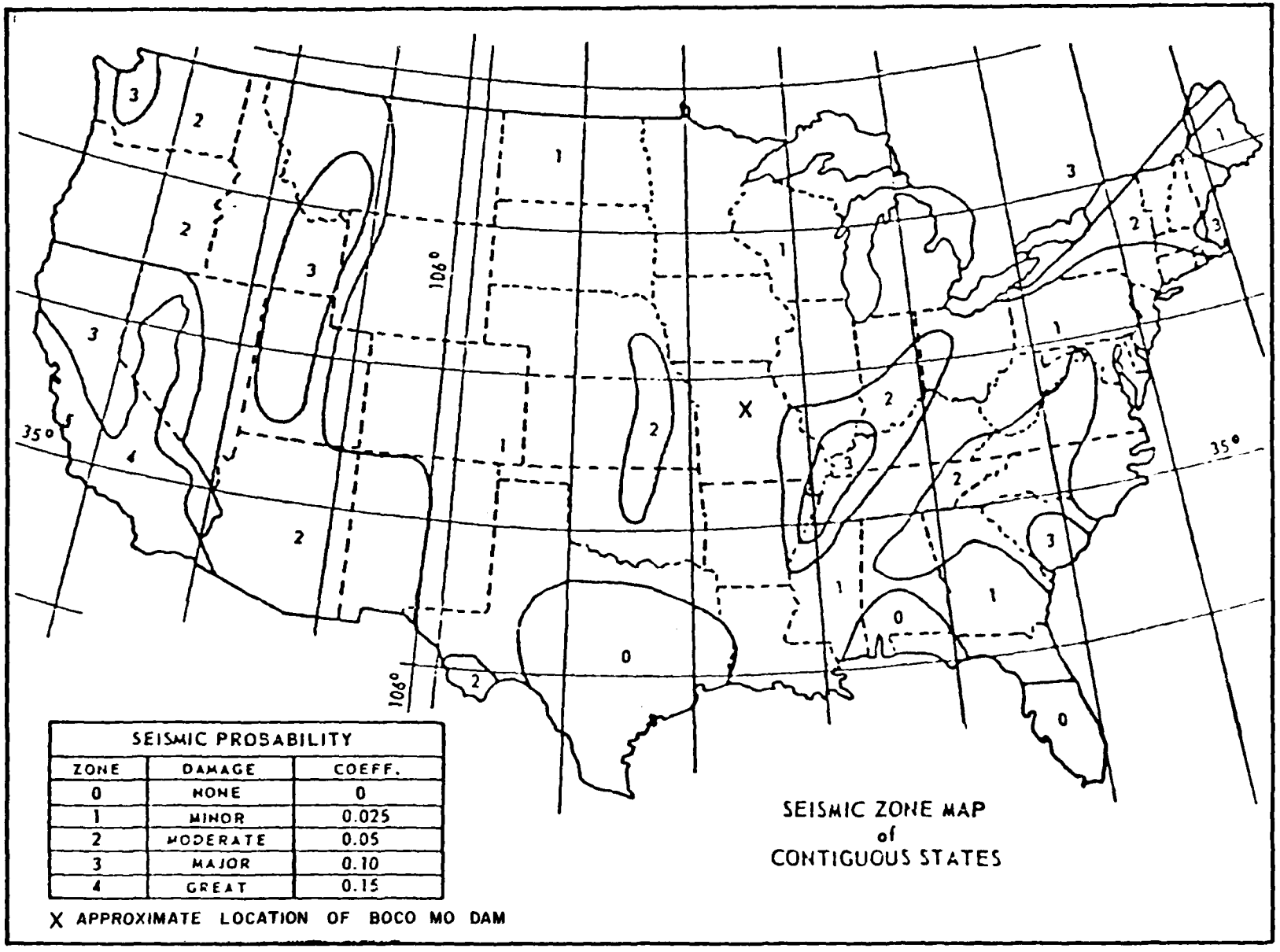
GEOLOGIC MAP OF MISSOURI
DEPARTMENT OF NATURAL RESOURCES
MISSOURI GEOLOGICAL SURVEY
KENNETH H. ANDERSON, 1979

REGIONAL GEOLOGICAL MAP OF BOCO MO DAM

BOCO MO DAM
PLATE 5

LEGEND

PERIOD	SYMBOL	DESCRIPTION
QUATERNARY	Qal	ALLUVIUM: SAND, SILT, GRAVEL
PENNSYLVANIAN	Pu	PENNSYLVANIAN UNDIFFERENTIATED
	Pm	MARMATON GROUP: CYCLIC DEPOSITS OF SHALE, LIMESTONE AND SANDSTONE
	Pcc	CHEROKEE GROUP: CYCLIC DEPOSITS OF SHALE, LIMESTONE AND SANDSTONE
MISSISSIPPIAN	Mo	KEOKUK - BURLINGTON FORMATION: CHERTY GRAYISH BROWN SANDY LIMESTONE
	Mk	CHOUTEAU GROUP: NORTHVIEW, COMPTON AND BACHELOR FORMATION (LIMESTONE AND SHALE)
DEVONIAN	D	SULPHUR SPRING GROUP: BUSHBERG SANDSTONE, GLEN PARK LIMESTONE, GRASSY CREEK SHALE
ORDOVICIAN	Osp	ST PETER SANDSTONE
	Ojc.	SMITHVILLE FORMATION, POWELL DOLOMITE



SEISMIC PROBABILITY		
ZONE	DAMAGE	COEFF.
0	NONE	0
1	MINOR	0.025
2	MODERATE	0.05
3	MAJOR	0.10
4	GREAT	0.15

X APPROXIMATE LOCATION OF BOCO MO DAM

SEISMIC ZONE MAP
of
CONTIGUOUS STATES

PLATE 6

LOCATION: NE¼ sec. 10, T. 49 N., R. 13 W., Browns Quadrangle.

GEOLOGIC SUITABILITY: Poor

GEOLOGIC SETTING:

The dam site (NW¼ SW¼ SE¼ sec. 10) is located in an area where faulting has affected bedrock. The most direct evidence of this faulting is an active sinkhole near the dam site. However, bedrock exposed upstream also points out the affect of faulting. In essence, this faulting of the bedrock has caused the overlying bedrock, the coal bearing strata, to drop relatively to the underlying bedrock, a massive limestone. This underlying bedrock formation is Mississippian age Burlington limestone. This formation, while prone to sinkhole development in many areas, is not characterized by sinkholes north of Columbia. Thus, development of the sinkhole at this site is believed to be primarily associated with faulting which has intensified solutioning and enlargment of caverns that has occurred in the Burlington limestone bedrock. The overlying bedrock, exposed upstream, in which coal beds occur, is a part of lower Pennsylvanian age strata. The relatively thick limestone, the Ardmore, is underlain by the Crowburg coal. These strata which have a relative dip toward the southwest do not occur at the dam site because of the affects of faulting. Further upstream, the underlying Mississippian or Burlington limestone is again present. However, this time there is a normal sequence of bedrock with the overlying Pennsylvanian age formations on the nearby hillslopes where strip mining has taken place. Thus, no faulting or extreme dipping of rock strata occurs in this portion of the valley.

Soil characteristics change relative to the change in underlying bedrock formations. Where the Burlington or Mississippian limestone is present, the soil is a stoney clay with 50% or more stone made up of chert fragments which are residual from the weathering of the underlying limestone. Because of the irregular limestone surface soil thickness will vary from a few feet to 15 or 20 feet. Where the Pennsylvanian sediments are present, the influence of a predominately shale bedrock sequence is paramount. Here the soil cover is generally stone free. The underlying shale may be moderately weathered so that a thickness of 4 to 6 feet of clay rich material can be obtained before sound shale is encountered.

RECOMMENDATIONS:

Basically, the site is poor to consider, even for further exploration. The underlying Burlington limestone is characterized by solution openings which are formed in a random pattern. These cannot be predicted as can the solution openings in many rock formations where interconnected horizontal and vertical openings exist. The solution openings that characterized the development of sinkholes in the Burlington are not related to a definite vertical or horizontal fracture or parting plane pattern. Thus, it is essentially impossible to find an opening and consequently extremely difficult to close such an opening by grouting. The active sinkhole points out the severity in which underground solution development has taken place.

While there is the possibility of moving the dam site upstream, a leakage hazard still exists. The possible leakage or movement of water along the bedrock of the Pennsylvanian age strata would be intensified with the downstream inclination of these rock layers. The contact between the Ardmore limestone and the underlying fissile shale (slate) is a typical leakage horizon. The possibility of water moving from the exposed bedrock within the lake area downstream into the area affected by faulting cannot be discounted. If this should occur, the water leaking from the lake could move laterally even away from the valley and hinder a grout program. It should be noted, however, that grouting would be more successful in the Pennsylvanian sediments then the underlying Burlington limestone as previously described.

If further interest exists in additional exploration of the dam site, it is suggested that several holes be drilled into the bedrock along the floodplain. These holes oriented approximately parallel with the stream channel should be spaced on approximate 200 feet centers. Closer spacing should then be accomplished after the preliminary exploration was completed. Holes should be drilled from 20 to 30 feet into the underlying bedrock. It is suggested that coring would not be necessary. However, preparation should be made for pressure testing. Close monitoring of the drilling should be accomplished so that zones of water loss or soft areas, possible affected by faulting, could also be noted.

SUMMARY:

The site is poor for a lake on Slacks Creek, although it is possible to move the dam upstream. However, if this is considered, a detailed subsurface

exploration program should be conducted. Burlington limestone is present in the stream channel upstream to the mine road crossing. Consequently, considerable extent of limestone which could cause water leakage exists and thus, the exploration steps should be thoroughly completed. Sites on tributary valleys are feasible with the exception of those valleys in the immediate area that is affected by faulting.

J. Hadley Williams, Chief
Applied Engineering & Urban Geology Section
Missouri Geological Survey
November 8, 1972

APPENDIX A

PHOTOGRAPHS TAKEN DURING INSPECTION

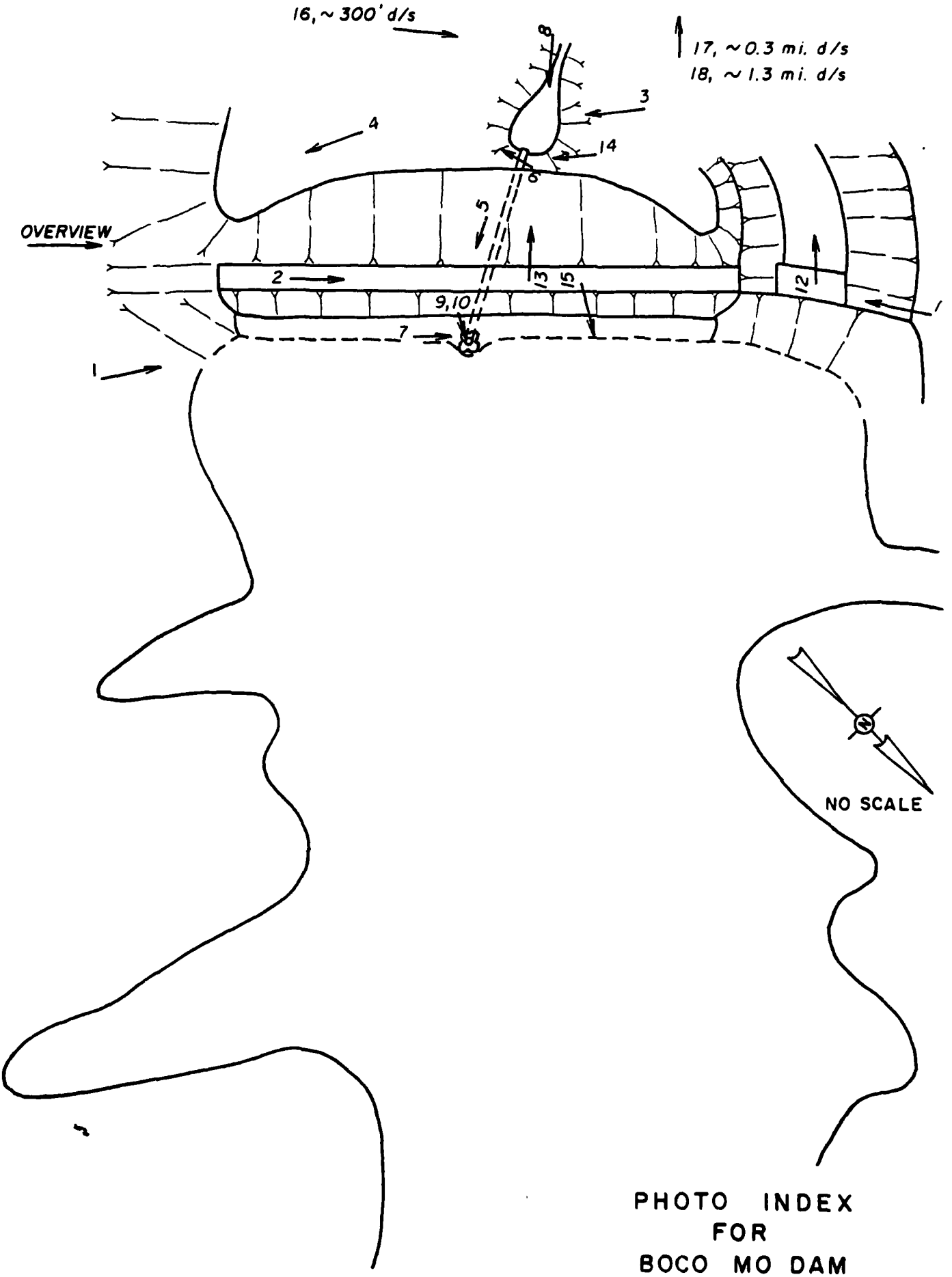


PHOTO INDEX
FOR
BOCO MO DAM

BoCo Mo Dam

Photographs

Photo 1 - Overview of the upstream slope showing the location of the service spillway drop inlet and the wave erosion along the berm.

Photo 2 - View of the top of dam looking toward the right abutment.

Photo 3 - View of the downstream slope from near the service spillway outlet showing the boggy area near the outlet (right side of Photo), the large erosion gully on the left abutment (see Photo 4), and a portion of the pool at the service spillway outlet.

Photo 4 - View of the large erosion gully on the left downstream abutment.

Photo 5 - Closeup view of the downstream slope showing the cattle damage, some minor cracking and the inadequate grass cover.

Photo 6 - View of the flowing seepage to the left of the service spillway outlet.

Photo 7 - View of the drop inlet of the service spillway showing the trashrack-cattle guard combination, the dumped concrete collars and the cloverleaf shape of the inlet.

Photo 8 - View of the outlet of the service spillway from the downstream end of the stilling pool. Note location of the low level drain to the left (in Photo) of the outlet.

Photo 9 - View of the inside of the drop inlet of the service spillway showing the transition from the cloverleaf shaped upper segment to the circular shaped lower segment.

Photo 10 - Closeup view of the steel lining of the service spillway drop inlet showing the corrosion along the joint and on the backside of the lining.

Photo 11 - View of the emergency spillway control section looking toward the embankment, and area of sparse protective vegetation.

Photo 12 - View of the emergency spillway discharge channel from the control section showing areas of sparse protective vegetation and the intersection with downstream channel tributary.

Photo 13 - View of the downstream channel.

Photo 14 - View of the low level drain gate valve and outlet pipe of the drain.

Photo 15 - View of the reservoir and rim.

Photo 16 - View of progressive sinkhole located approximately 300 feet downstream of the dam.

Photo 17 - View of a dwelling approximately 0.3 miles downstream of the dam with the downstream channel on the right side of the photo.

Photo 18 - View of a dwelling approximately 1.3 miles downstream of the dam with the downstream channel on the right side of the photo.

Photo 1

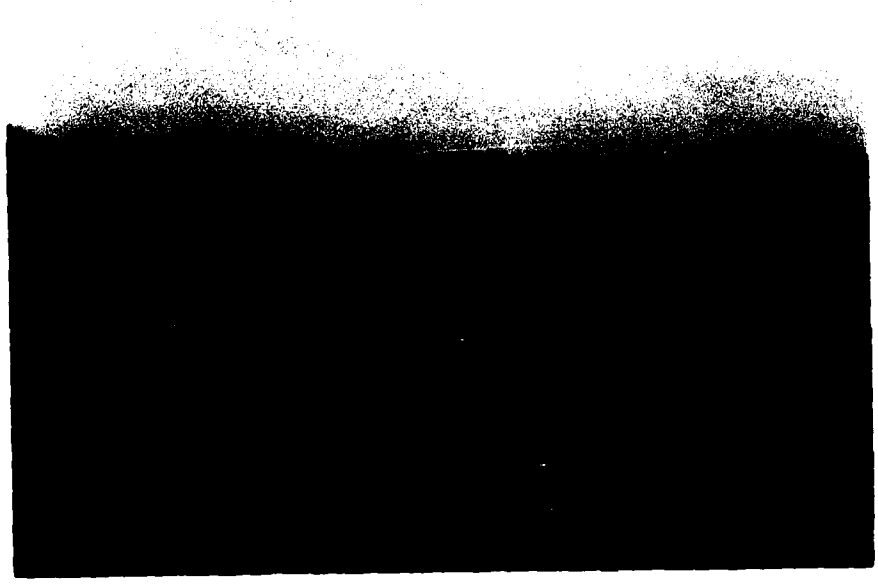


Photo 2

Photo 3

Photo 4

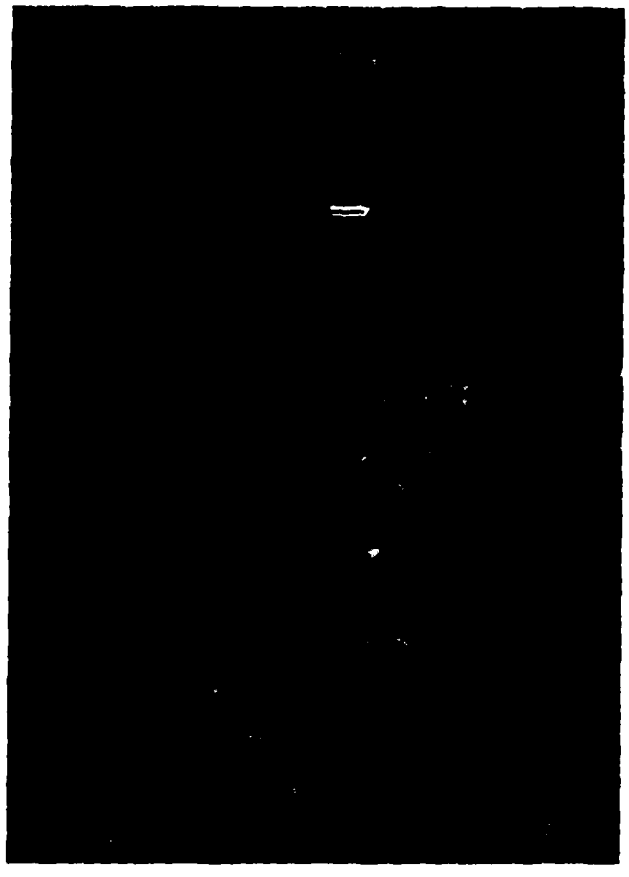


Photo 5

Photo 6

Photo 7

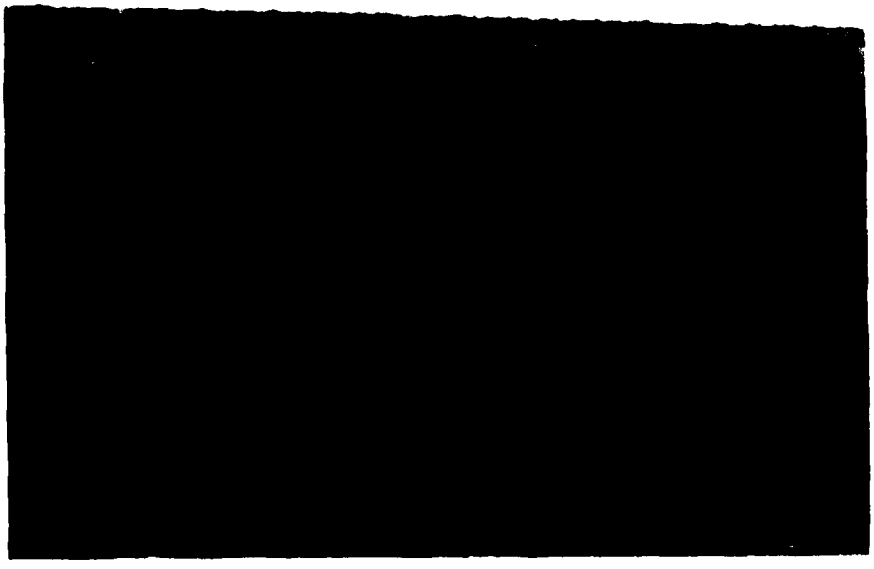


Photo 8

Photo 9

Photo 10

Photo 11

Photo 12

Photo 13

Photo 14

Photo 15

Photo 16

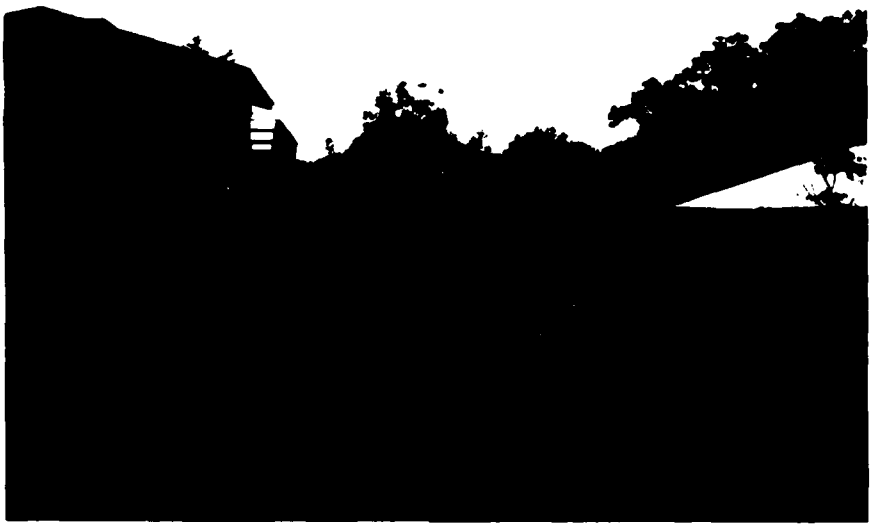


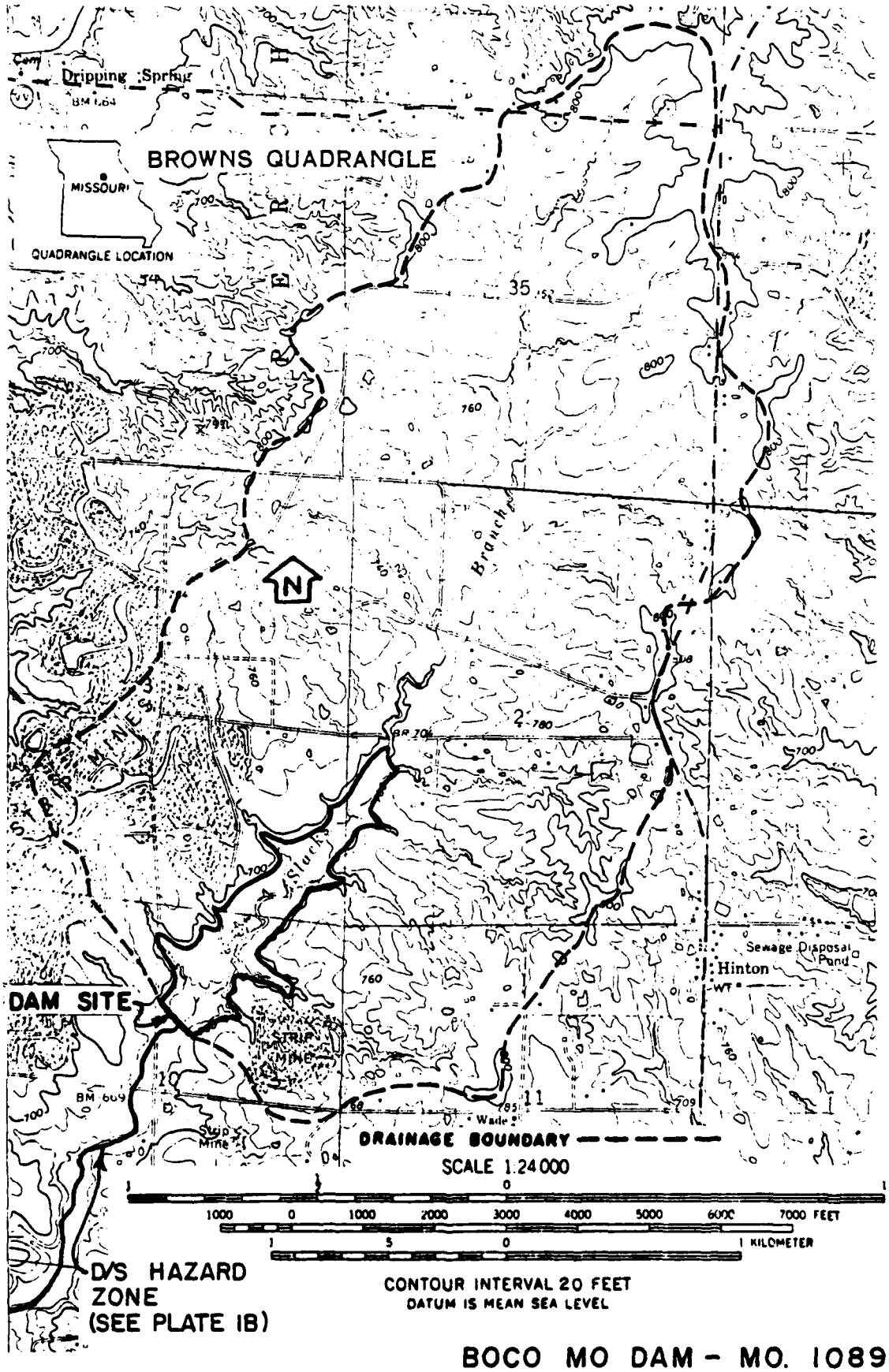
Photo 17

Photo 18

APPENDIX B

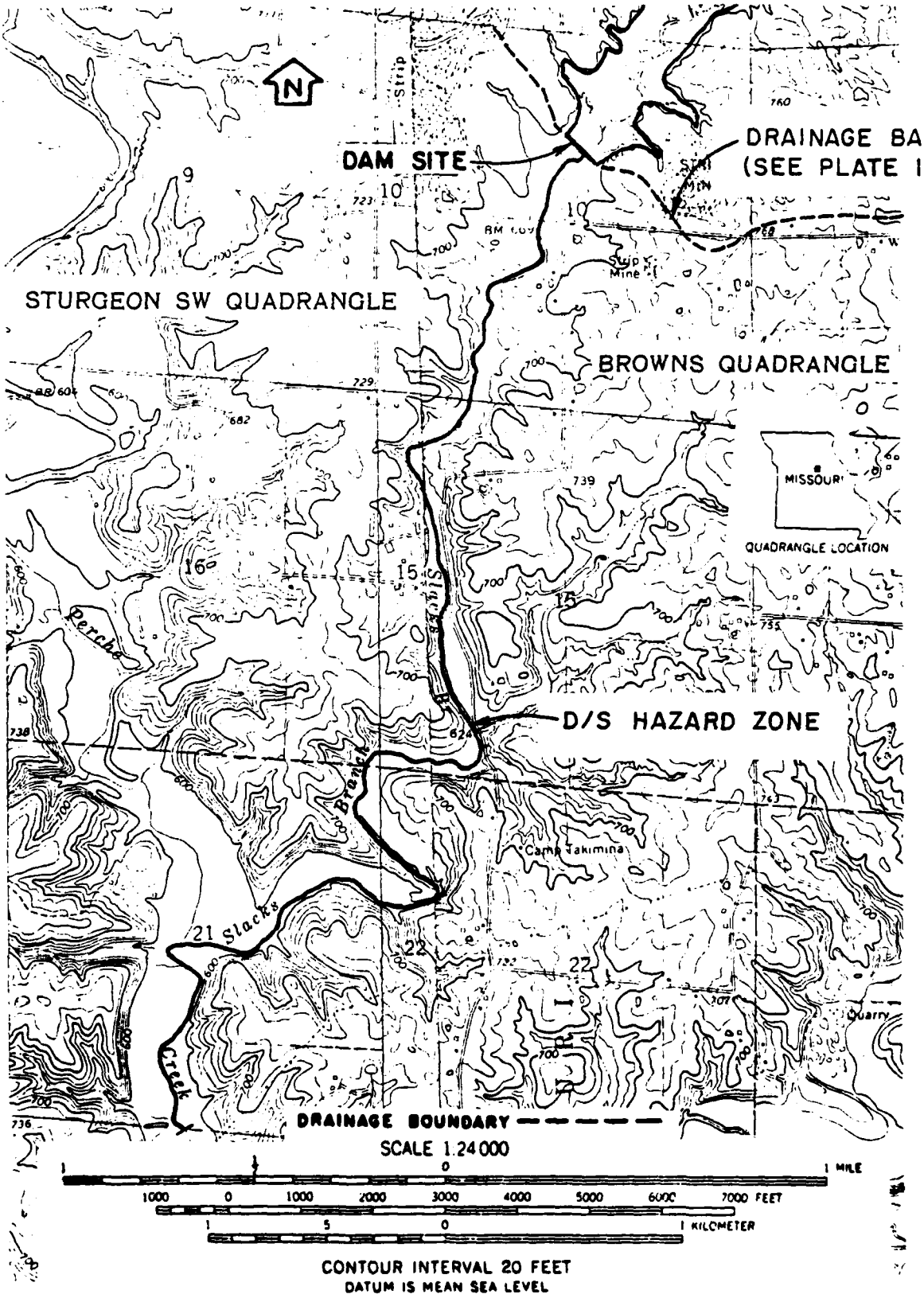
HYDROLOGIC AND HYDRAULIC COMPUTATIONS

PLATE IA, APPENDIX B



BOCO MO DAM - MO. 10893
DRAINAGE BASIN
AND
DOWNSTREAM HAZARD ZONE

PLATE 1B, APPENDIX B



BOCO MO DAM - MO. 10893
DRAINAGE BASIN
AND
DOWNSTREAM HAZARD ZONE

ECI-4 **PRC ENGINEERING CONSULTANTS, INC.**

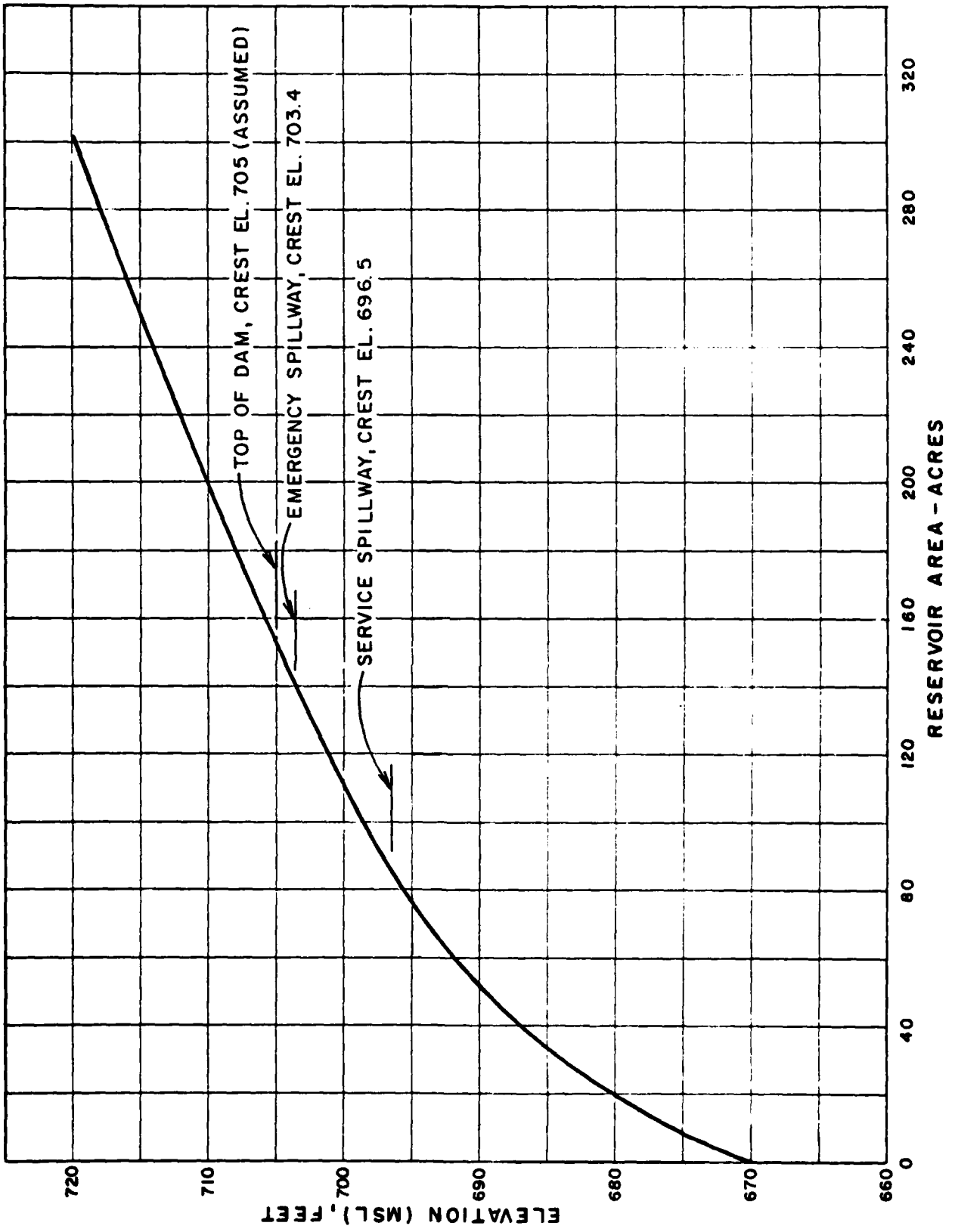
DAM SAFETY INSPECTION - MISSOURI SHEET NO. 1 OF 1

DAM NAME: BaCa Mo DAM ID NO.: MO 10992 JOB NO. 1263

RESERVOIR ELEVATION - AREA DATA BY JFS DATE 4/

ELEV. (M.S.L.) (Ft.)	RESERVOIR SURFACE AREA (Acres)	REMARKS
670	0	Estimated Streambed Elevation at Dam
680	20	Measured from USGS Map
690	61.5	Measured from USGS Map
696.5	86	Service Spillway Crest
703.4	140	Emergency Spillway Crest
705	153	Top of Dam (Assumed)
710	290	Interpolated from Curve
720	392	Measured from USGS Map

PLATE 2, APPENDIX B



BOCO MO DAM (MO. 10893)
RESERVOIR ELEVATION-AREA CURVE

ECI-4 **PRC ENGINEERING CONSULTANTS, INC.**

DAM SAFETY INSPECTION / MISSOURI — SHEET NO. 1 OF 1

DAM NAME: B a C r No (MO 0893) — JOB NO. 1263

UNIT HYDROGRAPH PARAMETERS — BY JEK — DATE

1) DRAINAGE AREA, $A = 3.18$ sq. mi = (2,035 acres)

2) LENGTH OF STREAM, $L = (7.5" \times 2000' = 15{,}000') = 2.84$ mi.

3) ELEVATION AT DRAINAGE DIVIDE ALONG THE LONGEST STREAM,

$H_1 = 822$

4) ELEVATION OF RESERVOIR AT SPILLWAY CREST, $H_2 = 696.5$

5) ELEVATION OF CHANNEL BED AT 0.85L, $E_{85} = 767$

6) ELEVATION OF CHANNEL BED AT 0.10L, $E_{10} = 698$

7) AVERAGE SLOPE OF THE CHANNEL, $S_{AVG} = (E_{85} - E_{10}) / 0.75L = (767-698)/11{,}250 = 0.006$

8) TIME OF CONCENTRATION:

A) BY KIRPICH'S EQUATION,

$t_c = [(11.9 \times L^3)/(H_1 - H_2)]^{0.385} = [(11.9 \times (2.84)^3)/(822-696.5)]^{0.385} = 1.35$ hr.

B) BY VELOCITY ESTIMATE,

SLOPE = 0.006 $\Rightarrow$ AVG. VELOCITY = 2 fps

$t_c = L/V = 15{,}000$ ft $/ (2$ ft/s $\times 3600$ s/hr$) = 2.08$ hr

USE $t_c = 1.35$ hr

9) LAG TIME, $t_l = 0.6\, t_c = 0.6(1.35) = 0.81$ hr

10) UNIT DURATION, $D \leq t_l / 3 = 0.81$ hr$/3 = 0.27$ hr. $\neq 0.083$ hr.

USE $D = 0.25$ hr

11) TIME TO PEAK, $T_p = D/2 + t_l = 0.25/2 + 0.81 = 0.94$ hr.

12) PEAK DISCHARGE,

$q_p = (484 \times A) / T_p = 484 \times 3.18$ mi^2/0.94 hr $= 1{,}637$ cfs

ECI-4 **PRC ENGINEERING CONSULTANTS, INC.**

DAM SAFETY INSPECTION / MISSOURI - 1980 SHEET NO. 1 OF 1

DAM NAME: BoCo Mo DAM (MO 10893) JOB NO. 1263

CURVE NUMBER DETERMINATION BY JFK DATE 5-80

I) SOIL GROUP

WATERSHED SOILS IN THE BASIN CONSIST OF:

WELLER (C) - KESWICK (D) - LINDLEY (C) - MANDEVILLE (B)

GROUP C SOILS SEEM TO PREDOMINATE THE BASIN. THEREFORE, ASSUME GROUP C SOILS FOR THE ENTIRE WATERSHED FOR HYDROLOGIC PURPOSES.

II) COVER COMPLEX

ASSUMED LAND USE	ASSUMED HYDROLOGIC CONDITION	PER CENT AREA	CN (AMC II)
PASTURE	FAIR	60	79
WOODS	FAIR	30	73
Row Crops (Contoured)	GOOD	10	82

III) CURVE NUMBER

WEIGHTED AVERAGE CN = 78 FOR AMC II

CURVE NUMBER = 90 FOR AMC III

ECI-4 **PRC ENGINEERING CONSULTANTS, INC.**

DAM SAFETY INSPECTION / MISSOURI — SHEET NO. 1 OF 1
DAM NAME: BoCo Mo DAM (MO 10893) — JOB NO. 1263
PROBABLE MAXIMUM PRECIPITATION — BY JFK DATE 6/16/80

HLC

DETERMINATION OF PMP

1) Determine drainage area of the basin

D.A. = 3.18 sq. mi

2) Determine PMP Index Rainfall (for D.A. = 200 sq. mi. & 24 hr. duration)

Location of centroid of basin,

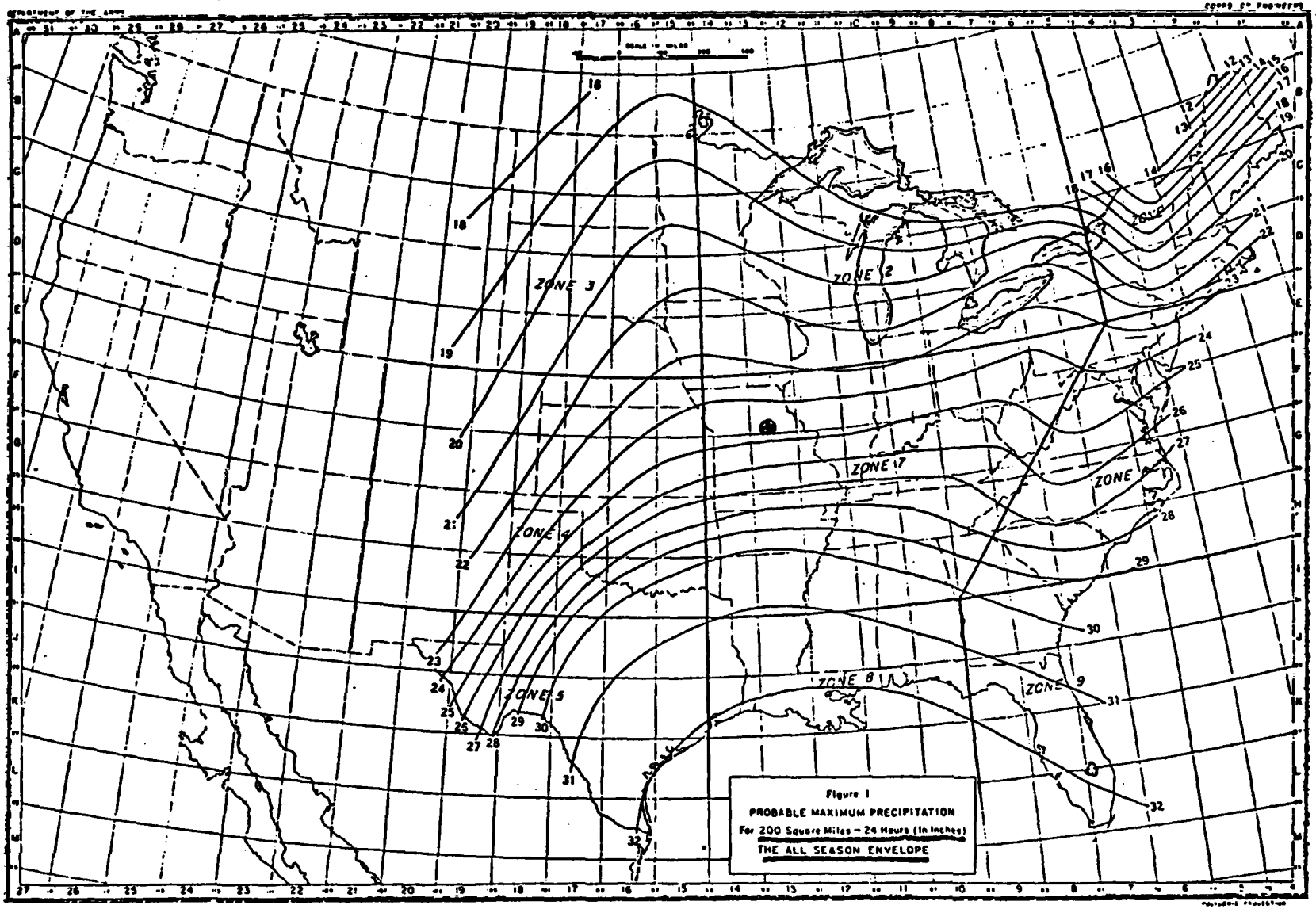
Long. = 92° 21' 54" Lat. = 39° 3' 12"

PMP = 24.7" (from Fig. 1, HMR 33)

Zone = 7

3) Determine basin rainfall in terms of percentage of PMP Index Rainfall for various durations.
(from Fig. 2, HMR 33)

Duration (Hrs.)	Percent of Index Rainfall (%)	Total Rainfall (Inches)	Rainfall Increments (Inches)	Duration of Increment (Hrs.)
6	100	24.7"	24.7"	6
12	120	29.6"	4.9"	6
24	130	32.1"	2.5"	12
48	140	34.6"	2.5"	24



⊕ LOCATION OF BASIN CENTROID

BOCO MO DAM (MO. 10893)

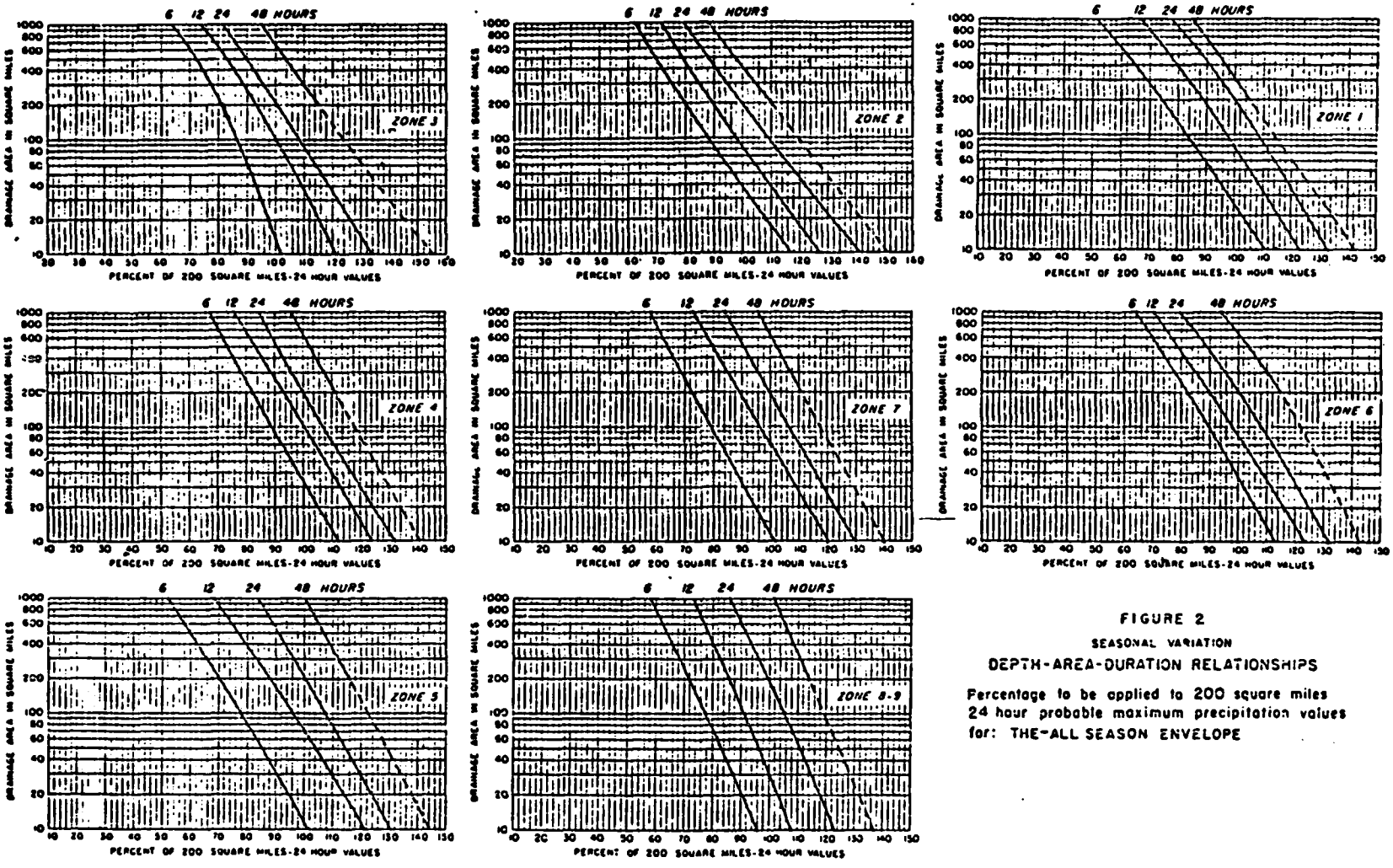


FIGURE 2

SEASONAL VARIATION

DEPTH-AREA-DURATION RELATIONSHIPS

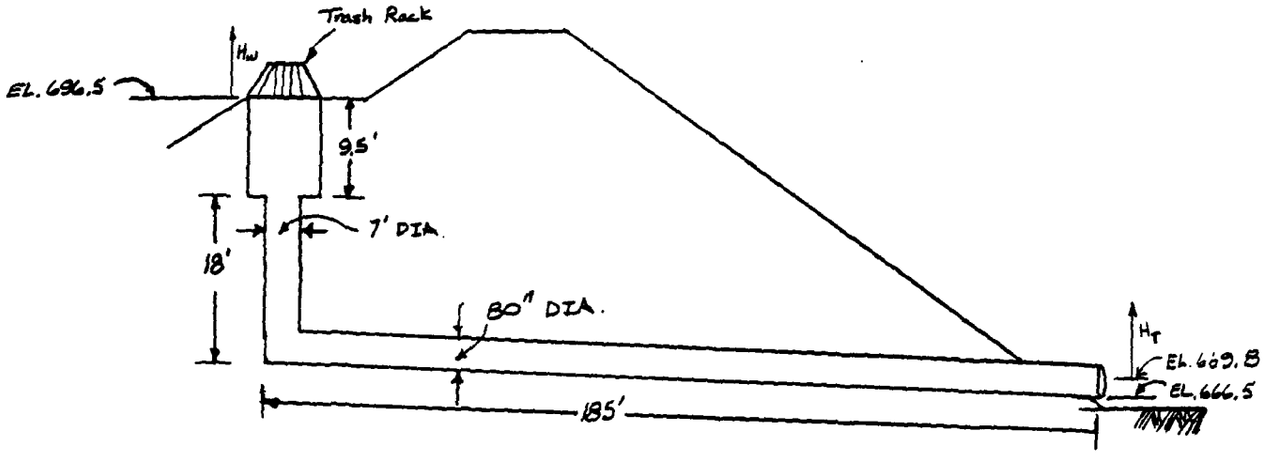
Percentage to be applied to 200 square miles 24 hour probable maximum precipitation values for: THE-ALL SEASON ENVELOPE

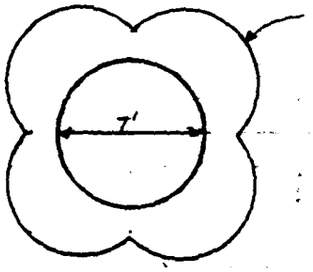
EC1-4 **PRC ENGINEERING CONSULTANTS, INC.**

DAM SAFETY INSPECTION / MISSOURI - 1980 — SHEET NO. 1 OF 3

EOCA MO DAM (MO. 10893) — JOB NO 1263

SERVICE SPILLWAY RATING CURVE — BY JFK HLC DATE 6/16/80





for Weir Flow:

$Q = C L H_w^{1.5}$, $L = 4(\pi r) = 4(\pi \times 3.5) = 44$

$C = 3.6$ (assumed)

H_w = W.S. ELEV - 696.5

$= 158.4\ H_w^{1.5}$

for Orifice Flow:

$Q = CA\sqrt{2gH_T}$, $A = \pi r^2 = \pi (3.33)^2 = 34.9$

$C = 0.6$

H_T = W.S. ELEV - 665.3

$= 168\sqrt{H_T}$

for Pressure Flow:

$H_T = (K_{entrance} + K_{trashrack} + K_{bend\ \&\ contraction} + K_{friction} + K_{exit})\ V^2/2g$

$V = \left(\frac{2g}{\Sigma K} H_T\right)^{1/2}$

$Q = VA$, where

$K_{entrance} = 0.5$

$K_{trashrack} = 0.25$

$K_{friction} = f \frac{L}{D}$ ($\epsilon/D = 0.005/6.67 = 0.0007$, $f = 0.0185$: use the same f value for all three sections of pipe)

$K_{f,clover} = f \frac{L}{D}$, $\frac{A}{C} = \frac{\pi r^2}{2\pi r} = \frac{r}{2}$

$r = 2A/C$

$D = 2r = 4A/C$

$A_{clover} = (7')^2 + 4(\pi(3.5')^2/2) = 126$

$= 0.0185 \frac{9.5}{4(126/44)} = 0.015$

$K_{f,7'} = f \frac{L}{D}$, $A_{7'} = \pi(3.5')^2 = 38.48$

$= 0.0185 \frac{18}{7} = 0.048$

$K_{f,80"} = f \frac{L}{D}$, $A_{80"} = 34.91$

$= 0.0185 \frac{185}{6.67} = 0.513$

$K_{bend\ \&\ contraction} = 0.5$

$K_{exit} = 1.0$

$\Sigma K = 0.5 + 0.25 + 0.015 \left(\frac{34.9}{126}\right)^2 + 0.048 \left(\frac{34.9}{38.48}\right)^2 + 0.513 + 0.5 + 1.0$

$= 2.804$

$$V = \left(\frac{2g}{2.804} H_T\right)^{1/2}$$

$$= 4.79 \sqrt{H_T}$$

$$Q = VA = 4.79\,(34.9)\sqrt{H_T}$$

$$= 167.3 \sqrt{H_T}$$

at W.S. ELEV = 697

weir flow, $Q = 158\,(0.5)^{1.5} = 56$ cfs

at W.S. ELEV = 698

weir flow, $Q = 158\,(1.5)^{1.5} = 290$ cfs

at W.S. ELEV = 699

weir flow, $Q = 158\,(2.5)^{1.5} = 625$ cfs ← weir flow controls

orifice flow, $Q = 168\,(29.2)^{1/2} = 908$ cfs

pressure flow, $Q = 167.3\,(29.2)^{1/2} = 904$ cfs

at W.S. ELEV = 700

weir flow, $Q = 158\,(3.5)^{1.5} = 1035$ cfs

orifice flow, $Q = 168\,(30.2)^{1/2} = 923$ cfs

pressure flow, $Q = 167.3\,(30.2)^{1/2} = 919$ cfs ← pressure flow controls

∴ For W.S. ELEV. = 700 and above, pressure flow controls and

$Q = 167.3 \sqrt{H_T}$ where H_T = W.S. ELEV - 669.8

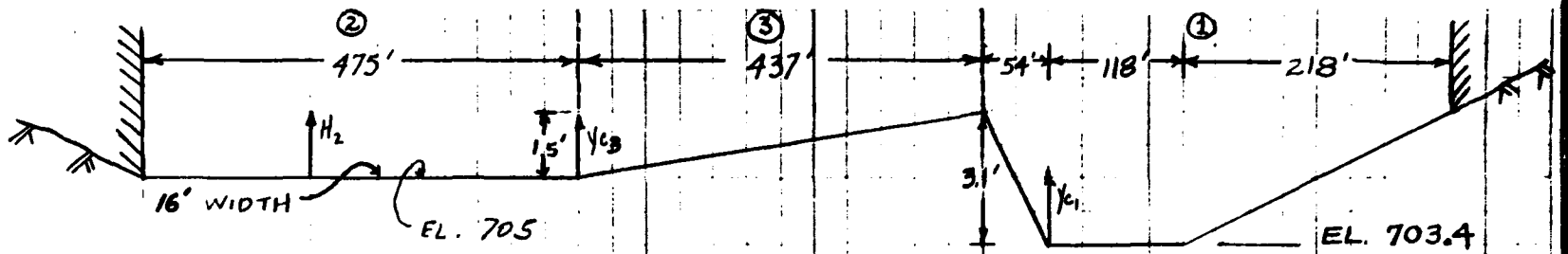
PRC ENGINEERING CONSULTANTS, INC.

DAM SAFETY INSPECTION / MISSOURI - 1980 SHEET NO. 1 OF 3

BoCo Mo Dam (MO 10893) JOB NO. 1263

EMERGENCY SPILLWAY AND OVERTOP RATING CURVE BY JFK DATE 6/11/80

ECI-4



AREA ①:

for $yc_1 < 3.1$, $T_1 = 87.74\, yc_1 + 118$

$A_1 = (yc_1/2)[T + 118]$

for $yc_1 \geq 3.1$, $T_1 = 390$

$A_1 = 390\, yc_1 - 421.61$

AREA ②:

H_2 = W.S. ELEV - 705

AREA ③:

for $yc_3 < 1.5$, $yc_3 = 4/5\, H_2$

$T_3 = 291.33\, yc_3$

$A_3 = (T)\, yc_3/2$

for $yc_3 \geq 1.5$, $yc_3 = 2/3(H_2 + 0.375)$

$T_3 = 437$

$A_3 = 437\,(yc_3 - 0.75)$

yc_1	T_1	A_1	$V_1 = \left(\frac{A_1 g}{T_1}\right)^{1/2}$	$Q_1 = VA_1$	$V_1^2/2g$	W.S. ELEV $= yc_1 + V_1^2/2g + 703.4$	H_2	C_2	L_2	$Q_2 = C_2 L_2 H_2^{1.5}$	yc_3	T_3	A_3	$Q_3 = \left(\frac{A_3^3 g}{T_3}\right)^{1/2}$	$Q_{TOTAL} = Q_1 + Q_2 + Q_3$
0	0	0	0	0	0	703.4	—	—	—	—	—	—	—	—	0
0.5	161.9	70.0	3.73	261	0.22	704.1	—	—	—	—	—	—	—	—	261
1	205.7	161.9	5.03	815	0.39	704.8	—	—	—	—	—	—	—	—	815
1.5	249.6	275.7	5.96	1644	0.55	705.5	0.5	3.01	475	505.5	0.40	116.5	23.3	59	2208.5
2	293.5	411.5	6.72	2765	0.70	706.1	1.1	3.04	475	2192	0.88	254.4	112.8	425	5382
3	381.2	748.8	7.95	5955	0.99	707.4	2.4	3.05	475	5386.5	1.85	437	480.7	2861	14202.5

ECI-4 **PRC ENGINEERING CONSULTANTS, INC.**

DAM SAFETY INSPECTION / MISSOURI - '980 SHEET NO. 2 OF 3

BeCo Mo DAM (MO. 10893) JOB NO. 1263

EMERGENCY SPILLWAY AND OVERTOP RATING CURVE (cont'd) BY JPK DATE 6/11/80

	Y_{c_1}	T_1	A_1	$V_1 = \left(\frac{A_1 g}{T_1}\right)^{1/2}$	$Q_1 = V_1 A_1$	$V_1^2/2g$	W.S. ELEV $Y_{c_1} + V_1^2/2g + 703.4$	H_2	C_2	L_2	$Q_2 = C_2 L_2 H_2^{1.5}$	Y_{c_3}	T_3	A_3	$Q_3 = \left(\frac{A_3^3 g}{T_3}\right)^{1/2}$	$Q_{total} = Q_1 + Q_2 + Q_3$
4		390	1138.4	9.69	11037	1.46	708.9	3.9	3.08	475	11267.9	2.85	437	911.7	7546	29850.9
5		390	1528.4	11.23	17169	1.96	710.4	5.4	3.09	475	18418	3.85	437	1351.7	13535	49122
6		390	1918.4	12.58	24144	2.46	711.9	6.9	3.09	475	26602.7	4.85	437	1791.7	20587	71333.7

ECI-4 **PRC ENGINEERING CONSULTANTS, INC.**

DAM SAFETY INSPECTION / MISSOURI - 1980 SHEET NO. 3 OF 3

BoCo Mo DAM (MO 10893) JOB NO. 1263

EMERGENCY SPILLWAY SLOPE BY JFK DATE 6/17/80

CHECK EMERGENCY SPILLWAY SLOPE FOR CRITICAL FLOW

$S_b = 4.5'/50' = 0.09$

for $y = 0.5'$,

$A = 70$
$R = 0.43$
$Q = 261$
$n = 0.025$

$$S_c = \left[Q \frac{n}{1.49} \frac{1}{A} \frac{1}{R^{2/3}}\right]^2$$

$$S_c = \left[261 \frac{0.025}{1.49} \frac{1}{70} \frac{1}{(0.43)^{2/3}}\right]^2$$

$S_c = 0.0121 < S_b$ O.K.

for $y = 3'$,

$A = 748.8$
$R = 1.96$
$Q = 5955$
$n = 0.025$

$$S_c = \left[5955 \frac{0.025}{1.49} \frac{1}{748.8} \frac{1}{(1.96)^{2/3}}\right]^2$$

$S_c = 0.0072 < S_b$ O.K.

∴ Critical depth assumption at emergency spillway is valid

ECI-4 **PRC ENGINEERING CONSULTANTS, INC.**

DAM SAFETY INSPECTION / MISSOURI - 1980 SHEET NO. 1 OF 1

BoCo Mo DAM (MO. 10893) JOB NO. 1263

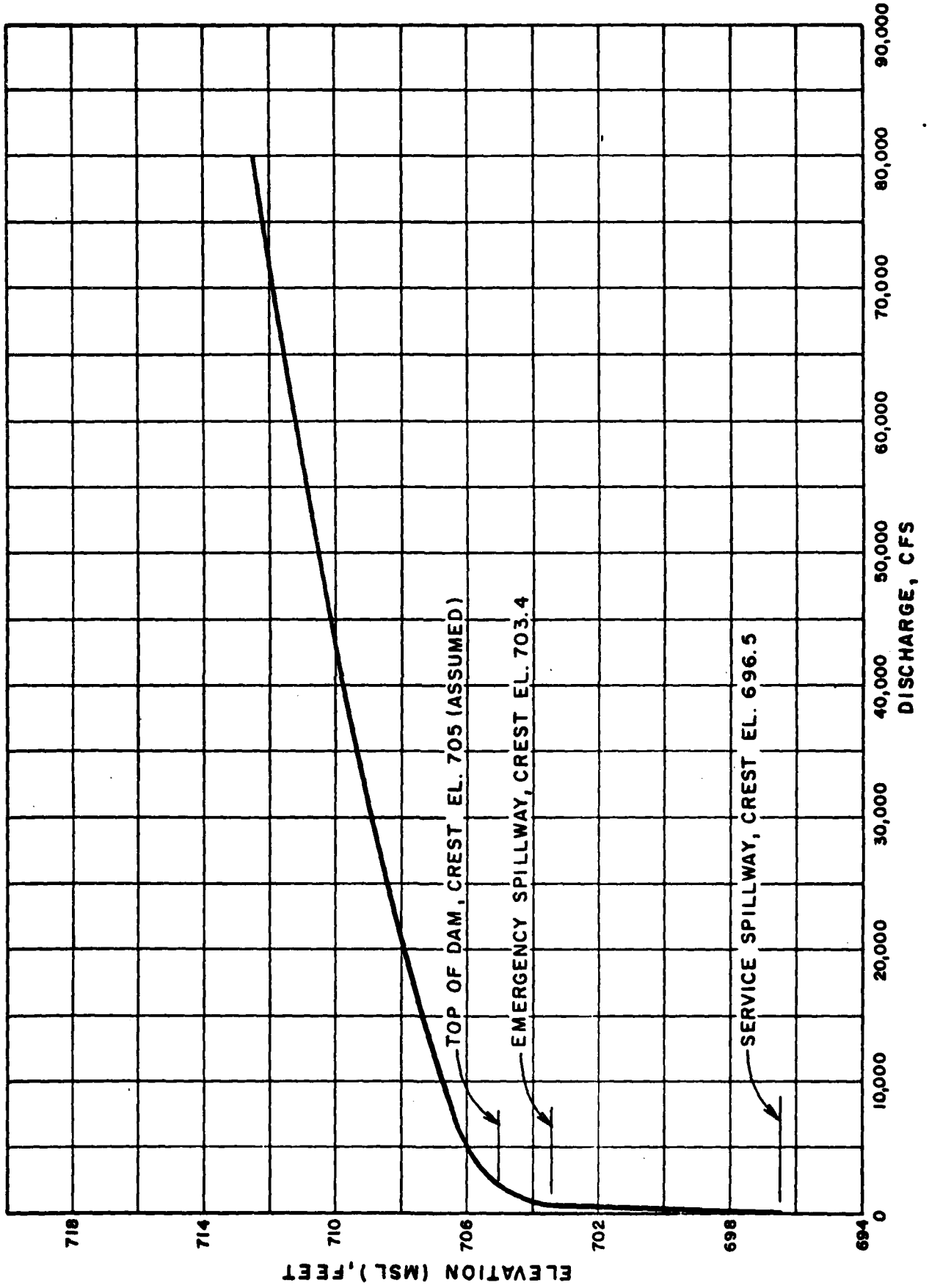
COMBINED RATING CURVE BY JFK DATE 6/16/80

SERVICE SPILLWAY, EMERGENCY SPILLWAY, AND OVERTOP DISCHARGES

W.S. ELEV	H_w or H_T	Q_1, SERVICE SPILLWAY	Q_2, E. SPLWY AND OVERTOP	$Q_{TOTAL} = Q_1 + Q_2$
696.5	0	0		0
697	0.5	56 *		56
698	1.5	290 *		290
699	2.5	625 *		625
700	30.2	919		919
701	31.2	935		935
702	32.2	949		949
703A	33.6	970	0	970
704.1	34.3	980	261	1241
704.8	35.0	990	815	1805
705.5	35.7	1000	2209	3209
706.1	36.3	1008	5382	6390
707.4	37.6	1026	14203	15229
708.9	39.1	1046	29581	30627
710.4	40.6	1066	49122	50188
711.9	42.1	1086	71334	72420

* Weir flow controls, $Q = 158.4\ H_w^{1.5}$ a For W.S. ELEV. = 700 and above, pressure flow controls $Q = 167.3\ (H_T)^{1/2}$

PLATE 3, APPENDIX B



BOCO MO DAM (MO. 10893)
SPILLWAY & OVERTOP RATING CURVE

PERCENT OF PMF FLOOD ROUTING
EQUAL TO SPILLWAY CAPACITY

PREVIEW OF SEQUENCE OF STREAM NETWORK CALCULATIONS

RUNOFF HYDROGRAPH AT 10893
ROUTE HYDROGRAPH TO 10893
END OF NETWORK

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**************************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
 LAST MODIFICATION 26 FEB 79
**************************************

RUN  DATE* 80/09/17.
     TIME* 08.23.32.

                         DAM SAFETY INSPECTION - MISSOURI
                          BOCO MO DAM (MO. 10893)
                              PERCENT PMF

                               JOB SPECIFICATION
        NQ      NHR     NMIN    IDAY     IHR    IMIN    METRC    IPLT    IPRT   NSTAN
       192        0       15       0       0       0        0       0      -4       0
                                JOPER     NWT   LROPT    TRACE
                                    5       0       0        0

                        MULTI-PLAN ANALYSES TO BE PERFORMED
                           NPLAN= 1 NRTIO= 3 LRTIO= 1
          RTIOS=   .30    .35    .40

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

                           SUB-AREA RUNOFF COMPUTATION

        INPUT RUNOFF PARAMETERS

                 ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
               [illegible]   0       0       0       0       0       1       0       0

                              HYDROGRAPH DATA
        IHYDG    IUHG   TAREA    SNAP   TRSDA   TRSPC    RATIO   ISNOW   ISAME   LOCAL
           1        1 [illegible]  0.00    3.18    1.00    0.000       0       1       0

                               PRECIP DATA
              SPFE     PMS      R6     R12     R24     R48     R72     R96
              0.00   24.70  100.00  120.00  130.00  140.00    0.00    0.00

                                LOSS DATA
   LROPT  STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
           0.00    0.00    1.00    0.00    0.00    1.00   -1.00  -90.00    0.00     .05

         CURVE NO. =  -90.00   WETNESS =   -1.00   EFFECT CN =   90.00

                           UNIT HYDROGRAPH DATA
                           TC=  0.00     LAG=   .41

                              RECESSION DATA
                    STRTQ=   0.00    QRCSN=   0.00    RTIOR= 1.00

                           END-OF-PERIOD FLOW
    MO.DA  HR.MN  PERIOD   RAIN   EXCS   LOSS   COMP Q     MO.DA  HR.MN  PERIOD   RAIN   EXCS   LOSS   COMP Q
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                                                            SUM  34.58   33.55   1.23   27163P.
                                                               ( 878.)( 847.)(  31.)( 7691.93)

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

                                   HYDROGRAPH ROUTING

              ROUTE HYDROGRAPH THROUGH BOCO MO RESERVOIR

                       ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                       10[illegible]       1       0       0       0       0       1       0       0
                                            ROUTING DATA
              QLOSS    CLOSS     AVG    IRES   ISAME    IOPT    IPMP            LSTR
                0.0    0.0[illegible]    0.00       1       1       0       0               0

                       NSTPS   NSTDL     LAG   AMSKK       X     TSK   STORA  ISPRAT
                           1       0       0   0.000   0.000   0.000   -6[illegible]7.      -1

   STAGE    696.50   697.00   698.00   699.00   700.00   701.00   702.30   703.40   704.10   704.80
            705.5[illegible]   70[illegible].10   707.40   708.90   710.40   711.90

    FLOW      0.00    56.00   290.00   625.00   919.00   935.00   949.00   970.00  1241.00  1805.00
           322[illegible].00  65[illegible]0.00 15229.00 30627.00 50188.00 72420.00

SURFACE AREA=      0.     2[illegible].     52.     86.    140.    15[illegible].    200.    33[illegible].

   CAPACITY=      0.     [illegible]7.    412.    [illegible].   1526.   1861.   2740.   5235.

  ELEVATION=    [illegible]70.    680.    690.    697.    703.    705.    710.    720.

                  CREL   SPWID   COQW    EXPW   ELEVL    COQL   CAREA    EXPL
                 696.5     0.0     0.0     0.0     0.0     0.0     0.0     0.0

                                     DAM DATA
                           TOPEL    COQD    EXPD   DAMWID
                           705.0     0.0     0.0       0.

   PEAK OUTFLOW IS    1457. AT TIME  42.75 HOURS

   PEAK OUTFLOW IS    2279. AT TIME  42.25 HOURS

   PEAK OUTFLOW IS    [illegible]179. AT TIME  41.75 HOURS

          **********     **********     **********     **********     **********
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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 .33	RATIO 2 .35	RATIO 3 .40
HYDROGRAPH AT	[illegible]	3.15	1	4920.	5740.	6560.
		(8.24)		(139.32)	(162.53)	(185.75)
ROUTED TO	[illegible]	3.15	1	1457.	2279.	3179.
		(8.24)		(41.27)	(64.52)	(90.02)

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	696.50	696.50	705.00
STORAGE	868.	868.	1861.
OUTFLOW	0.	0.	2206.

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
.30	704.57	0.00	1766.	1457.	0.00	42.75	0.00
.35	705.09	.09	1866.	2279.	.75	42.25	0.00
.41	705.49	.49	1936.	3179.	2.25	41.75	0.00

HEC1DB INPUT DATA

AD-A106 625 PRC CONSOER TOWNSEND INC ST LOUIS MO F/G 13/13
NATIONAL DAM SAFETY PROGRAM. BOCO MO DAM (MO 10893), MISSOURI ---ETC(U)
SEP 80 W G SHIFRIN DACW43-80-C-0094

UNCLASSIFIED NL

2 OF 2
AD A
106 625

END
DATE FILMED
11-81
DTIC

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**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION        JULY 1978
  LAST MODIFICATION  26 FEB 79
**********************************
            A1                         DAM SAFETY INSPECTION - MISSOURI
            A2                             BOCO MO DAM (MO. 10893)
            A3                             PMF AND 50 PERCENT PMF
            B      192       0      15       0       0       0       0       0       0       0
            B1       5
            J        1       2       1
            J1       1      .5
            K        0   10593                                       1
            K1   INPUT RUNOFF PARAMETERS
            M        1       2    3.18            7.18       1                       1
            P             24.7     100     120     130     140
            T                                                       -1     -90             .05
            W2             .81
            X        0       2       1
            K        1   10993                                       1
            K1   ROUTE HYDROGRAPH THROUGH BOCO MO RESERVOIR
            Y                                1       1
            Y1       1                                           -696.5      -1
            Y4   696.5     697     698     699     700     701     702   703.4   704.1   704.8
            Y4   705.5   706.1   707.4   708.9   710.4   711.9
            Y5       0      56     290     625     919     935     949     970    1241    1805
            Y5    3209    6390   15229   30627   50188   72420
            $A       0      20    51.5      86     140     153     200     302
            $E     670     680     690   696.5   703.4     705     710     720
            $$   696.5
            $D     705
            K       99
```

INFLOW PMF AND ONE-HALF PMF HYDROGRAPHS

PREVIEW OF SEQUENCE OF STRTAN NETWORK CALCULATIONS

RUNOFF HYDROGRAPH AT 10693
ROUTE HYDROGRAPH TO 10493
END OF NETWORK

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**************************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION        JULY 1978
  LAST MODIFICATION  26 FEB 79
**************************************

RUN  DATE= 80/03/17.
     TIME= 07.35.23.


                          DAM SAFETY INSPECTION - MISSOURI
                            BGCO MO DAM (NO. 10693)
                            PMF AND 50 PERCENT PMF

                               JOB SPECIFICATION
         NQ    NHR   NMIN   IDAY    IHR   IMIN  METRC   IPLT   IPRT  NSTAN
        192      0     15      0      0      0      0      0      0      0
                               JOPER    NWT  LROPT  TRACE
                                   5      0      0      0

                         MULTI-PLAN ANALYSES TO BE PERFORMED
                           NPLAN= 1 NRTIO= 2 LRTIO= 1
              RTIOS=   1.00    .50

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

                            SUB-AREA RUNOFF COMPUTATION

          INPUT RUNOFF PARAMETERS

                  ISTAQ  ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                  1-AS1      0       0       0       0       0       1       0       0

                               HYDROGRAPH DATA
          IHYDG   IUHG   TAREA    SNAP   TRSDA   TRSPC   RATIO   ISNOW   ISAME   LOCAL
              1      2    3.18    0.00    3.18    1.00   1.000       0       1       0

                                 PRECIP DATA
               SPFE     PMS      R6     R12     R24     R48     R72     R96
               0.00   24.70  100.00  120.00  130.00  140.00    0.00    0.00

                                  LOSS DATA
       LROPT  STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
          0    0.00    0.00    1.00    0.00    0.00    1.00   -1.00  -90.00    0.00     .05

          CURVE NO = -90.00  WETNESS =  -1.00  EFFECT CN =  90.00

                             UNIT HYDROGRAPH DATA
                           TC=  0.00    LAG=   .81

                                RECESSION DATA
                  STRTQ=   0.00   QRCSN=   0.00   RTIOR= 1.00

       UNIT HYDROGRAPH 19 END OF PERIOD ORDINATES, TC=  0.00 HOURS, LAG=   .81  VOL= 1.00
          264.    881.   1530.   1632.   1364.    913.    579.    377.    239.    150.
          101.     65.     43.     27.     18.     13.      7.      3.
```

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	.15	1	.00	.00	.00	0.	1.02	.15	97	.04	.04	.00	44.
1.01	.30	2	.00	.00	.00	0.	1.02	.30	98	.04	.04	.00	72.
1.01	.45	3	.00	.00	.00	0.	1.02	.45	99	.04	.04	.00	122.
1.01	1.00	4	.00	.00	.00	1.	1.02	1.00	100	.04	.04	.00	176.
1.01	1.15	5	.00	.00	.00	1.	1.02	1.15	101	.04	.04	.00	221.
1.01	1.30	6	.00	.00	.00	1.	1.02	1.30	102	.04	.04	.00	251.
1.01	1.45	7	.00	.00	.00	1.	1.02	1.45	103	.04	.04	.00	271.
1.01	2.00	8	.00	.00	.00	1.	1.02	2.00	104	.04	.04	.00	284.
1.01	2.15	9	.00	.00	.00	1.	1.02	2.15	105	.04	.04	.00	292.
1.01	2.30	10	.00	.00	.00	1.	1.02	2.30	106	.04	.04	.00	298.
1.01	2.45	11	.00	.00	.00	1.	1.02	2.45	107	.04	.04	.00	302.
1.01	3.00	12	.00	.00	.00	1.	1.02	3.00	108	.04	.04	.00	305.
1.01	3.15	13	.00	.00	.00	1.	1.02	3.15	10.	.04	.04	.00	307.
1.01	3.30	14	.00	.00	.00	1.	1.02	3.30	110	.04	.04	.00	308.
1.01	3.45	15	.00	.00	.00	1.	1.02	3.45	111	.04	.04	.00	309.
1.01	4.00	16	.00	.00	.00	1.	1.02	4.00	112	.04	.04	.00	310.
1.01	4.15	17	.00	.00	.00	1.	1.02	4.15	113	.04	.04	.00	311.
1.01	4.30	18	.00	.00	.00	1.	1.02	4.30	114	.04	.04	.00	312.
1.01	4.45	19	.00	.00	.00	1.	1.02	4.45	115	.04	.04	.00	312.
1.01	5.00	20	.00	.00	.00	1.	1.02	5.00	116	.04	.04	.00	313.
1.01	5.15	21	.00	.00	.00	1.	1.02	5.15	117	.04	.04	.00	313.
1.01	5.30	22	.00	.00	.00	1.	1.02	5.30	118	.04	.04	.00	314.
1.01	5.45	23	.00	.00	.00	1.	1.02	5.45	119	.04	.04	.00	314.
1.01	6.00	24	.00	.00	.00	1.	1.02	6.00	120	.04	.04	.00	315.
1.01	6.15	25	.00	.00	.00	1.	1.02	6.15	121	.21	.19	.01	356.
1.01	6.30	26	.00	.00	.00	2.	1.02	6.30	122	.21	.19	.01	493.
1.01	6.45	27	.00	.00	.00	3.	1.02	6.45	123	.21	.20	.01	732.
1.01	7.00	28	.00	.00	.00	4.	1.02	7.00	124	.21	.20	.01	988.
1.01	7.15	29	.00	.00	.00	5.	1.02	7.15	125	.21	.20	.01	1204.
1.01	7.30	30	.00	.00	.00	5.	1.02	7.30	126	.21	.20	.01	1350.
1.01	7.45	31	.00	.00	.00	6.	1.02	7.45	127	.21	.20	.01	1444.
1.01	8.00	32	.00	.00	.00	6.	1.02	8.00	128	.21	.20	.01	1508.
1.01	8.15	33	.00	.00	.00	6.	1.02	8.15	129	.21	.20	.01	1550.
1.01	8.30	34	.00	.00	.01	6.	1.02	8.30	130	.21	.20	.01	1580.
1.01	8.45	35	.00	.00	.01	7.	1.02	8.45	131	.21	.20	.01	1600.
1.01	9.00	36	.00	.00	.01	7.	1.02	9.00	132	.21	.20	.01	1614.
1.01	9.15	37	.00	.00	.01	9.	1.02	9.15	133	.21	.20	.01	1624.
1.01	9.30	38	.00	.00	.01	11.	1.02	9.30	134	.21	.20	.00	1632.
1.01	9.45	39	.00	.00	.01	13.	1.02	9.45	135	.21	.20	.00	1638.
1.01	10.00	40	.00	.00	.01	15.	1.02	10.00	136	.21	.20	.00	1643.
1.01	10.15	41	.00	.00	.01	18.	1.02	10.15	137	.21	.20	.00	1647.
1.01	10.30	42	.00	.00	.01	21.	1.02	10.30	138	.21	.20	.00	1649.
1.01	10.45	43	.00	.00	.01	24.	1.02	10.45	139	.21	.20	.00	1652.
1.01	11.00	44	.00	.00	.01	27.	1.02	11.00	140	.21	.20	.00	1654.
1.01	11.15	45	.00	.00	.01	29.	1.02	11.15	141	.21	.20	.00	1655.
1.01	11.30	46	.00	.00	.01	31.	1.02	11.30	142	.21	.20	.00	1657.
1.01	11.45	47	.00	.00	.01	34.	1.02	11.45	143	.21	.20	.00	1659.
1.01	12.00	48	.00	.00	.01	36.	1.02	12.00	144	.21	.20	.00	1660.
1.01	12.15	49	.00	.00	.03	42.	1.02	12.15	145	.62	.61	.01	1769.
1.01	12.30	50	.00	.00	.03	55.	1.02	12.30	146	.62	.61	.01	2120.
1.01	12.45	51	.00	.00	.03	77.	1.02	12.45	147	.62	.61	.01	2753.
1.01	13.00	52	.00	.00	.02	103.	1.02	13.00	148	.62	.61	.01	3419.
1.01	13.15	53	.00	.00	.03	138.	1.02	13.15	149	.74	.74	.01	4010.
1.01	13.30	54	.00	.00	.03	156.	1.02	13.30	150	.74	.74	.01	4493.
1.01	13.45	55	.00	.00	.02	182.	1.02	13.45	151	.74	.74	.00	4918.
1.01	14.00	56	.00	.00	.02	207.	1.02	14.00	152	.74	.74	.00	5275.

1.01	14.15	57	.07	.05	.02	233.	1.02	14.15	153	.93	.92	.00	5593.
1.01	14.30	58	.07	.05	.02	260.	1.02	14.30	154	.93	.92	.00	6936.
1.01	14.45	59	.07	.05	.02	292.	1.02	14.45	155	.93	.92	.00	6333.
1.01	15.00	60	.07	.05	.02	323.	1.02	15.00	156	.93	.92	.00	6711.
1.01	15.15	61	.07	.05	.02	351.	1.02	15.15	157	.94	.94	.00	7016.
1.01	15.30	62	.14	.11	.04	389.	1.02	15.30	158	1.88	1.87	.01	7476.
1.01	15.45	63	.46	.38	.08	514.	1.02	15.45	159	5.26	5.25	.01	9338.
1.01	16.00	64	.10	.09	.02	741.	1.02	16.00	160	1.31	1.31	.00	12808.
1.01	16.15	65	.07	.06	.01	955.	1.02	16.15	161	.86	.86	.00	15986.
1.01	16.30	66	.07	.05	.01	990.	1.02	16.30	162	.86	.86	.00	16400.
1.01	16.45	67	.07	.06	.01	915.	1.02	16.45	163	.86	.86	.00	14782.
1.01	17.00	68	.07	.06	.01	77[illegible].	1.02	17.00	164	.86	.86	.00	12316.
1.01	17.15	69	.05	.05	.01	651.	1.02	17.15	165	.68	.68	.00	10352.
1.01	17.30	70	.05	.05	.01	585.	1.02	17.30	166	.68	.68	.00	9039.
1.01	17.45	71	.05	.05	.01	520.	1.02	17.45	167	.68	.68	.00	7979.
1.01	18.00	72	.05	.05	.01	474.	1.02	18.00	168	.68	.68	.00	7196.
1.01	18.15	73	.00	.00	.00	429.	1.02	18.15	169	.06	.06	.00	6458.
1.01	18.30	74	.00	.00	.00	376.	1.02	18.30	170	.06	.06	.00	5538.
1.01	18.45	75	.00	.00	.00	297.	1.02	18.45	171	.06	.06	.00	4358.
1.01	19.00	76	.00	.00	.00	215.	1.02	19.00	172	.06	.06	.00	3194.
1.01	19.15	77	.00	.00	.00	152.	1.02	19.15	173	.06	.06	.00	2255.
1.01	19.30	78	.00	.00	.00	110.	1.02	19.30	174	.06	.06	.00	1628.
1.01	19.45	79	[illegible]	[illegible]	[illegible]	[illegible]	1.02	19.45	175	.06	.06	.00	1228.
1.01	20.00	80	[illegible]	[illegible]	[illegible]	[illegible]	1.02	20.00	176	.06	.06	.00	959.
1.01	20.15	81	.00	.00	.00	54.	1.02	20.15	177	.06	.06	.00	788.
1.01	20.30	82	.00	.00	.00	47.	1.02	20.30	178	.06	.06	.00	685.
1.01	20.45	83	.00	.00	.00	42.	1.02	20.45	179	.06	.06	.00	619.
1.01	21.00	84	.00	.00	.00	[illegible]	1.02	21.00	180	.06	.06	.00	577.
1.01	21.15	85	.00	.00	.00	38.	1.02	21.15	181	.06	.06	.00	549.
1.01	21.30	86	.00	.00	.00	[illegible]	1.02	21.30	182	.06	.06	.00	531.
1.01	21.45	87	.00	.00	.00	36.	1.02	21.45	183	.06	.06	.00	520.
1.01	22.00	88	.00	.00	.00	35.	1.02	22.00	184	.06	.06	.00	513.
1.01	22.15	89	.00	.00	.00	35.	1.02	22.15	185	.06	.06	.00	508.
1.01	22.30	90	.00	.00	.00	35.	1.02	22.30	186	.06	.06	.00	506.
1.01	22.45	91	.00	.00	.00	35.	1.02	22.45	187	.06	.06	.00	506.
1.01	23.00	92	.00	.00	.00	35.	1.02	23.00	188	.06	.06	.00	506.
1.01	23.15	93	.00	.00	.00	35.	1.02	23.15	189	.06	.06	.00	506.
1.01	23.30	94	.00	.00	.00	35.	1.02	23.30	190	.06	.06	.00	506.
1.01	23.45	95	.00	.00	.00	35.	1.02	23.45	191	.06	.06	.00	506.
1.02	0.00	96	.00	.00	.00	35.	1.03	1.00	192	.06	.06	.00	506.

SUM 34.58 33.35 1.23 271638.
(878.)(847.)(31.)(7691.93)

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	16400.	8767.	2826.	1414.	271334.
CMS	464.	22[illegible].	76.	40.	76[illegible]5.
INCHES		25.60	31.54	33.08	33.06
MM		599.42	801.24	840.21	840.21
AC-FT		4000.	5347.	5607.	5607.
THOUS CU M		4935.	6596.	6917.	6917.

HYDROGRAPH AT STA 10893 FOR PLAN 1, RTIO 1

0.	0.	0.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	2.	3.	4.	5.	5.
6.	6.	6.	6.	7.	7.	9.	11.	13.	15.
16.	21.	24.	26.	29.	31.	34.	36.	42.	55.

77.	103.	130.	190.	182.	267.	233.	260.	292.	323.
351.	969.	914.	1014.	955.	998.	913.	772.	658.	583.
920.	470.	429.	370.	293.	218.	152.	110.	83.	65.
54.	47.	42.	40.	36.	36.	36.	35.	35.	35.
[illegible]	35.	35.	35.	35.	35.	44.	72.	122.	176.
[illegible]	291.	271.	284.	292.	298.	302.	305.	307.	308.
[illegible]	310.	311.	312.	312.	313.	313.	314.	314.	315.
[illegible]	473.	732.	988.	1284.	1350.	1444.	1508.	1550.	1580.
1600.	1614.	1624.	1632.	1638.	1643.	1647.	1649.	1652.	1654.
[illegible]	1657.	1659.	1663.	1769.	2126.	2753.	3619.	4010.	4493.
[illegible]	[illegible]	5593.	5936.	6333.	6711.	7016.	7476.	9338.	12808.
[illegible]	16430.	14782.	12316.	10352.	9039.	7974.	7196.	6458.	5538.
[illegible]	3194.	2253.	1628.	1228.	959.	789.	685.	619.	577.
[illegible]	531.	520.	513.	508.	506.	506.	506.	506.	506.
[illegible]	506.								

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	16403.	8367.	2696.	1414.	271594.
CMS	464.	228.	76.	40.	7695.
INCHES		23.60	31.54	33.08	33.08
MM		599.42	801.24	840.21	840.21
AC-FT		4000.	5347.	5607.	5607.
THOUS CU M		4934.	6596.	6917.	6917.

HYDROGRAPH AT STA 10893 FOR PLAN 1, RTIO 2

0.	0.	0.	0.	0.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	2.	2.	3.
3.	3.	3.	3.	3.	4.	4.	5.	6.	8.
9.	10.	12.	13.	14.	16.	17.	18.	21.	27.
39.	52.	65.	73.	91.	104.	116.	130.	146.	161.
[illegible]	194.	257.	371.	477.	499.	457.	386.	323.	291.
[illegible]	[illegible]	[illegible]	185.	146.	107.	76.	55.	42.	33.
7.	23.	21.	20.	19.	18.	16.	19.	17.	17.
17.	17.	17.	17.	17.	17.	22.	36.	61.	88.
111.	126.	135.	142.	146.	149.	151.	152.	153.	154.
155.	155.	156.	156.	156.	156.	157.	157.	157.	187.
[illegible]	247.	[illegible]	694.	659.	675.	[illegible]	754.	775.	790.
[illegible]	807.	[illegible]	816.	819.	821.	824.	825.	826.	827.
[illegible]	[illegible]	829.	[illegible]	984.	1064.	1376.	1709.	2005.	2247.
2057.	2638.	2797.	2568.	3167.	3355.	3508.	3738.	4669.	6404.
7393.	9200.	7391.	6156.	5176.	4520.	3990.	3598.	3229.	2769.
2174.	1597.	1127.	913.	614.	480.	374.	342.	309.	288.
274.	266.	263.	256.	254.	253.	253.	253.	253.	253.
[illegible]	253.								

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	8210.	4034.	1348.	707.	[illegible]
CMS	232.	114.	38.	20.	[illegible]
INCHES		11.80	15.77	16.54	16.54
MM		299.71	400.62	420.10	420.10
AC-FT		2000.	2674.	2804.	2804.
THOUS CU M		2467.	3298.	3458.	3458.

PMF AND ONE-HALF PMF ROUTING

HYDROGRAPH ROUTING

ROUTE HYDROGRAPH THROUGH BOCO NO RESERVOIR

ISTAG	ICOMP	IECON	ITYPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
10893	1	6	0	0	0	1	0	0

ROUTING DATA

QDOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP	LSTR
0.9	0.000	0.00	1	1	0	0	0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	0.000	0.000	0.000	-697.	-1

ELEV	696.50	697.00	697.50	698.00	700.00	701.00	702.00	703.40	704.10	704.80
	705.50	706.10	707.40	708.90	710.40	711.90				
FLOW	0.00	56.00	270.00	625.00	919.00	935.00	949.00	970.00	1241.00	1805.00
	3284.00	6350.00	15229.00	30627.00	50188.00	72420.00				
SURFACE AREA=	0.	39.	52.	86.	149.	177.	200.	302.		
CAPACITY=	0.	67.	412.	854.	1666.	1861.	2740.	5243.		
ELEVATION=	696.	698.	698.	697.	703.	705.	710.	720.		

EREL	SPAID	CQID	EXPD	ELEVL	COQL	CAREA	EXPL
696.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DAM DATA

TOPEL	COQD	EXPD	DAMLID
705.0	0.0	0.0	0.

STATION 10893, PLAN 1, RATIO 1

END-OF-PERIOD HYDROGRAPH ORDINATES

OUTFLOW

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	2.	2.	2.	2.	2.	3.
3.	3.	4.	4.	5.	6.	6.	7.	8.	9.
11.	13.	15.	19.	23.	27.	32.	38.	44.	51.
60.	76.	96.	123.	160.	201.	239.	269.	291.	314.
340.	341.	340.	352.	351.	344.	343.	320.	304.	288.
278.	267.	256.	245.	235.	229.	216.	207.	198.	190.
182.	175.	167.	161.	154.	148.	143.	138.	136.	137.
140.	145.	151.	157.	164.	171.	177.	184.	190.	196.
201.	207.	212.	217.	222.	226.	231.	235.	239.	242.
247.	256.	275.	307.	361.	423.	478.	553.	616.	671.
722.	771.	817.	861.	902.	920.	922.	924.	927.	929.
931.	933.	935.	936.	938.	941.	944.	947.	956.	963.
1012.	1234.	1678.	2484.	3899.	5046.	6968.	6656.	7707.	9709.
12468.	14621.	15178.	14241.	12657.	10884.	9483.	8257.	7445.	6575.
5721.	4734.	3704.	3022.	2648.	2270.	1943.	1734.	1625.	1516.
1414.	1321.	1238.	1193.	1162.	1127.	1093.	1061.	1030.	1002.
974.	569.								

STORAGE

854.	854.	854.	854.	854.	854.	854.	854.	854.	854.
854.	854.	854.	854.	854.	854.	854.	854.	854.	854.
854.	854.	855.	854.	855.	855.	855.	855.	855.	855.
[illegible]	855.	855.	856.	855.	855.	856.	856.	856.	856.
[illegible]	857.	857.	858.	858.	859.	859.	860.	860.	861.
862.	864.	866.	869.	872.	875.	879.	883.	888.	894.
[illegible]	906.	915.	924.	939.	955.	970.	982.	991.	998.
1003.	1006.	1008.	1009.	1009.	1007.	1004.	1000.	995.	991.
[illegible]	981.	977.	973.	968.	964.	961.	957.	954.	950.
947.	944.	941.	939.	936.	934.	[illegible]	930.	929.	929.
931.	932.	935.	937.	940.	945.	945.	948.	950.	953.
955.	957.	959.	961.	963.	965.	967.	968.	970.	971.
973.	977.	984.	996.	1012.	1030.	1049.	1069.	1089.	1108.
1129.	1154.	1161.	1177.	1193.	1206.	1223.	1238.	1253.	1268.
[illegible]	1298.	[illegible]	1327.	1343.	1364.	1395.	1439.	1497.	1565.
1641.	1723.	1806.	[illegible]	1947.	1993.	2021.	2041.	2066.	2115.
2193.	2236.	2252.	2228.	2186.	2144.	2109.	2062.	2069.	2039.
2115.	1984.	1953.	1924.	1894.	1866.	1841.	1818.	1796.	1776.
1759.	1741.	1725.	1711.	1697.	1684.	1671.	1659.	1648.	1638.
[illegible]	1618.								

STAGE

696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5
696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5
696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5
696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5
696.5	[illegible]	696.5	696.5	696.6	696.6	696.6	696.6	696.6	696.6
696.6	696.6	696.6	696.7	696.7	696.7	696.8	696.8	696.9	697.0
697.0	697.1	697.	697.3	697.4	697.6	697.8	697.9	698.0	698.1
698.1	698.2	698.2	698.2	698.2	698.2	699.1	698.1	698.0	698.0
697.9	697.9	697.9	697.8	697.8	697.7	697.7	697.6	697.6	697.6
697.5	697.5	697.5	697.4	697.4	697.4	697.4	697.4	697.3	697.3
697.4	697.4	697.4	697.4	697.5	697.5	697.5	697.5	697.6	697.6
697.6	697.7	697.7	697.7	697.7	697.7	697.7	[illegible]	697.8	697.8
697.8	697.9	697.9	698.1	698.3	698.4	698.6	698.8	699.0	699.2
699.3	699.5	699.7	699.8	699.9	700.1	700.2	700.3	700.5	700.6
700.7	700.9	701.0	701.1	701.2	701.4	701.7	702.0	702.4	703.0
703.3	704.1	704.6	705.1	705.6	705.8	706.0	706.1	706.3	706.6
707.0	707.2	707.4	707.5	707.2	706.8	706.6	706.4	706.3	706.1
706.0	705.8	705.6	705.4	705.2	705.0	704.9	704.7	704.6	704.4
704.3	704.2	704.1	704.0	703.9	703.8	703.7	703.6	703.6	703.5
703.4	703.3								

PEAK OUTFLOW IS 15176. AT TIME 40.75 HOURS

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	15176.	7366.	2351.	1221.	234401.
CMS	430.	209.	67.	35.	6638.
INCHES		21.55	27.51	28.57	28.57
MM		547.31	698.66	725.68	725.68
AC-FT		3653.	4663.	4843.	4843.
THOUS CU M		4505.	5751.	5974.	5974.

STATION 10893, PLAN 1, RATIO 2

END-OF-PERIOD HYDROGRAPH ORDINATES

OUTFLOW

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
2.	2.	2.	2.	3.	3.	[illegible]	4.	4.	5.
5.	6.	8.	9.	11.	14.	16.	19.	22.	26.
29.	33.	38.	45.	55.	77.	98.	114.	127.	136.
[illegible]	149.	153.	155.	158.	154.	151.	147.	142.	136.
131.	125.	120.	115.	110.	105.	101.	96.	92.	88.
[illegible]	81.	76.	75.	72.	69.	66.	64.	64.	64.
66.	69.	72.	75.	79.	83.	86.	90.	93.	56.
99.	102.	105.	107.	110.	112.	115.	117.	119.	121.
123.	128.	137.	152.	172.	196.	221.	246.	272.	300.
334.	366.	395.	424.	455.	475.	498.	519.	539.	558.
576.	592.	607.	622.	635.	655.	[illegible]	734.	755.	867.
771.	925.	[illegible]	930.	941.	947.	952.	958.	966.	1114.
[illegible]	2967.	5143.	5970.	5818.	5326.	4781.	4277.	3836.	3406.
3061.	2602.	3462.	2107.	1791.	1661.	1531.	1407.	1291.	1213.
1165.	1114.	[illegible]	1023.	981.	965.	967.	966.	964.	962.
961.	955.								

STORAGE

854.	854.	854.	854.	854.	854.	854.	854.	854.	854.
854.	854.	854.	854.	854.	854.	854.	854.	854.	854.
854.	854.	854.	854.	854.	854.	854.	854.	854.	854.
854.	855.	855.	[illegible]	855.	855.	855.	855.	855.	855.
855.	855.	856.	856.	856.	856.	857.	857.	857.	858.
[illegible]	859.	860.	861.	863.	865.	867.	869.	871.	874.
877.	880.	884.	889.	897.	906.	914.	920.	925.	929.
932.	934.	936.	936.	937.	936.	935.	933.	931.	929.
927.	925.	923.	921.	919.	917.	915.	914.	912.	910.
[illegible]	[illegible]	[illegible]	905.	904.	903.	902.	901.	901.	901.
902.	903.	904.	905.	907.	908.	910.	911.	912.	913.
915.	915.	917.	918.	919.	920.	921.	921.	922.	923.
924.	926.	[illegible]	935.	943.	953.	963.	973.	984.	994.
1007.	1013.	1022.	1030.	1038.	1045.	1052.	1059.	1065.	1071.
1076.	1081.	1086.	1090.	1095.	1102.	1115.	1130.	1155.	1180.
1217.	1243.	1280.	1321.	1355.	1412.	1464.	1519.	1596.	1679.
1759.	1919.	1996.	2021.	2017.	2002.	1988.	1970.	1957.	1944.
1928.	1906.	1885.	1853.	1827.	1863.	1779.	1756.	1735.	1716.
1697.	1679.	1667.	1646.	1630.	1615.	1601.	1586.	1571.	1556.
1542.	1527.								

STAGE

696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5
696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5
696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5
696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5
696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5	696.5
696.5	696.6	696.6	696.6	696.6	696.6	696.6	696.7	696.7	696.7
696.9	696.8	696.8	696.9	697.0	697.1	697.2	697.2	697.3	697.3
697.4	697.4	697.4	697.4	697.4	697.4	697.4	697.4	697.4	697.3
697.3	697.3	697.3	697.2	697.2	697.2	697.2	697.2	697.2	697.1
697.1	697.1	697.1	697.1	697.1	697.1	697.0	697.0	697.0	697.0
697.0	697.1	697.1	697.1	697.1	697.1	697.1	697.1	697.2	697.2
697.2	697.2	697.2	697.2	697.2	697.2	697.3	697.3	697.3	697.3
697.3	697.3	697.3	697.4	697.5	697.6	697.7	697.8	697.9	698.0
698.1	698.2	698.3	698.4	698.5	698.6	698.6	698.7	698.7	698.8

698.9	698.9	699.0	699.0	699.0	699.1	699.2	699.4	699.6	699.8
700.1	700.4	700.7	701.0	701.4	701.8	702.2	702.6	703.1	703.6
704.0	704.4	704.9	705.0	706.0	706.0	705.9	705.8	705.7	705.6	705.5
705.4	705.3	705.1	705.0	704.8	704.6	704.5	704.3	704.2	704.0
703.9	703.8	703.7	703.6	703.4	703.3	703.2	703.1	703.0	702.9
703.0	702.7								

PEAK OUTFLOW IS 5970. AT TIME 41.00 HOURS

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	5970.	2788.	1033.	547.	165113.
CMS	169.	79.	29.	15.	2920.
INCHES		0.16	12.09	12.57	12.57
PH		307.16	307.07	315.23	319.23
AC-FT		1383.	2044.	2130.	2130.
THOUS CU M		1705.	2520.	2626.	2628.

SUMMARY OF PMF AND ONE-HALF PMF FLOOD ROUTING

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 1.00	RATIO 2 .50
HYDROGRAPH AT	10893	5.18 (8.24)	1	14900. (404.39)	8200. (232.19)
ROUTED TO	10892	5.18 (8.24)	1	15178. (429.79)	5974. (169.04)

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ..... INITIAL VALUE SPILLWAY CREST TOP OF DAM

ELEVATION	696.50	696.50	709.00
STORAGE	859.	859.	1661.
OUTFLOW	0.	0.	2206.

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
1.00	707.39	2.39	2252.	15178.	5.75	40.75	0.00
.50	706.02	1.02	2021.	5970.	3.00	41.00	0.00

END

DATE
FILMED

11-81

DTIC