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NATIONAL DAM SAFETY PROGRAM. CHRISTIANSEN LAKE DAM (MO 20145), --ETC(U)
JUL 80 P R ZAMAN, E R BURTON, H L CALLAHAN DACW43-80-C-0074

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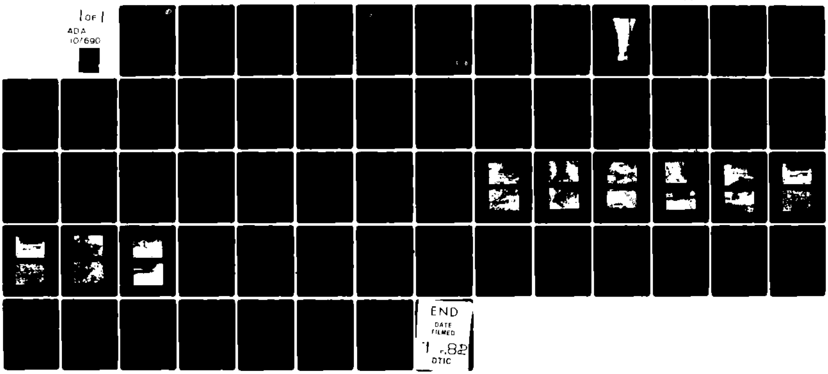

MISSOURI-KANSAS CITY BASIN

CHRISTIANSEN LAKE DAM

JACKSON COUNTY, MISSOURI

MO 20145

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

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

St. Louis District

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

FOR: STATE OF MISSOURI

JULY 1980

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Dam Safety, Lake, Dam Inspection, Private Dams

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

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

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MISSOURI-KANSAS CITY BASIN

CHRISTIANSEN LAKE DAM

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PHASE 1 INSPECTION REPORT
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United States Army
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St. Louis District

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

FOR: STATE OF MISSOURI

JULY 1980

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

REPLY TO
ATTENTION OF

LMSED-PD

SUBJECT: Christiansen Lake Dam, MO. I.D. No. 20145
Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Christiansen Lake Dam.

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:

a. Spillway will not pass 50 percent of the Probable Maximum Flood without overtopping the dam.

b. Overtopping of the dam could result in failure of the dam.

c. Dam failure significantly increases the hazard to loss of life downstream.

SUBMITTED BY: SIGNED — Chief, Engineering Division — 9 OCT 1980 (Date)

APPROVED BY: SIGNED — Colonel, CE, District Engineer — 9 OCT 1980 (Date)

CHRISTIANSEN LAKE DAM

JACKSON COUNTY, MISSOURI

MISSOURI INVENTORY NO. 20145

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

PREPARED BY:

BLACK & VEATCH
CONSULTING ENGINEERS
KANSAS CITY, MISSOURI

UNDER DIRECTION OF

ST. LOUIS DISTRICT CORPS OF ENGINEERS

FOR

GOVERNOR OF MISSOURI

JULY 1980

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam	Christiansen Lake Dam
State Located	Missouri
County Located	Jackson County
Stream	Blue Branch of Sni-a-Bar Creek
Date of Inspection	25 July 1980

Christiansen Lake Dam was inspected by a team of engineers from Black & Veatch, Consulting Engineers for the St. Louis District, Corps of Engineers. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

The guidelines used in the assessment were furnished by the Department of the Army, Office of the Chief of Engineers and developed with the help of several Federal and state agencies, professional engineering organizations, and private engineers. Based on these guidelines, this dam is classified as a small size dam with a high downstream hazard potential. According to the St. Louis District, Corps of Engineers, failure would threaten lives and property. The estimated damage zone extends approximately two miles downstream of the dam. Within the estimated damage zone are more than forty dwellings Contents of the estimated downstream hazard zone were verified by the inspection team.

Our inspection and evaluation indicates the spillways do not meet the criteria set forth in the guidelines for a dam having the above size and hazard potential. The spillways will not pass the probable maximum flood without overtopping but will pass 20 percent of the probable maximum flood. The spillways will pass the flood which has a one percent probability of occurrence in any given year (100-year flood). The spillway design flood recommended by the guidelines is 50 to 100 percent of the probable maximum flood. Considering the hazard zone, the spillway design flood should be 100 percent of the probable maximum flood. The probable maximum flood is defined as the flood discharge which may be expected from the most severe combination of critical meteorologic and hydrologic conditions which are reasonably possible in the region.

Based on visual observations, this dam appears to be in fair condition. Deficiencies visually observed by the inspection team were the extremely dense unmowed grass, trees and brush cover, erosion on the upstream slope, many animal burrows on the embankment, cracks on the embankment crest, trees in the emergency spillway, and the deteriorated principal spillway pipe. In addition the emergency spillway discharges directly to a heavily developed housing area. Seepage and stability analyses required by the guidelines were not available.

There were no observed deficiencies or conditions existing at the time of the inspection which indicated an immediate safety hazard. Future corrective action and regular maintenance will be required to correct or control the described deficiencies. In addition, detailed seepage and stability analyses of the existing dam, as required by the guidelines, should be performed. A detailed report discussing each of these deficiencies is attached.

Paul R. Zaman, PE
Illinois 62-29261

Edwin R. Burton, PE
Missouri E-10137

Harry L. Callahan, Partner
Black & Veatch

OVERVIEW OF DAM

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
CHRISTIANSEN LAKE DAM

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SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. The National Dam Inspection Act, Public Law 92-367, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of safety inspection of dams throughout the United States. Pursuant to the above, the District Engineer of the St. Louis District, Corps of Engineers, directed that a safety inspection of the Christiansen Lake Dam be made.

b. Purpose of Inspection. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

c. Evaluation Criteria. Criteria used to evaluate the dam were furnished by the Department of the Army, Office of the Chief of Engineers, in "Recommended Guidelines for Safety Inspection of Dams." These guidelines were developed with the help of several Federal agencies and many state agencies, professional engineering organizations, and private engineers.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances.

(1) The dam is an earth structure located in the valley of Blue Branch of Sni-a-Bar Creek (Plate 1). The watershed area is hilly consisting of 30 percent residential area and 70 percent grassland (Plate 2). It should be noted that Plate 2, Vicinity Topography, does not show the recent residential developments in the watershed and immediately downstream of the dam. The residential area is characterized by grassland with small trees. The storm sewers from the residential area to the east drain into the lake. The dam is approximately 700 feet in length along the crest and 19 feet high. The dam crest is 13 feet wide. The downstream face of the dam slopes mildly from the crest to the valley floor below.

(2) The principal spillway from the lake is an uncontrolled 12-inch concrete bell and spigot sewer pipe with a 4.5-foot square concrete drop inlet installed in the embankment. The box-type inlet has a depth of two feet with 6-inch thick walls. No trash rack was provided except for a makeshift diamond mesh screen covering one-half of the opening. The spillway discharge pipe remains underground for a considerable distance downstream of the toe of the dam and exits about 10 feet upstream of twin 66-inch corrugated metal pipes under Moreland School Road.

The emergency spillway consists of a poorly defined trapezoidal cut in the natural overburden around the right end of the dam. A low dike 75 to 100 feet long forms the left bank of the downstream unmowed grass-lined channel and separates the emergency spillway from the embankment. The dike keeps the flow from following the toe of the dam. The downstream channel curves to the left to a natural low area leading to the twin 66-inch corrugated metal pipes under Moreland School Road.

(3) Pertinent physical data are given in paragraph 1.3.

b. Location. The dam is located in central Jackson County, Missouri, as indicated on Plate 1. The lake formed by the dam is shown on the United States Geological Survey 7.5 minute series quadrangle map for Lake Jacomo, Missouri in Section 07 of T48N, R30W.

c. Size Classification. Criteria for determining the size classification of dams and impoundments are presented in the guidelines referenced in paragraph 1.1c above. Based on these criteria, the dam and impoundment are in the small size category. A small size dam is classified as having a height less than 40 feet, but greater than or equal to 25 feet and a storage capacity less than 1,000 acre-feet, but greater than or equal to 55 acre-feet.

d. Hazard Classification. The hazard classification assigned by the Corps of Engineers for this dam is as follows: The Christiansen Lake Dam has a high hazard potential, meaning that the dam is located where failure may cause loss of life, and serious damage to homes, agricultural, industrial and commercial facilities, and to important public utilities, main highways, or railroads. For the Christiansen Lake Dam the estimated flood damage zone extends approximately two miles downstream of the dam. Within the estimated damage zone are more than forty dwellings. The contents of the estimated downstream hazard zone were verified by the inspection team.

e. Ownership. The dam is owned by Mr. Paul A. Christiansen, 3333 Lakeshore Drive, Blue Springs, Missouri.

f. Purpose of Dam. The dam forms a 12-acre lake used for recreation.

g. Design and Construction History. Design and construction assistance was provided by the Missouri Conservation Commission. The dam was constructed in 1951.

h. Normal Operating Procedure. Normal rainfall, runoff, transpiration, evaporation, and overflow through the uncontrolled outlet pipe all combine to maintain a relatively stable water surface elevation.

1.3 PERTINENT DATA

a. Drainage Area - 204 acres

b. Discharge at Damsite.

(1) Normal discharge at the damsite is through an uncontrolled 12-inch outlet pipe.

(2) Estimated experienced maximum flood at damsite - Unknown.

(3) Estimated ungated spillway capacity at maximum pool elevation 1,280 cfs (Probable Maximum Flood Pool El. 933.4).

c. Elevation (Feet above m.s.l.).

(1) Top of dam - 931.2 (see Plate 4)

(2) Emergency spillway crest - 929.5

(3) Principal spillway drop inlet crest - 928.6

(4) Streambed at toe of dam - 912 ±

(5) Maximum tailwater - Unknown.

d. Reservoir.

(1) Length of maximum pool - 1,800 feet ± (Probable maximum flood pool level)

(2) Length of normal pool - 1,200 feet ± (Principal spillway drop inlet)

e. Storage (Acre-feet).

(1) Top of dam - 101

(2) Emergency spillway crest - 68

(3) Principal spillway drop inlet crest - 54

(4) Design surcharge - Not available.

f. Reservoir Surface (Acres).

(1) Top of dam - 21.9

(2) Emergency spillway crest - 17.4

(3) Principal spillway drop inlet crest - 12.0

g. Dam.

(1) Type - Earth embankment

(2) Length - 700 feet

(3) Height - 19 feet ±

(4) Top width - 13 feet

(5) Side slopes - upstream face 1.0 V on 5.1 H, downstream face varies between 1.0 V on 7.6 H and 1.0 V on 7.8 H (see Plate 4)

(6) Zoning - Unknown.

(7) Impervious core - Unknown.

(8) Cutoff - Unknown.

(9) Grout curtain - Unknown.

h. Diversion and Regulating Tunnel - None.

i. Principal Spillway.

(1) Type - 12-inch concrete bell and spigot sewer pipe with a 4.5-foot square concrete drop inlet.

(2) Drop inlet crest elevation - 928.6

(3) Inlet invert elevation - 926.6

(4) Outlet invert elevation - 912.4

(5) Gates - None.

(6) Upstream channel - There are a few trees and some brush at the lake inlet.

(7) Downstream channel - Twin 66-inch corrugated metal pipes carry the flow under Moreland School Road to the streambed.

j. <u>Emergency Spillway</u>.

(1) Type - Grass open channel.

(2) Width of channel - 50 feet.

(3) Emergency spillway crest - 929.5

(4) Gates - None.

(5) Upstream channel - Grass lined to control section.

(6) Downstream channel - Natural open channel to twin 66-inch corrugated metal pipes under Moreland School Road and then to the stream bed.

k. <u>Regulating Outlets</u> - None.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

Design data was unavailable.

2.2 CONSTRUCTION

Construction records were unavailable, however, according to the owner, the dam was constructed in 1951.

2.3 OPERATION

No records of operation or of past floods were available.

2.4 GEOLOGY

The site of the dam and reservoir is located in a broad shallow valley. The dam impounds the Blue Branch of Sni-a-Bar Creek.

The soils of the area of the dam and reservoir consist of the Polo, Knox and Snead soil series. The Polo soils are located along the slopes above the reservoir and consist of well-drained soils formed in loess and residuum from limestone or shale. They are classified as low or high-plastic clay (CL or CH). The Knox soils are located on the uplands around the reservoir and are formed in loess. These soils are classified for engineering purposes as low-plastic silt (ML) or low-plastic clay (CL). The Snead soils are located along the valley in which the reservoir is located and are formed in residuum weathered from clayey shales and thin interbedded limestones. These soils are classified for engineering purposes as low or high-plastic clay (CL or CH).

The bedrock in the area of the dam and reservoir consists of interbedded limestones and shales of the Kansas City group.

2.5 EVALUATION

a. Availability. No engineering data were available.

b. Adequacy. No engineering data were available for making a detailed assessment of the design, construction, and operation. 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 validity of the design, construction, and operation could not be determined due to the lack of engineering data.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. A visual inspection of Christiansen Lake Dam was made on 25 July 1980. The inspection team included professional engineers with experience in dam design and construction, hydrology, hydraulic engineering, and geotechnical engineering. The inspection team consisted of Edwin Burton, hydrologist/hydraulic engineer and team leader; Robert Pinker, geologist; Gary Van Riessen, geotechnical engineer; Andrew Dywan, civil engineer; John Ruhl, hydrologist/hydraulic engineer; and William Fish, surveyor. The owner, Mr. Paul Christiansen, was present after the inspection. The dam is in fair condition. Specific observations are discussed below. No observations were made of the condition of the upstream face of the dam below the pool elevation at the time of the inspection.

b. Dam. The inspection team observed the following conditions at the dam. Some cracks about 1/2 inch wide and 6 inches deep were observed on the dam crest. The length of the cracks could not be determined due to heavy vegetal cover hindering observation. These cracks were probably due to the recent hot, dry weather. No sliding, sinkholes or other signs of settlement were observed. The embankment has no visible stability problems. No instruments to measure the performance of the dam were located.

No evidence of seepage in the embankment, foundation or abutments was observed. No toe drains or relief wells were observed.

The dam crest and the upstream and downstream slopes were observed to have a dense, unmowed grass cover with dense brush, vines and many trees up to 15 inches in diameter. This dense cover made the downstream slope practically unobservable. Many animal burrows were observed on the crest including one which was 8 inches in diameter. Most of the upstream slope at the normal water surface was protected by hand-placed concrete blocks. These are probably pieces of salvaged concrete curbstones. Some erosion due to wave action, noted by steep or near vertical banks, was observed above the hand-placed riprap. The material being eroded is classified as a CL. No evidence was found to indicate that the embankment had ever been overtopped. The Owner also stated that the embankment has not been overtopped.

c. Appurtenant Structures. The inspection team observed the following items pertaining to the appurtenant structures. The alignment of the pipe was not determined due to the heavy growth of brush. The inlet end and the outlet end of the pipe were observable. Three to four feet of the inside of the pipe was observed from the outlet end. One hole caused by a break in the discharge line was located just downstream of the toe of the embankment. The discharge pipe was also exposed in the low washed-out area near the outlet end. During full pipe flow, water will be lost to overland flow through these openings. It should be noted that a flow (trickle) of 2 to 3 gallons per hour was observed at the spillway pipe outlet even though the lake water surface was about one foot below the entrance level of the drop inlet. The spillway pipe at the drop inlet was found to be about 1/4 full of silt.

The emergency spillway consists of a grass-lined notch or low point at the right abutment in silty, sandy clay (CL) material. A low protective dike along the left side of the spillway channel directs the flow away from the embankment. Large flows will not be confined along the right side of the channel. The trees and brush growing in the channel will act as an obstruction. The high grass should lay down under high flows. An abnormally large spillway discharge would probably not damage the embankment but would probably cause damage to Moreland School Road and the heavily developed housing area just below the road.

d. Geology. The soils in the area of the dam and reservoir consist of silty clay with a trace of sand. The soils are formed in residuum from shale and limestone bedrock.

No outcrops were observed in the area of the dam and reservoir. However, excavations for houses downstream of the dam encountered shale and limestone at 2 to 5 feet. The bedrock is part of the Kansas City group.

Samples of the embankment were taken near the water at the upstream crest. The materials in the samples consisted of low-plastic, sandy, silty clay classified as CL. Based on these samples and visual observations, it is anticipated that the embankment consists of sandy, silty clay (CL).

It is anticipated that the foundation and abutments of the dam consist of limestone and shale overlain by 2 to 5 feet of residual silty, clay soil.

e. Reservoir Area. No slumping or slides of the reservoir banks were observed. The upstream channel area contains mostly grassland and the housing development with a few trees and some brush along the lake inlet.

The lake has major amounts of siltation. The water was very murky with less than one-inch of visibility. Several silt build-up areas or deltas were observed at the storm sewer outlets along the east bank of the lake. The owner stated that soundings which were taken about ten years ago revealed that the maximum depth in the lake was approximately 12 feet.

f. Downstream Channel. The area between the principal spillway outlet and the culverts under Moreland School Road has been eroded.

3.2 EVALUATION

The various deficiencies observed at the time of the inspection are not believed to represent an immediate safety hazard. They do, however, warrant monitoring and control.

The growth of trees and brush and the uncut grass could cause deterioration of the embankment and impede discharges through the emergency spillway. The roots of trees can loosen the embankment material and also can leave voids through which water can pass. Brush on the dam prevents inspection of the embankment and kills the smaller grasses whose roots are more effective in protecting the surface soil of the slope from erosion. The brush and tall uncut grass provides habitat for burrowing animals which can damage the embankment. Piping failure of the embankment has resulted in similar small earth dams due to burrowing animal damage. Seepage and water entering burrows, voids, and cracks can cause internal erosion creating cavities and underground channels, thereby weakening the embankment and/or abutments.

The insufficient amount of riprap on the upstream face of the dam has resulted in wave action erosion of the embankment. If not corrected, wave action will continue to erode the embankment and could lead to slope stability problems.

The emergency spillway discharges directly to the heavily developed housing area downstream of the dam.

The breaks in the principal spillway outlet pipe near the toe of the embankment and near the outlet end should be repaired. Flow from the outlet end of the pipe indicates that there is leakage into the pipe from seepage which could be a source of internal erosion and/or piping through the embankment.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

The pool is primarily controlled by rainfall, runoff, evaporation, transpiration, and capacity of the uncontrolled principal spillway outlet pipe.

4.2 MAINTENANCE OF DAM

No maintenance was evident.

4.3 MAINTENANCE OF OPERATING FACILITIES

No operating facilities exist.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

There is no existing warning system or preplanned scheme for alerting downstream residents for this dam. There are no existing restrictions to further development in the area downstream of the dam.

4.5 EVALUATION

A maintenance program should be initiated to include mowing the grass cover on the embankment in order to discourage animal burrowing. The brush and trees on the embankment should be removed. Measures to correct the erosion should include placing additional riprap on the upstream slope.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data.

b. Experience Data. The drainage area and lake surface area are developed from USGS Lake Jacomo Quadrangle Map. The dam layout is from a survey made during the inspection.

c. Visual Observations.

(1) The principal spillway is in a deteriorated condition. The lake level at the time of the inspection (El.927.7) was below the inlet level however, there was a small amount of flow from the pipe outlet. Only the inlet and outlet ends were observable. The spillway pipe discharges with a free outfall into an eroded hole at the inlet to two 66-inch pipe under Moreland School Road. Flow from the principal spillway would not be hindered by obstructions in the downstream channel.

(2) The emergency spillway channel is poorly defined but shows no evidence of erosion. The emergency spillway channel is lined with extremely dense and tall grass. Growth of trees and brush in the spillway channel will cause some restriction to flow.

(3) Spillway discharges do not endanger the integrity of the dam.

d. Overtopping Potential. The spillways will not pass the probable maximum 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 meteorologic and hydrologic conditions that are reasonably possible in the region. The spillways will pass 20 percent of the probable maximum flood without overtopping the dam. The spillways will also pass the one percent probability flood estimated to have a peak outflow of 284 cfs developed by a 24-hour, one percent probability rainfall. According to the recommended guidelines from the Department of the Army, Office of the Chief of Engineers, a high hazard dam of small size should pass 50 to 100 percent of the probable maximum flood. Considering the downstream hazard, the appropriate spillway design flood should be 100 percent of the probable maximum flood. The portion of the estimated peak discharge of the probable maximum flood overtopping the dam would be 1,620 cfs of the total discharge from the reservoir of 2,900 cfs. The estimated duration of overtopping is 5.1 hours with a maximum height of 2.2 feet. The portion of the estimated peak discharge of 50 percent of the probable maximum flood overtopping the dam would be 270 cfs of the total discharge from the reservoir of 1,110 cfs. The estimated duration of overtopping is 1.5 hours with a maximum height of 1.0 feet. The embankment could be jeopardized should overtopping occur for these periods of time.

According to the St. Louis District, Corps of Engineers, the effect from rupture of the dam could extend approximately two miles downstream of the dam. More than forty dwellings could be severely damaged and lives could be lost should failure of the dam occur. Contents of the estimated downstream hazard zone were verified by the inspection team.

The Blue Branch of Sni-a-Bar Creek below the dam is in a Zone B flood insurance zone. The City of Blue Springs, Missouri has no building restrictions in this area other than providing warning that property is within a flood zone.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations. Visual observations of conditions which affect the structural stability of this dam are discussed in Section 3, paragraph 3.1b.

b. Design and Construction Data. No design data relating to the structural stability of the dam were found. 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.

c. Operating Records. No operational records exist.

d. Postconstruction Changes. It is not known whether any past construction changes have been made.

e. Seismic Stability. The dam is located in Seismic Zone 1 which is a zone of minor seismic risk. A properly designed and constructed earth dam using sound engineering principles and conservatism should pose no serious stability problems during earthquakes in this zone. The seismic stability of an earth dam is dependent upon a number of factors: embankment and foundation material classifications and shear strengths; abutment materials, conditions, and strengths; embankment zoning; and embankment geometry. Adequate descriptions of embankment design parameters, foundation and abutment conditions, or static stability analyses to assess the seismic stability of this embankment were not available and therefore no inferences will be made regarding the seismic stability. An assessment of the seismic stability should be included as part of the stability analysis required by the guidelines.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. Several conditions observed during the visual inspection by the inspection team should be monitored and/or controlled. These are erosion of the upstream face of the embankment, cracks in the embankment crest, the dense growth of grass brush and trees on the embankment and emergency spillway, animal burrows in the embankment and the deteriorated principal spillway pipe. In addition, the emergency spillway discharges into a heavily developed housing area. 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.

b. Adequacy of Information. Due to the lack of engineering design data, the conclusions in this report were based only on performance history and visual conditions. The inspection team considers that these data are sufficient to support the conclusions herein. 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.

c. Urgency. A program should be developed as soon as possible to monitor at regular intervals the deficiencies described in this report. The remedial measures recommended in paragraph 7.2b should be accomplished in the near future. The item recommended in paragraph 7.2a should be pursued on a high priority basis.

d. Necessity for Phase II. The Phase I investigation does not raise any serious questions relating to the safety of the dam nor does it identify any serious dangers which would require a Phase II investigation. However, the additional analyses noted in paragraph 2.5b are necessary for compliance with the guidelines.

e. Seismic Stability. This dam is located in Seismic Zone 1. Adequate description of embankment design parameters, foundation and abutment conditions, or static stability analyses to assess the seismic stability of this embankment was not available and therefore no inferences will be made regarding the seismic stability. An assessment of the seismic stability should be included as part of the recommended stability analysis.

7.2 REMEDIAL MEASURES

a. Alternatives. The spillway sizes and/or the height of the dam could be increased or the lake level lowered permanently to increase available flood storage in order to pass the spillway design flood.

b. Operation and Maintenance Procedures. The following operation and maintenance procedures should be carried out under the direction of a professional engineer experienced in the design, construction, and maintenance of earth dams.

(1) Additional riprap should be placed on the upstream face of the dam above the normal lake level to prevent erosion of the embankment material.

(2) The animal burrows in the embankment should be corrected since they can lead to piping. Control measures should be implemented to discourage increased animal activity in the area.

(3) An improved maintenance program to remove and control the growth of brush and trees on the embankment and in the emergency spillway should be developed. Grass cover on the embankment should be cut periodically.

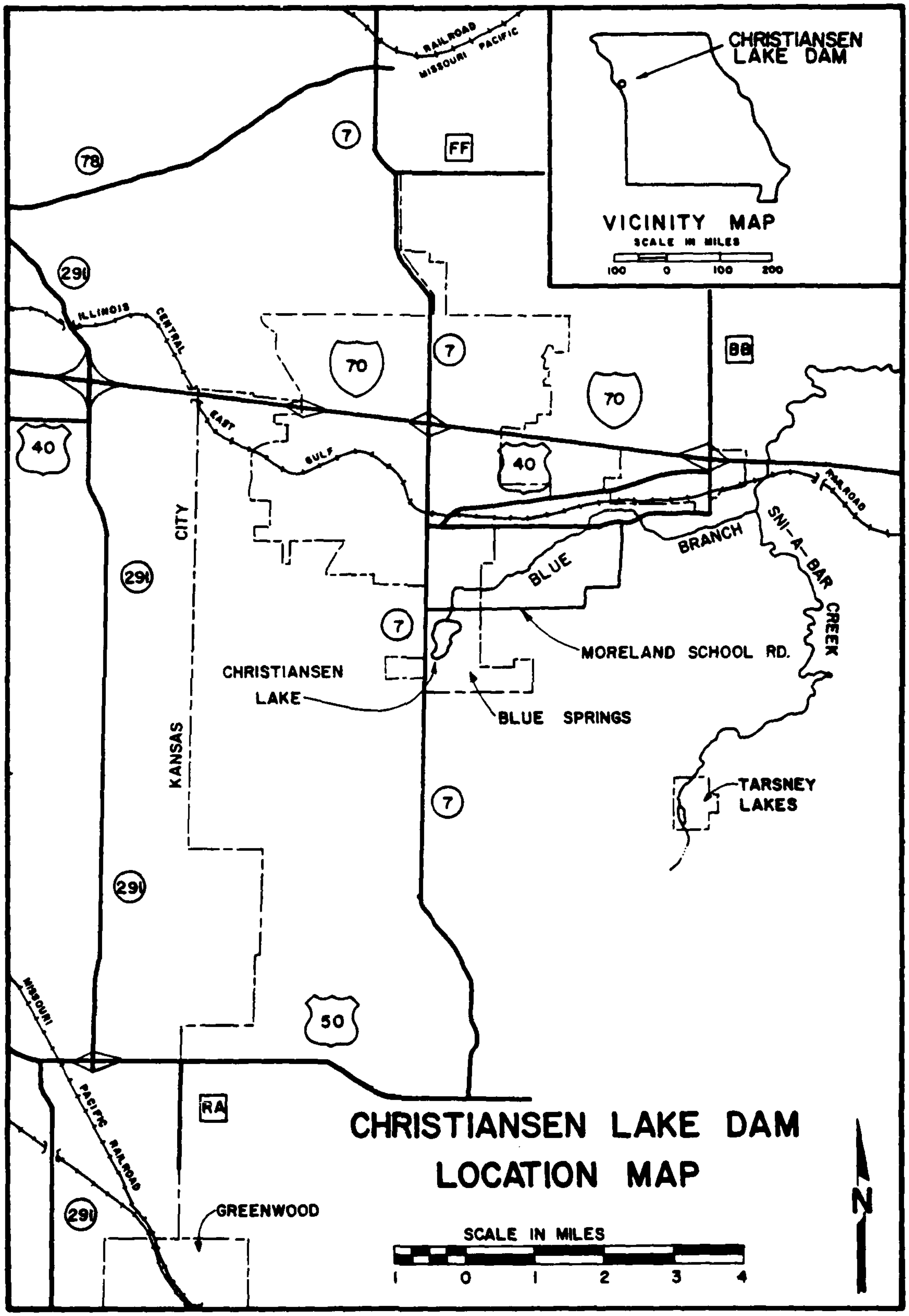
(4) The principal spillway pipe should be repaired.

(5) The cracks in the embankment crest should be repaired.

(6) The right side of the emergency spillway channel should be banked in order to prevent discharge into the housing development downstream.

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

(8) A detailed inspection of the dam should be made periodically More frequent inspections may be required if additional deficiencies are observed or the severity of the reported deficiencies increase.



CHRISTIANSEN LAKE DAM
LOCATION MAP

PLATE I

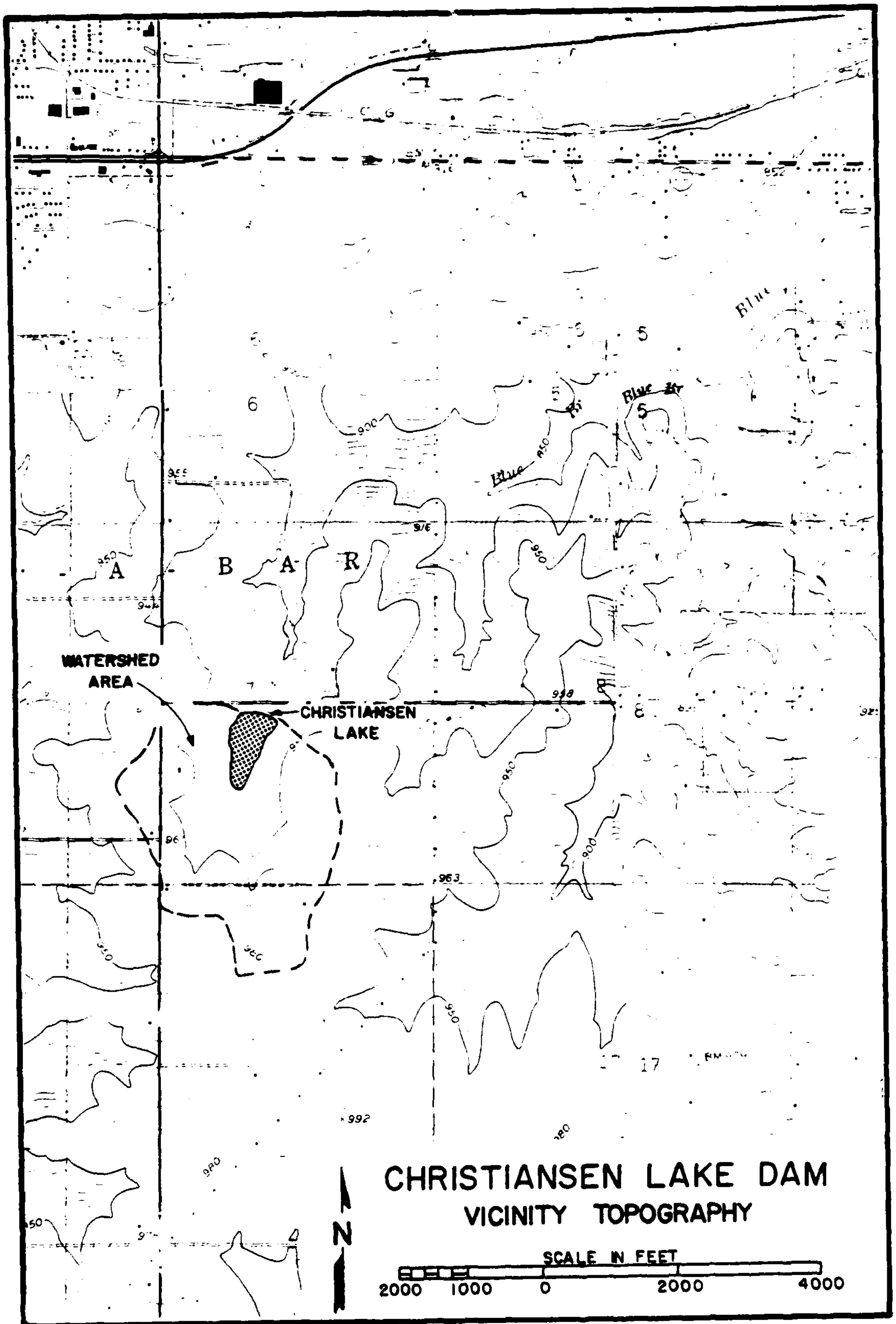

WATERSHED AREA
CHRISTIANSEN LAKE
CHRISTIANSEN LAKE DAM
VICINITY TOPOGRAPHY
SCALE IN FEET
2000 1000 0 2000 4000
N

PLATE 2

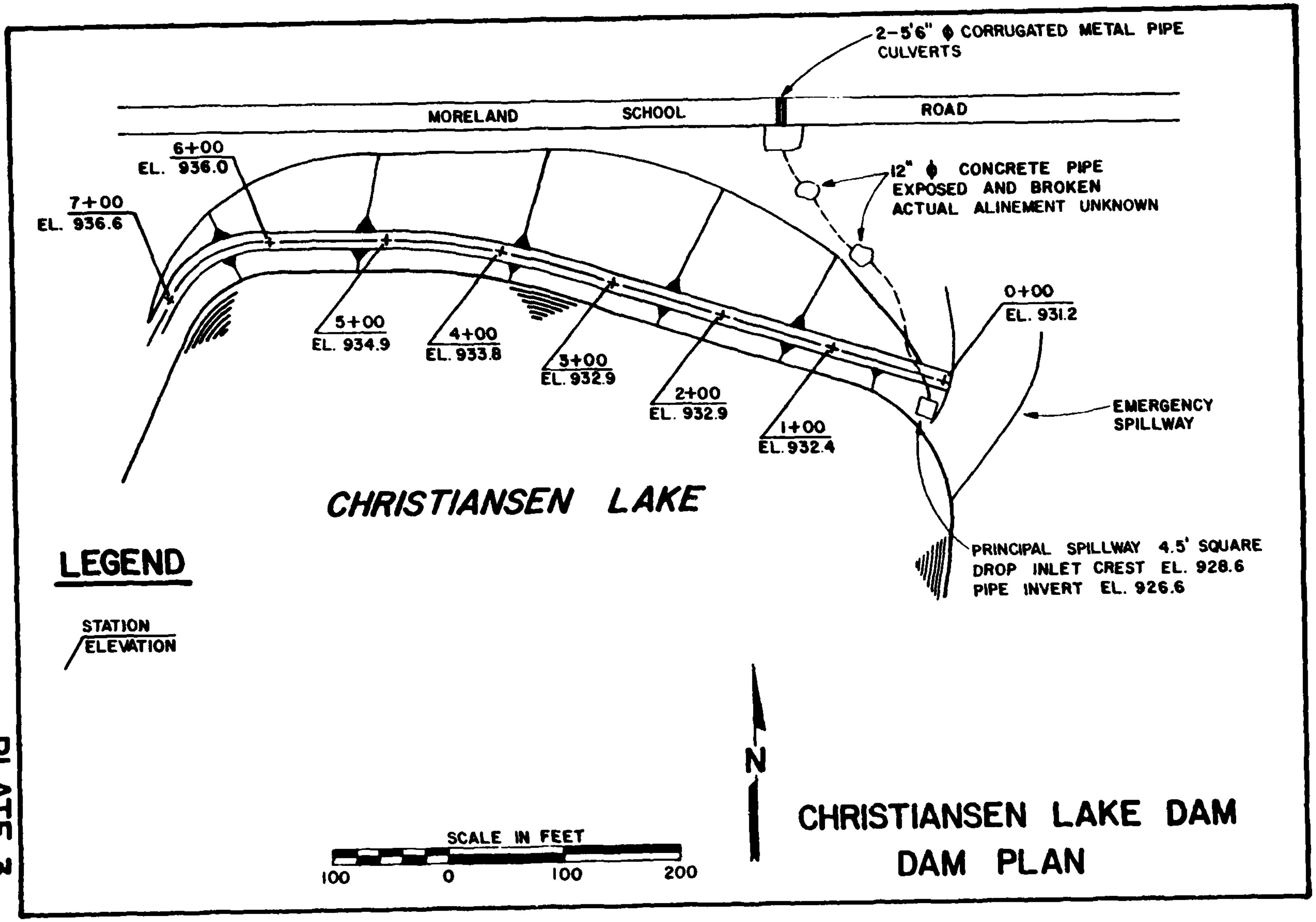
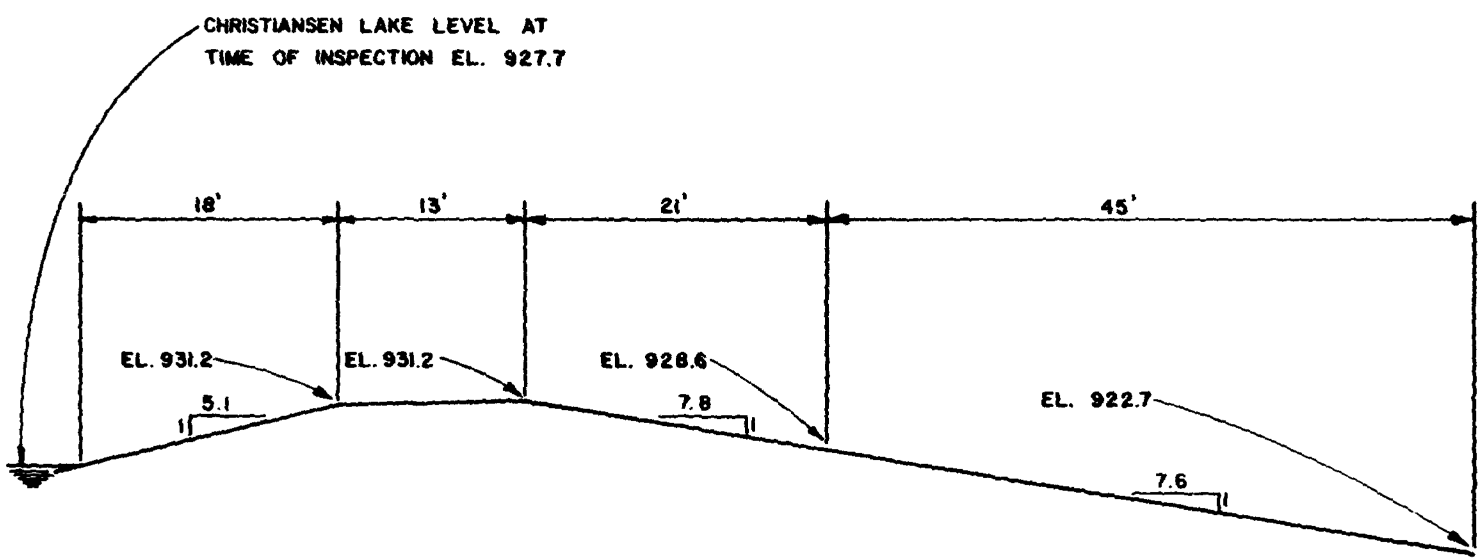

2-5'6" ϕ CORRUGATED METAL PIPE CULVERTS
MORELAND SCHOOL ROAD
12" ϕ CONCRETE PIPE EXPOSED AND BROKEN ACTUAL ALINEMENT UNKNOWN
6+00 EL. 936.0
7+00 EL. 936.6
5+00 EL. 934.9
4+00 EL. 933.8
3+00 EL. 932.9
2+00 EL. 932.9
1+00 EL. 932.4
0+00 EL. 931.2
EMERGENCY SPILLWAY
PRINCIPAL SPILLWAY 4.5' SQUARE DROP INLET CREST EL. 928.6 PIPE INVERT EL. 926.6
CHRISTIANSEN LAKE
LEGEND
STATION
ELEVATION
N
SCALE IN FEET
100
0
100
200
CHRISTIANSEN LAKE DAM
DAM PLAN

PLATE 3

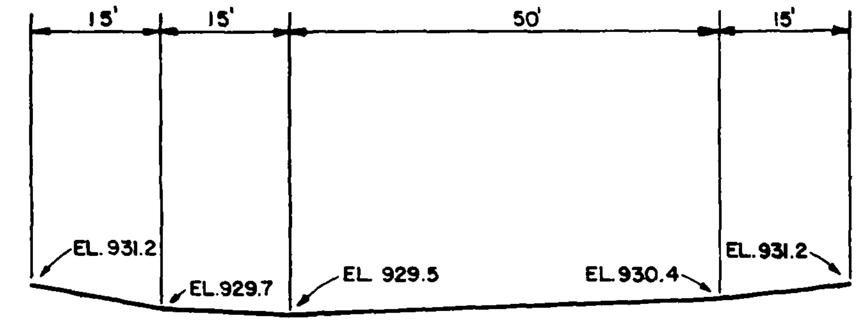


NOTE:
CROSS SECTION TAKEN
NEAR STATION 0+00

CHRISTIANSEN LAKE DAM
DAM CROSS SECTION

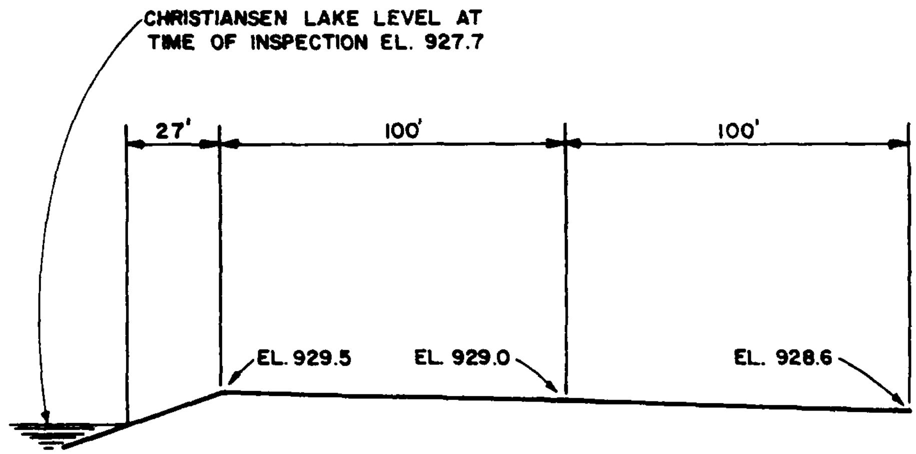
PLATE 4

SCALE: 1" = 20'



NOTE:
SURVEY LOOKING DOWNSTREAM

CROSS SECTION



SCALE: 1" = 50'

PROFILE

CHRISTIANSEN LAKE DAM
EMERGENCY SPILLWAY CROSS
SECTION AND PROFILE

PLATE 5

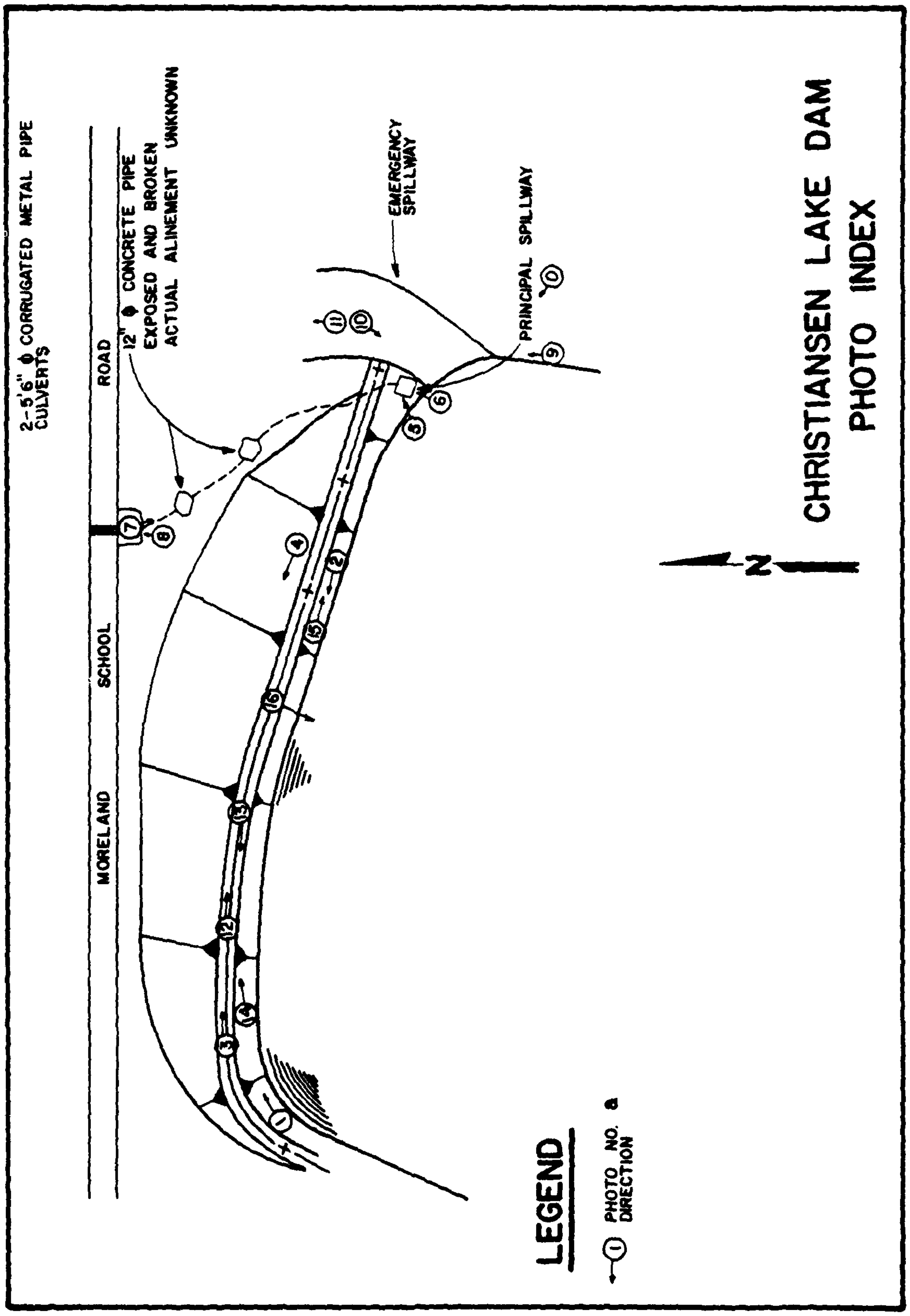

CHRISTIANSEN LAKE DAM
PHOTO INDEX
LEGEND
PHOTO NO. & DIRECTION
MORELAND SCHOOL ROAD
2-5'6" ϕ CORRUGATED METAL PIPE CULVERTS
12" ϕ CONCRETE PIPE EXPOSED AND BROKEN ACTUAL ALINEMENT UNKNOWN
EMERGENCY SPILLWAY
PRINCIPAL SPILLWAY
N

PLATE 6

PHOTO 1: TYPICAL VIEW OF UPSTREAM FACE OF DAM AT WATERLINE

PHOTO 2: TYPICAL VIEW OF UPSTREAM FACE OF DAM

PHOTO 3: TYPICAL CREST OF DAM

PHOTO 4: TYPICAL VIEW OF DOWNSTREAM SIDE OF DAM

PHOTO 5: DROP INLET STRUCTURE TO PRINCIPAL SPILLWAY

PHOTO 6: PRINCIPAL SPILLWAY PIPE INLET END

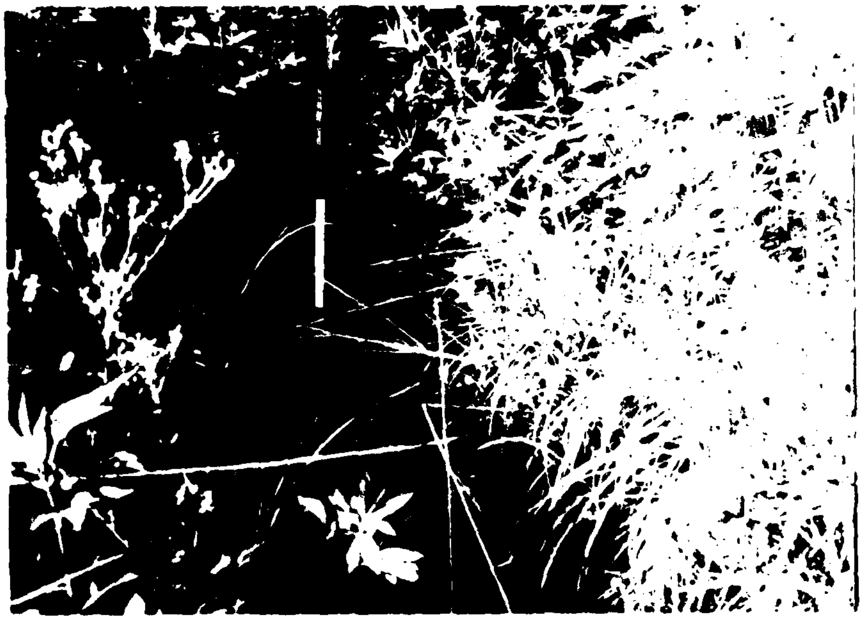


PHOTO 7: PRINCIPAL SPILLWAY PIPE OUTLET END

PHOTO 8: CULVERT UNDER MORELAND SCHOOL ROAD
BELOW PRINCIPAL SPILLWAY OUTLET

PHOTO 9: EMERGENCY SPILLWAY

PHOTO 10: EMERGENCY SPILLWAY LOOKING UPSTREAM

PHOTO 11: AREA BELOW EMERGENCY SPILLWAY LOOKING DOWNSTREAM

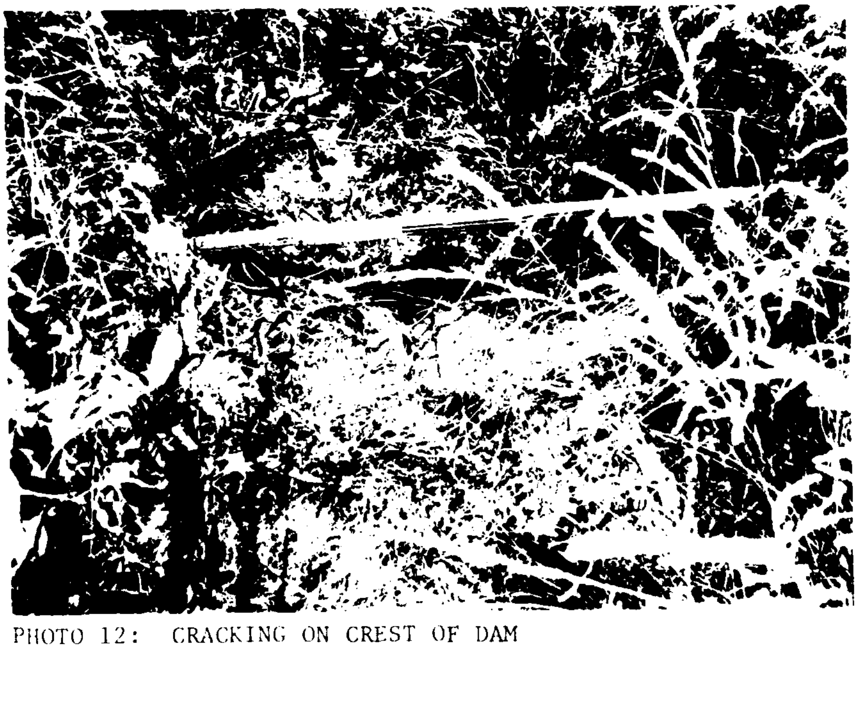


PHOTO 12: CRACKING ON CREST OF DAM

PHOTO 11: AREA BELOW EMERGENCY SPILLWAY LOOKING DOWNSTREAM

PHOTO 12: CRACKING ON CREST OF DAM

PHOTO 13: ANIMAL BURROW ON CREST OF DAM

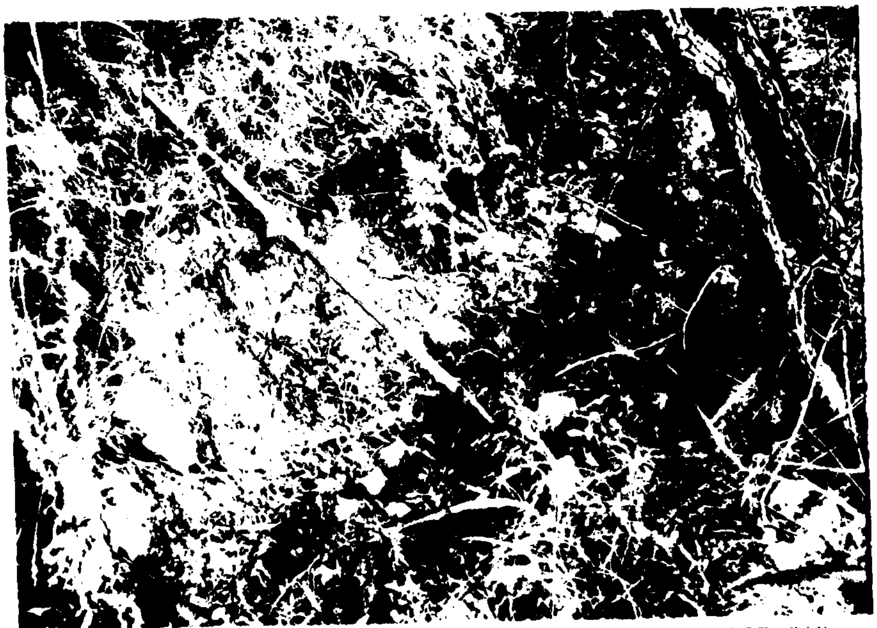


PHOTO 14: EROSION OF UPSTREAM FACE OF DAM ABOVE RIP RAP

PHOTO 15: EROSION OF UPSTREAM FACE OF DAM

PHOTO 16: LAKE AND WATERSHED VIEWED FROM DAM

APPENDIX A

HYDROLOGIC AND HYDRAULIC ANALYSES

HYDROLOGIC AND HYDRAULIC ANALYSES

To determine the overtopping potential, flood routings were performed by applying the Probable Maximum Precipitation (PMP) to a synthetic unit hydrograph to develop the inflow hydrograph. The inflow hydrograph was then routed through the reservoir and spillways. The overtopping analysis was determined using the computer program HEC-1 (Dam Safety Version) (1).

The PMP was determined from regional charts prepared by the National Weather Service in "Hydrometeorological Report No. 33" (HMR-33). Reduction factors were not applied. The rainfall distribution for the 24-hour PMP storm was determined according to the procedures outlined in HMR-33 and EM 1110-2-1411. The Kansas City, Missouri rainfall distribution (5 min. interval - 24 hours duration), as provided by the St. Louis District, Corp of Engineers, was used when the one percent chance probability flood was routed through the reservoir and spillways.

The synthetic unit hydrograph for the watershed was developed by the computer program using the Soil Conservation Service (SCS) method. The parameters for the unit hydrograph are shown in Table 1.

The SCS curve number (CN) method was used in computing the infiltration losses for the rainfall-runoff relationship. The CN values used, and the result from the computer output, are shown in Table 2.

The reservoir routing was performed using the Modified Puls Method. The initial reservoir pool elevation for the routing of each storm was determined to be equivalent to the drop inlet crest elevation of the principal spillway at elevation 928.6 feet m.s.l. in accordance with antecedent storm conditions preceding the one percent probability and probable maximum storms outlined by the U.S. Army Corps of Engineers, St. Louis District (2). The hydraulic capacity of the spillways and the storage capacity of the reservoir were defined by the elevation, surface area, storage, and discharge relationships shown in Table 3.

The rating curve for the spillways is shown in Table 4. The flow over the crest of the dam and through the emergency spillway was determined using the non-level dam crest option ($L and $V cards) of the HEC-1 program. The program assumes critical flow over a broad-crested weir. Principal spillway release rates were based on the pipe flow equation.

The result of the routing analysis indicates that 20 percent of the PMF will not overtop the dam.

A summary of the routing analysis for different ratios of the PMF is shown in Table 5.

The computer input data and a summary of the output data are presented at the back of this appendix.

TABLE 1

SYNTHETIC UNIT HYDROGRAPH

Parameters:

Drainage Area (A)	204 acres
Length of Watercourse (L)	0.53 miles
Difference in Elevation (H)	63 feet
Time of concentration (T_c)	0.25 hours
Lag Time (L_g)	0.15 hours
Duration (D)	2 min. (use 5 min.)

Time (Min.) *	Discharge (cfs) *
0	0
5	297
10	790
15	696
20	352
25	176
30	86
35	42
40	21
45	10
50	6
55	2

* From HEC-1 computer output

FORMULAS USED:

$$T_c = \left(\frac{11.9\, L^3}{H}\right)^{0.385} \quad (3)$$

$$D = 0.133\, T_c$$

$$L_g = 0.6\, T_c$$

TABLE 2

RAINFALL-RUNOFF VALUES

Selected Storm Event	Storm Duration (Hours)	Rainfall (Inches)	Runoff (Inches)	Loss (Inches)
PMP	24	32.11	30.53	1.58
1% Probability	24	7.59	4.67	2.92

Additional Data:

1) The soil association in this watershed are Knox, Polo, and Snead (4).
   100 percent of drainage area in hydrologic soil group C.
   70 percent of the land use was grassland .
   30 percent of the land use was low density urban area.
2) SCS Runoff Curve CN = 88 (AMC III) for the PMF.
3) SCS Runoff Curve CN = 75 (AMC II) for the one percent probability flood (5 and 6).

TABLE 3

ELEVATION, SURFACE AREA, STORAGE, AND DISCHARGE RELATIONSHIPS

Elevation (feet-MSL)	Lake Surface Area (acres)	Lake Storage (acre-ft)	Spillway Discharge (cfs)
*928.6	12.0	54	0
**929.5	17.4	68	13
***931.2	21.9	101	445

*Principal Spillway Drop Inlet Crest
**Emergency Spillway Crest
***Top of Dam

The relationships in Table 3 were developed from the Lake Jacomo, Missouri. 7.5 minute quadrangle map and the field measurements.

TABLE 4

SPILLWAY RATING CURVE

Reservoir Elevation (ft)	Principal Spillway Discharge (cfs)	Emergency Spillway Discharge (cfs)	Total Spillway Discharge (cfs)
*928.6	0	-	0
**929.5	13	0	13
930.0	13	50	63
931.0	13	328	341
***931.2	13	432	445

*Principal Spillway Drop Inlet Crest
**Emergency Spillway Crest
***Top of Dam

METHOD USED:

Emergency spillway releases were computed by HEC-1 from spillway geometry data input on $L and $V cards. Discharges through the emergency spillway for the probable maximum flood and 50 percent of the probable maximum flood were determined by the equations for flow over a non-level crest:

$$d_c = 2/3\ (H_m + 1/4\ \Delta Y)$$
$$A = 1/2\ T\ (2d_c - \Delta Y)$$
$$Q = (A^3 g/T)^{0.5}$$

where:

d_c = critical depth (feet)

H_m = available specific energy which is taken to be the height of the water surface in the reservoir above the bottom of the section (feet)

ΔY = change in elevation across the section (feet)

A = flow area (sq. ft.)

T = top width (feet)

Q = flow (cfs)

g = 32.2 ft/sec^2 = acceleration due to gravity.

TABLE 4

SPILLWAY RATING CURVE
(Continued)

Principal spillway release rates are based on the pipe flow equation:

$Q = Ca[2gh]^{1/2}$
C = coefficient of discharge = 0.49
a = net area = 0.79 square feet
h = difference between the energy gradient elevation upstream and the tailwater elevation downstream. (7)

The principal spillway has a drop inlet which exhibits weir flow, however due to the size of the pipe the discharge capability is controlled by the pipe flow equation.

TABLE 5

RESULTS OF FLOOD ROUTINGS

Ratio of PMF	Peak Inflow (CFS)	Peak Lake Elevation (ft.-MSL)	Total Storage (AC.-FT.)	Peak Outflow (CFS)	Depth (ft.) Over Top of Dam
-	0	*928.6	54	0	-
0.20	780	931.0	96	341	0
0.50	1,950	932.2	123	1,107	1.0
1.00	3,901	933.	152	2,900	2.2

*Principal Spillway Drop Inlet Crest

(1) U.S. Army Corps of Engineers, Hydrologic Engineering Center, Flood Hydrograph Package (HEC-1), Dam Safety Version, July 1978, Davis, California.

(2) U.S. Army Corps of Engineers, St. Louis District, Hydrologic/ Hydraulic Standards, Phase I Safety Inspection of Non-Federal Dams, 12 December 1979.

(3) U.S. Department of the Interior, Bureau of Reclamation, Design of Small Dams, 1974, Washington, D.C.

(4) U.S. Department of Agriculture, Soil Conservation Service, Preliminary Soils Report for Jackson County, Missouri.

(5) U.S. Department of Agriculture, Soil Conservation Service, National Engineering Handbook, Section 4, Hydrology, August 1972.

(6) U.S. Department of Agriculture, Soil Conservation Service, Technical Release No. 55, Urban Hydrology for Small Watersheds, January, 1975.

(7) Horace W. King and Ernest F. Brater, Handbook of Hydraulics, Sixth Edition, McGraw Hill Book Company, 1976.

(8) U.S. Department of Agriculture, Soil Conservation Service, Soil Survey Interpretations and Field Maps, 1980.

(9) Mary H. McCracken, Missouri Division of Geological Survey, Geologic Map of Missouri, 1961.

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B L A C K   &   V E A T C H                                     PROGRAM  H21/02-0      PAGE    1
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      3 A2      CHRISTIANSEN LAKE
      4 A3      PMF AND RATIOS
      5 B    288              5                                        3
      6 B1      5
      7 J       1       8       1
      8 J10.05  0.1     0.15    0.2     0.25    0.3     0.5     1.0
      9 K            HEAD
     10 K1      CALCULATE INFLOW HYDROGRAPH
     11 M       1       20.32                   1.
     12 P       24.7    101.    120.    130.
     13 T                                                      -1      -88
     14 W2      0.15
     15 X               1.
     16 K       1      DAM                                      1
     17 K1      ROUTE HYDROGRAPH THROUGH DAM
     18 Y                              1
     19 Y1      1                                       -928.6          -1
     20 Y4928.6 929.6   935.6   945.6
     21 Y50.    13.     15.     18.
     22 $A0.    12.     19.5    39.6
     23 $E915.  928.6   930.    940.
     24 $$928.6
     25 $C931.2
     26 $L0.    50.     95.     190.    330.    470.    610.    860.    960.    960.
     27 $V929.5 929.6   931.2   932.4   932.8   933.    934.    936.    937.    945.
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     29 A
     30 A
     31 A
     32 A
     33 A
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FLOOD HYDROGRAPH PACKAGE - HEC-1

*********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  06 FEB 80
*********************************
                           MISSOURI DAM INSPECTIONS
                           CHRISTIANSEN LAKE
                           PMF AND RATIOS
                                          JOB SPECIFICATION
            NQ     NHR    NMIN    IDAY     IHR    IMIN   METRC    IPLT    IPRT   NSTAN
           288       0       5       0       0       0       0       0       3       0
                                  JOPER     NWT   LROPT   TRACE
                                      5       0       0       0

                                     MULTI-PLAN ANALYSES TO BE PERFORMED
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             RTIOS=    .05     .10     .15     .20     .25     .30     .50    1.00

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

                                      SUB-AREA RUNOFF COMPUTATION

                   CALCULATE INFLOW HYDROGRAPH
                         ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                          HEAD       0       0       0       0       0       0       0       0
                                              HYDROGRAPH DATA
            IHYDG    IUHG   TAREA    SNAP   TRSDA   TRSPC   RATIO   ISNOW   ISAME   LOCAL
                1       2     .32     .00     .32    1.00    .000       0       0       0
                                               PRECIP DATA
                     SPFE     PMS      R6     R12     R24     R48     R72     R96
                      .00   24.70  101.00  120.00  130.00     .00     .00     .00
                                                LOSS DATA
       LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
           0     .00     .00    1.00     .00     .00    1.00   -1.00  -88.00     .00     .00

          CURVE NO = -88.00  WETNESS =   -1.00  EFFECT CN =   88.00
                                         UNIT HYDROGRAPH DATA
                                    TC=   .00    LAG=   .15

                                         RECESSION DATA
                            STRTQ=      .00    QRCSN=     .00    RTIOR= 1.00

            TIME INCREMENT TOO LARGE--(NHQ IS GT LAG/2)

            UNIT HYDROGRAPH 11 END OF PERIOD ORDINATES, TC=     .00 HOURS, LAG=     .15  VOL= 1.00
        297.      790.      696.      352.      176.       86.       42.       21.       10.        6.
          2.
```

[illegible] TOO LARGE--(NHR IS GT LAG/2)

UNIT HYDROGRAPH 11 END OF PERIOD ORDINATES, TC= .00 HOURS, LAG= .15 VOL= 1.00

297. 790. 696. 352. 176. 86. 42. 21. 10. 6.
2.

0

END-OF-PERIOD FLOW

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.05	1	.01	.00	.01	0.	1.01	12.05	145	.21	.20	.01	195.
1.01	.10	2	.01	.00	.01	0.	1.01	12.10	146	.21	.20	.01	304.
1.01	.15	3	.01	.00	.01	0.	1.01	12.15	147	.21	.20	.01	400.
1.01	.20	4	.01	.00	.01	0.	1.01	12.20	148	.21	.20	.01	449.
1.01	.25	5	.01	.00	.01	0.	1.01	12.25	149	.21	.20	.01	474.
1.01	.30	6	.01	.00	.01	0.	1.01	12.30	150	.21	.20	.01	487.
1.01	.35	7	.01	.00	.01	0.	1.01	12.35	151	.21	.20	.01	493.
1.01	.40	8	.01	.00	.01	0.	1.01	12.40	152	.21	.20	.01	497.
1.01	.45	9	.01	.00	.01	0.	1.01	12.45	153	.21	.20	.01	499.
1.01	.50	10	.01	.00	.01	0.	1.01	12.50	154	.21	.20	.01	501.
1.01	.55	11	.01	.00	.01	0.	1.01	12.55	155	.21	.20	.00	502.
1.01	1.00	12	.01	.00	.01	0.	1.01	13.00	156	.21	.20	.00	502.
1.01	1.05	13	.01	.00	.01	0.	1.01	13.05	157	.25	.24	.01	515.
1.01	1.10	14	.01	.00	.01	0.	1.01	13.10	158	.25	.24	.00	548.
1.01	1.15	15	.01	.00	.01	0.	1.01	13.15	159	.25	.24	.00	577.
1.01	1.20	16	.01	.00	.01	0.	1.01	13.20	160	.25	.24	.00	592.
1.01	1.25	17	.01	.00	.01	0.	1.01	13.25	161	.25	.25	.00	599.
1.01	1.30	18	.01	.00	.01	0.	1.01	13.30	162	.25	.25	.00	603.
1.01	1.35	19	.01	.00	.01	0.	1.01	13.35	163	.25	.25	.00	606.
1.01	1.40	20	.01	.00	.01	0.	1.01	13.40	164	.25	.25	.00	607.
1.01	1.45	21	.01	.00	.01	0.	1.01	13.45	165	.25	.25	.00	608.
1.01	1.50	22	.01	.00	.01	0.	1.01	13.50	166	.25	.25	.00	609.
1.01	1.55	23	.01	.00	.01	1.	1.01	13.55	167	.25	.25	.00	609.
1.01	2.00	24	.01	.00	.01	1.	1.01	14.00	168	.25	.25	.00	609.
1.01	2.05	25	.01	.00	.01	2.	1.01	14.05	169	.31	.31	.00	628.
1.01	2.10	26	.01	.00	.01	2.	1.01	14.10	170	.31	.31	.00	677.
1.01	2.15	27	.01	.00	.01	3.	1.01	14.15	171	.31	.31	.00	720.
1.01	2.20	28	.01	.00	.01	4.	1.01	14.20	172	.31	.31	.00	742.
1.01	2.25	29	.01	.00	.01	4.	1.01	14.25	173	.31	.31	.00	754.
1.01	2.30	30	.01	.00	.01	5.	1.01	14.30	174	.31	.31	.00	759.
1.01	2.35	31	.01	.00	.01	5.	1.01	14.35	175	.31	.31	.00	762.
1.01	2.40	32	.01	.00	.01	6.	1.01	14.40	176	.31	.31	.00	764.
1.01	2.45	33	.01	.00	.01	6.	1.01	14.45	177	.31	.31	.00	765.
1.01	2.50	34	.01	.00	.01	7.	1.01	14.50	178	.31	.31	.00	765.
1.01	2.55	35	.01	.00	.01	7.	1.01	14.55	179	.31	.31	.00	766.
1.01	3.00	36	.01	.00	.01	8.	1.01	15.00	180	.31	.31	.00	766.
1.01	3.05	37	.01	.00	.01	8.	1.01	15.05	181	.19	.19	.00	730.
1.01	3.10	38	.01	.00	.01	9.	1.01	15.10	182	.38	.38	.00	691.
1.01	3.15	39	.01	.00	.01	9.	1.01	15.15	183	.38	.38	.00	755.
1.01	3.20	40	.01	.00	.01	9.	1.01	15.20	184	.57	.57	.00	900.
1.01	3.25	41	.01	.00	.01	10.	1.01	15.25	185	.66	.66	.00	1122.
1.01	3.30	42	.01	.00	.01	10.	1.01	15.30	186	1.61	1.60	.01	1630.
1.01	3.35	43	.01	.00	.01	11.	1.01	15.35	187	2.65	2.64	.01	2828.
1.01	3.40	44	.01	.00	.01	11.	1.01	15.40	188	1.04	1.04	.00	3901.
1.01	3.45	45	.01	.00	.01	11.	1.01	15.45	189	.66	.66	.00	3613.
1.01	3.50	46	.01	.01	.01	12.	1.01	15.50	190	.57	.57	.00	2719.
1.01	3.55	47	.01	.01	.01	12.	1.01	15.55	191	.38	.38	.00	2034.
1.01	4.00	48	.01	.01	.01	13.	1.01	16.00	192	.38	.38	.00	1538.
1.01	4.05	49	.01	.01	.01	13.	1.01	16.05	193	.29	.29	.00	1208.
1.01	4.10	50	.01	.01	.01	13.	1.01	16.10	194	.29	.29	.00	969.
1.01	4.15	51	.01	.01	.01	13.	1.01	16.15	195	.29	.29	.00	853.
1.01	4.20	52	.01	.01	.01	14.	1.01	16.20	196	.29	.29	.00	784.

1.01	4.05	49	.01	.01	.01	13.	1.01	16.05	193	.29	.29	.00	1208.
1.01	4.10	50	.01	.01	.01	13.	1.01	16.10	194	.29	.29	.00	989.
1.01	4.15	51	.01	.01	.01	13.	1.01	16.15	195	.29	.29	.00	853.
1.01	4.20	52	.01	.01	.01	14.	1.01	16.20	196	.29	.29	.00	784.

B L A C K & V E A T C H PROJECT 9166. DATE 14 AUG 80 PAGE 6

FLOOD HYDROGRAPH PACKAGE - HEC-1 PROGRAM H21/02-OU TIME 17:16:27 CASE

1.01	4.25	53	.01	.01	.01	14.	1.01	16.25	197	.29	.29	.00	748.
1.01	4.30	54	.01	.01	.01	14.	1.01	16.30	198	.29	.29	.00	731.
1.01	4.35	55	.01	.01	.01	15.	1.01	16.35	199	.29	.29	.00	724.
1.01	4.40	56	.01	.01	.01	15.	1.01	16.40	200	.29	.29	.00	721.
1.01	4.45	57	.01	.01	.01	15.	1.01	16.45	201	.29	.29	.00	720.
1.01	4.50	58	.01	.01	.01	16.	1.01	16.50	202	.29	.29	.00	719.
1.01	4.55	59	.01	.01	.01	16.	1.01	16.55	203	.29	.29	.00	719.
1.01	5.00	60	.01	.01	.01	16.	1.01	17.00	204	.29	.29	.00	719.
1.01	5.05	61	.01	.01	.01	16.	1.01	17.05	205	.23	.23	.00	701.
1.01	5.10	62	.01	.01	.01	17.	1.01	17.10	206	.23	.23	.00	652.
1.01	5.15	63	.01	.01	.01	17.	1.01	17.15	207	.23	.23	.00	608.
1.01	5.20	64	.01	.01	.01	17.	1.01	17.20	208	.23	.23	.00	586.
1.01	5.25	65	.01	.01	.01	17.	1.01	17.25	209	.23	.23	.00	576.
1.01	5.30	66	.01	.01	.01	18.	1.01	17.30	210	.23	.23	.00	570.
1.01	5.35	67	.01	.01	.01	18.	1.01	17.35	211	.23	.23	.00	568.
1.01	5.40	68	.01	.01	.01	18.	1.01	17.40	212	.23	.23	.00	566.
1.01	5.45	69	.01	.01	.01	18.	1.01	17.45	213	.23	.23	.00	566.
1.01	5.50	70	.01	.01	.01	18.	1.01	17.50	214	.23	.23	.00	565.
1.01	5.55	71	.01	.01	.01	19.	1.01	17.55	215	.23	.23	.00	565.
1.01	6.00	72	.01	.01	.01	19.	1.01	18.00	216	.23	.23	.00	565.
1.01	6.05	73	.07	.04	.03	28.	1.01	18.05	217	.02	.02	.00	504.
1.01	6.10	74	.07	.04	.03	52.	1.01	18.10	218	.02	.02	.00	340.
1.01	6.15	75	.07	.04	.02	75.	1.01	18.15	219	.02	.02	.00	195.
1.01	6.20	76	.07	.04	.02	89.	1.01	18.20	220	.02	.02	.00	122.
1.01	6.25	77	.07	.04	.02	97.	1.01	18.25	221	.02	.02	.00	85.
1.01	6.30	78	.07	.04	.02	103.	1.01	18.30	222	.02	.02	.00	68.
1.01	6.35	79	.07	.05	.02	107.	1.01	18.35	223	.02	.02	.00	59.
1.01	6.40	80	.07	.05	.02	110.	1.01	18.40	224	.02	.02	.00	55.
1.01	6.45	81	.07	.05	.02	113.	1.01	18.45	225	.02	.02	.00	52.
1.01	6.50	82	.07	.05	.02	116.	1.01	18.50	226	.02	.02	.00	51.
1.01	6.55	83	.07	.05	.02	118.	1.01	18.55	227	.02	.02	.00	51.
1.01	7.00	84	.07	.05	.02	120.	1.01	19.00	228	.02	.02	.00	51.
1.01	7.05	85	.07	.05	.01	122.	1.01	19.05	229	.02	.02	.00	51.
1.01	7.10	86	.07	.05	.01	124.	1.01	19.10	230	.02	.02	.00	51.
1.01	7.15	87	.07	.05	.01	125.	1.01	19.15	231	.02	.02	.00	51.
1.01	7.20	88	.07	.05	.01	127.	1.01	19.20	232	.02	.02	.00	51.
1.01	7.25	89	.07	.05	.01	129.	1.01	19.25	233	.02	.02	.00	51.
1.01	7.30	90	.07	.05	.01	130.	1.01	19.30	234	.02	.02	.00	51.
1.01	7.35	91	.07	.05	.01	131.	1.01	19.35	235	.02	.02	.00	51.
1.01	7.40	92	.07	.05	.01	132.	1.01	19.40	236	.02	.02	.00	51.
1.01	7.45	93	.07	.05	.01	134.	1.01	19.45	237	.02	.02	.00	51.
1.01	7.50	94	.07	.06	.01	135.	1.01	19.50	238	.02	.02	.00	51.
1.01	7.55	95	.07	.06	.01	136.	1.01	19.55	239	.02	.02	.00	51.
1.01	8.00	96	.07	.06	.01	137.	1.01	20.00	240	.02	.02	.00	51.
1.01	8.05	97	.07	.06	.01	138.	1.01	20.05	241	.02	.02	.00	51.
1.01	8.10	98	.07	.06	.01	138.	1.01	20.10	242	.02	.02	.00	51.
1.01	8.15	99	.07	.06	.01	139.	1.01	20.15	243	.02	.02	.00	51.
1.01	8.20	100	.07	.06	.01	140.	1.01	20.20	244	.02	.02	.00	51.
1.01	8.25	101	.07	.06	.01	141.	1.01	20.25	245	.02	.02	.00	51.
1.01	8.30	102	.07	.06	.01	141.	1.01	20.30	246	.02	.02	.00	51.
1.01	8.35	103	.07	.06	.01	142.	1.01	20.35	247	.02	.02	.00	51.
1.01	8.40	104	.07	.06	.01	143.	1.01	20.40	248	.02	.02	.00	51.
1.01	8.45	105	.07	.06	.01	143.	1.01	20.45	249	.02	.02	.00	51.
1.01	8.50	106	.07	.06	.01	144.	1.01	20.50	250	.02	.02	.00	51.
1.01	8.55	107	.07	.06	.01	144.	1.01	20.55	251	.02	.02	.00	51.
1.01	9.00	108	.07	.06	.01	145.	1.01	21.00	252	.02	.02	.00	51.

[illegible]	8.45	105	.07	.06	.01	143.	[illegible]	20.45	249	.02	.02	.00	51.
[illegible]	8.50	106	.07	.06	.01	144.	1.01	20.50	250	.02	.02	.00	51.
1.01	8.55	107	.07	.06	.01	144.	1.01	20.55	251	.02	.02	.00	51.
1.01	9.00	108	.07	.06	.01	145.	1.01	21.00	252	.02	.02	.00	51.

1.01	9.05	109	.07	.06	.01	145.	1.01	21.05	253	.02	.02	.00	51.
1.01	9.10	110	.07	.06	.01	146.	1.01	21.10	254	.02	.02	.00	51.
1.01	9.15	111	.07	.06	.01	146.	1.01	21.15	255	.02	.02	.00	51.
1.01	9.20	112	.07	.06	.01	147.	1.01	21.20	256	.02	.02	.00	51.
1.01	9.25	113	.07	.06	.01	147.	1.01	21.25	257	.02	.02	.00	51.
1.01	9.30	114	.07	.06	.01	148.	1.01	21.30	258	.02	.02	.00	51.
1.01	9.35	115	.07	.06	.01	148.	1.01	21.35	259	.02	.02	.00	51.
1.01	9.40	116	.07	.06	.01	148.	1.01	21.40	260	.02	.02	.00	51.
1.01	9.45	117	.07	.06	.00	149.	1.01	21.45	261	.02	.02	.00	51.
1.01	9.50	118	.07	.06	.00	149.	1.01	21.50	262	.02	.02	.00	51.
1.01	9.55	119	.07	.06	.00	149.	1.01	21.55	263	.02	.02	.00	51.
1.01	10.00	120	.07	.06	.00	150.	1.01	22.00	264	.02	.02	.00	51.
1.01	10.05	121	.07	.06	.00	150.	1.01	22.05	265	.02	.02	.00	51.
1.01	10.10	122	.07	.06	.00	150.	1.01	22.10	266	.02	.02	.00	51.
1.01	10.15	123	.07	.06	.00	150.	1.01	22.15	267	.02	.02	.00	51.
1.01	10.20	124	.07	.06	.00	151.	1.01	22.20	268	.02	.02	.00	51.
1.01	10.25	125	.07	.06	.00	151.	1.01	22.25	269	.02	.02	.00	51.
1.01	10.30	126	.07	.06	.00	151.	1.01	22.30	270	.02	.02	.00	51.
1.01	10.35	127	.07	.06	.00	152.	1.01	22.35	271	.02	.02	.00	51.
1.01	10.40	128	.07	.06	.00	152.	1.01	22.40	272	.02	.02	.00	51.
1.01	10.45	129	.07	.06	.00	152.	1.01	22.45	273	.02	.02	.00	51.
1.01	10.50	130	.07	.06	.00	152.	1.01	22.50	274	.02	.02	.00	51.
1.01	10.55	131	.07	.06	.00	152.	1.01	22.55	275	.02	.02	.00	51.
1.01	11.00	132	.07	.06	.00	153.	1.01	23.00	276	.02	.02	.00	51.
1.01	11.05	133	.07	.06	.00	153.	1.01	23.05	277	.02	.02	.00	51.
1.01	11.10	134	.07	.06	.00	153.	1.01	23.10	278	.02	.02	.00	51.
1.01	11.15	135	.07	.06	.00	153.	1.01	23.15	279	.02	.02	.00	51.
1.01	11.20	136	.07	.06	.00	153.	1.01	23.20	280	.02	.02	.00	51.
1.01	11.25	137	.07	.06	.00	154.	1.01	23.25	281	.02	.02	.00	51.
1.01	11.30	138	.07	.06	.00	154.	1.01	23.30	282	.02	.02	.00	51.
1.01	11.35	139	.07	.06	.00	154.	1.01	23.35	283	.02	.02	.00	51.
1.01	11.40	140	.07	.06	.00	154.	1.01	23.40	284	.02	.02	.00	51.
1.01	11.45	141	.07	.06	.00	154.	1.01	23.45	285	.02	.02	.00	51.
1.01	11.50	142	.07	.06	.00	154.	1.01	23.50	286	.02	.02	.00	51.
1.01	11.55	143	.07	.06	.00	154.	1.01	23.55	287	.02	.02	.00	51.
1.01	12.00	144	.07	.06	.00	155.	1.02	.00	288	.02	.02	.00	51.

SUM 32.11 30.53 1.58 75523.
(816.)(775.)(40.)(2138.57)

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	3901.	844.	262.	262.	75489.
CMS	110.	24.	7.	7.	2138.
INCHES		24.53	30.48	30.48	30.48
MM		623.15	774.15	774.15	774.15
AC-FT		418.	520.	520.	520.
THOUS CU M		516.	641.	641.	641.

HYDROGRAPH AT STA HEAD FOR PLAN 1, RTIO 1

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	195.	42.	13.	13.	3774.
CMS	6.	1.	0.	0.	107.
INCHES		1.23	1.52	1.52	1.52

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	195.	42.	13.	17.	3774.
CMS	6.	1.	0.	0.	107.
INCHES		1.23	1.52	1.52	1.52

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
MM		31.16	38.71	38.71	38.71
AC-FT		21.	26.	26.	26.
THOUS CU M		26.	32.	32.	32.

HYDROGRAPH AT STA HEAD FOR PLAN 1, RTIO 2

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	390.	84.	26.	26.	7549.
CMS	11.	2.	1.	1.	214.
INCHES		2.45	3.05	3.05	3.05
MM		62.31	77.42	77.42	77.42
AC-FT		42.	52.	52.	52.
THOUS CU M		52.	64.	64.	64.

HYDROGRAPH AT STA HEAD FOR PLAN 1, RTIO 3

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	585.	127.	39.	39.	11323.
CMS	17.	4.	1.	1.	321.
INCHES		3.68	4.57	4.57	4.57
MM		93.47	116.12	116.12	116.12
AC-FT		63.	78.	78.	78.
THOUS CU M		77.	96.	96.	96.

HYDROGRAPH AT STA HEAD FOR PLAN 1, RTIO 4

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	780.	169.	52.	52.	15098.
CMS	22.	5.	1.	1.	428.
INCHES		4.91	6.10	6.10	6.10
MM		124.63	154.83	154.83	154.83
AC-FT		84.	104.	104.	104.
THOUS CU M		103.	128.	128.	128.

HYDROGRAPH AT STA HEAD FOR PLAN 1, RTIO 5

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	975.	211.	66.	66.	18872.
CMS	28.	6.	2.	2.	534.
INCHES		6.13	7.62	7.62	7.62
MM		155.79	193.54	193.54	193.54
AC-FT		105.	130.	130.	130.
THOUS CU M		129.	160.	160.	160.

HYDROGRAPH AT STA HEAD FOR PLAN 1, RTIO 6

HYDROGRAPH AT STA HEAD FOR PLAN 1, RTIO 6

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	1170.	253.	79.	79.	22647.
CMS	33.	7.	2.	2.	641.
INCHES		7.36	9.14	9.14	9.14
MM		186.94	232.25	232.25	232.25
AC-FT		126.	156.	156.	156.
THOUS CU M		155.	192.	192.	192.

HYDROGRAPH AT STA HEAD FOR PLAN 1, RTIO 7

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	1950.	422.	131.	131.	37745.
CMS	55.	12.	4.	4.	1069.
INCHES		12.27	15.24	15.24	15.24
MM		311.57	387.08	387.08	387.08
AC-FT		209.	260.	260.	260.
THOUS CU M		258.	321.	321.	321.

HYDROGRAPH AT STA HEAD FOR PLAN 1, RTIO 8

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	3901.	844.	262.	262.	75489.
CMS	110.	24.	7.	7.	2138.
INCHES		24.53	30.48	30.48	30.48
MM		623.15	774.15	774.15	774.15
AC-FT		418.	520.	520.	520.
THOUS CU M		516.	641.	641.	641.

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HYDROGRAPH ROUTING

ROUTE HYDROGRAPH THROUGH DAM

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
DAM	1	0	0	0	0	1	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP	LSTR
.0	.000	.00	1	0	0	0	0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	.000	.000	.000	-929.	-1

STAGE	928.60	929.60	935.60	945.60
FLOW	.00	13.00	15.00	18.00
SURFACE AREA=	0.	12.	19.	40.

FL	.00	13.00	15.00	18.00
SURFACE AREA=	0.	12.	19.	40.

CAPACITY=	0.	54.	76.	366.
ELEVATION=	915.	929.	930.	940.

CREL	SPWID	COQW	EXPW	ELEVL	COQL	CAREA	EXPL
928.6	.0	.0	.0	.0	.0	.0	.0

DAM DATA

TOPEL	COQD	EXPD	DAMWID
931.2	.0	.0	0.

CREST LENGTH	0.	50.	95.	190.	330.	470.	610.	860.	960.	960.
AT OR BELOW ELEVATION	929.5	929.6	931.2	932.4	932.8	933.0	934.0	936.0	937.0	945.0

STATION DAM, 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.	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.	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.	0.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	2.	2.	2.	2.	2.
2.	2.	2.	2.	2.	3.	3.	3.	3.	3.
3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
4.	4.	4.	4.	4.	4.	4.	4.	5.	5.
5.	5.	5.	5.	6.	6.	6.	6.	6.	6.
7.	7.	7.	7.	7.	7.	8.	8.	8.	8.
8.	9.	9.	9.	9.	9.	10.	11.	12.	13.
16.	17.	19.	20.	21.	22.	22.	23.	23.	24.
24.	25.	25.	25.	26.	26.	26.	26.	27.	27.
27.	27.	27.	27.	27.	27.	27.	27.	26.	25.
25.	24.	23.	22.	22.	21.	20.	20.	19.	19.
18.	18.	17.	17.	17.	16.	16.	16.	15.	15.
15.	15.	14.	14.	14.	14.	13.	13.	13.	13.
13.	13.	13	12.	12.	12.	12.	12.	12.	12.
12.	12.	12.	12.	12.	12.	12.	12.	12.	11.
11.	11.	11.	11.	11.	11.	11.	11.	11.	11.
11.	11.	11.	11.	11.	11.	11.	11.		

STORAGE

54.	54.	54.	54.	54.	54.	54.	54.	54.	54.
54.	54.	54.	54.	54.	54.	54.	54.	54.	54.
54.	54.	54.	54.	54.	54.	54.	54.	54.	54.
54.	54.	54.	54.	54.	54.	54.	54.	54.	54.

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)

RATIOS APPLIED TO FLOWS

OPERATION	STATION	AREA	PLAN	RATIO 1 .05	RATIO 2 .10	RATIO 3 .15	RATIO 4 .20	RATIO 5 .25	RATIO 6 .30	RATIO 7 .50	RATIO 8 1.00
HYDROGRAPH AT	HEAD	.32	1	195.	390.	585.	780.	975.	1170.	1950.	3901.
	(	.83)	(	5.52)(	11.05)(	16.57)(	22.09)(	27.61)(	33.14)(	55.23)(	110.46)(
ROUTED TO	DAM	.32	1	27.	123.	232.	341.	452.	571.	1107.	2900.
	(	.83)	(	.76)(	3.48)(	6.58)(	9.67)(	12.81)(	16.17)(	31.34)(	82.11)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	928.60	928.60	931.20
STORAGE	54.	54.	101.
OUTFLOW	0.	0.	445.

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
.05	929.75	.00	72.	27.	.00	18.00	.00
.10	930.28	.00	82.	123.	.00	16.08	.00
.15	930.66	.00	90.	232.	.00	16.00	.00
.20	930.96	.00	96.	341.	.00	16.00	.00
.25	931.22	.02	101.	452.	.17	15.92	.00
.30	931.45	.25	106.	571.	.58	15.92	.00
.50	932.20	1.00	123.	1107.	1.50	15.92	.00
1.00	933.37	2.17	152.	2900.	5.08	15.83	.00