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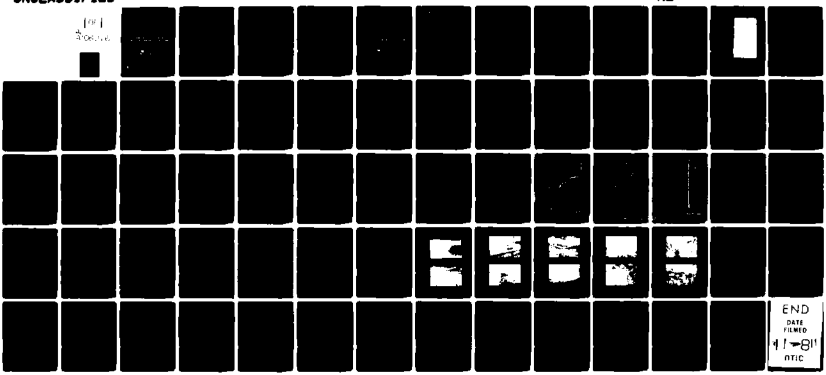

LEVEL II

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UPPER MISSISSIPPI - KASKASKIA - ST. LOUIS BASIN

RAINBOW LAKE DAM

FRANKLIN COUNTY, MISSOURI

MO 30544

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

OCTOBER 1980

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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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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UPPER MISSISSIPPI - KASKASKIA - ST. LOUIS BASIN

RAINBOW LAKE DAM

FRANKLIN COUNTY, MISSOURI

MO 30544

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

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

FOR: STATE OF MISSOURI

OCTOBER 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: Rainbow Lake Dam Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Rainbow Lake Dam (MO 30544).

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. The combined spillway capacity 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 — 18 DEC 1980 — Date

APPROVED BY: SIGNED — Colonel, CE, District Engineer — 22 DEC 1980 — Date

RAINBOW LAKE DAM

MISSOURI INVENTORY NO. 30544

FRANKLIN COUNTY, MISSOURI

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

PREPARED BY:

HORNER & SHIFRIN, INC.
5200 OAKLAND AVENUE
ST. LOUIS, MISSOURI 63110

FOR:

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS

OCTOBER 1980

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam:	Rainbow Lake Dam
State Located:	Missouri
County Located:	Franklin
Stream:	Tributary of Pin Oak Creek
Date of Inspection:	28 August 1980

The Rainbow Lake Dam was visually inspected by engineering personnel of Horner & Shifrin, Inc., Consulting Engineers, St. Louis, Missouri. The purpose of this inspection was to assess the general condition of the dam with respect to safety and, based upon this inspection and available data, determine if the dam poses a hazard to human life or property.

The following summarizes the findings of the visual inspection and the results of certain hydrologic/hydraulic investigations performed under the direction of the inspection team. Based on the visual inspection and the results of the hydrologic/hydraulic investigations, the present general condition of the dam is considered to be less than satisfactory. ~~The following~~ deficiencies were noticed during the inspection and are considered to have an adverse effect on the overall safety and future operation of the dam:

1. Seepage, as characterized by cattails, willow trees, soft ground, and standing water was observed in two areas adjacent to the toe of the downstream slope of the dam. Uncontrolled seepage could develop into a piping condition (progressive internal erosion) that can lead to failure of the dam. Saturation of the soil adjacent to the dam can weaken the foundation and impair the stability of the dam. To this respect, the main valve on the lake drawdown pipe was, at the time of the inspection, leaking moderately and contributing to the wet condition just downstream of the dam.

2. Erosion of the grass covered upstream face of the dam apparently by wave action and/or fluctuations of the lake surface level has created a near vertical bank approximately 12-to-18 inches high. A grass covered slope is not considered adequate protection to prevent erosion of the embankment by wave action or fluctuations of the lake level. Loss of material by erosion can be detrimental to the dam's stability.

3. At the time of the inspection, the grass and other turf cover on the dam slopes was about 3 feet high. Some areas of the dam were also covered with undergrowth including small trees and dense brush. The vegetative cover should not be allowed to reach a height that provides cover for burrowing animals or hinders inspection of the dam.

According to the criteria set forth in the recommended guidelines, the magnitude of the spillway design flood for the Rainbow Lake Dam, which is classified as small in size and of high hazard potential, is specified to be a minimum of one-half the Probable Maximum Flood (PMF). Considering the fact that approximately 30 mobile homes and a campground lie within the possible flood damage zone, it is recommended that the spillway for this dam be designed for the PMF. The Probable Maximum Flood (PMF) is the flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The PMF is ordinarily accepted as the inflow design flood for dams where failure of the structure would increase the danger to human life.

Results of a hydrologic/hydraulic analysis indicated that the spillways, principal plus emergency, are inadequate to pass lake outflow resulting from a storm of PMF magnitude or the outflow from the one percent chance (100-year frequency) flood without overtopping the dam. The spillways are capable of passing lake outflow corresponding to about 12 percent of the PMF lake inflow and the lake outflow resulting from the 10 percent chance (10-year frequency) flood. According to the St. Louis District, Corps of Engineers, the length of the downstream damage zone, should failure of the dam occur, is estimated to be two miles. Within the possible damage zone are a railroad embankment, State Highway M, a trailer court with about 30 mobile homes, a gasoline service station, and a campground.

A review of available data did not disclose that seepage or stability analyses of the dam were performed. This is considered a deficiency and should be rectified.

It is recommended that the Owner take the necessary action without undue delay to correct or control the deficiencies and safety defects reported herein.

Harold B. Lockett

Harold B. Lockett
P. E. Missouri E-4189

Albert B. Becker, Jr.

Albert B. Becker, Jr.
P. E. Missouri E-9168

OVERVIEW RAINBOW LAKE DAM

PHASE 1 INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

RAINBOW LAKE DAM - MO 30544

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PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

RAINBOW LAKE DAM - MO 30544

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. The National Dam Inspection Act, Public Law 92-367, dated 8 August 1972, 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 St. Louis District, Corps of Engineers, directed that a safety inspection of the Rainbow Lake Dam be made.

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

c. Evaluation Criteria. This evaluation was performed in accordance with the "Phase I" investigation procedures as prescribed in "Recommended Guidelines for Safety Inspection of Dams", Appendix D to "Report to the Chief of Engineers on the National Program of Inspection of Non-Federal Dams", dated May 1975.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances. The Rainbow Lake Dam is an earthfill type embankment rising approximately 27 feet above the natural streambed at the downstream toe of the barrier. The embankment has an upstream slope (above the waterline) of approximately 1v on 2.2h, a crest width of about 10 feet, and a downstream slope on the order of 1v on 2.4h, although the slope becomes less steep near the base of the dam. The length of the dam is approximately 597 feet and an unsurfaced roadway traverses the dam crest. A plan and profile of the dam is shown on Plate 3 and a cross-section of the dam, at about the location of the original stream on which the dam was constructed, is shown on Plate 4. At normal pool elevation, the reservoir impounded by the dam occupies approximately 8 acres. A 3-inch diameter pipe with the control valve located at the downstream end of the pipe serves as a lake drawdown facility. The outlet is located to the left of the center of the dam.

The dam has both a principal and an emergency spillway. The principal spillway, an excavated earth, trapezoidal section with a natural rock bottom, is located at the left, or east, abutment. The outlet channel for the principal spillway follows a series of rock falls through the exit section until it reaches the valley floor approximately 170 feet downstream of the dam. An earthen bank that parallels the spillway crest section, serves to confine flow to the channel and protect the dam. The emergency spillway, an excavated earth, dish-shaped section, is located at the right, or west, abutment. The outlet channel for the emergency spillway which is partially in rock through the exit section, reaches the valley floor at a point about 140 feet downstream of the dam. The outlet channel for the emergency spillway joins the outlet channel for the principal spillway at a point just upstream of the culvert that crosses the road approximately 180 feet downstream of the dam. Profiles and cross-sections of the principal and emergency spillway channels are shown on Plate 5.

b. Location. The dam is located on an unnamed tributary of Pin Oak Creek, about 1.0 mile northwest of Highway M and approximately 1.5 miles southwest of the Town of Villa Ridge, Missouri, as shown on the Regional Vicinity Map, Plate 1. The dam is located in Section 21, Township 43 North, Range 1 East, within Franklin County.

c. Size Classification. The size classification based on the height of the dam and storage capacity, is categorized as small (per Table 1, Recommended Guidelines for Safety Inspection of Dams).

d. Hazard Classification. The Rainbow Lake Dam, according to the St. Louis District, Corps of Engineers, has a high hazard potential, meaning that if the dam should fail, there may be loss of life, serious damage to homes, or extensive damage to agricultural, industrial and commercial facilities, important public utilities, main highways, or railroads. The estimated flood damage zone, should failure of the dam occur, as determined by the St. Louis District, extends two miles downstream of the dam. Within the possible damage zone are a railroad embankment, State Highway M, a trailer court with about 30 mobile homes, a gasoline service station, and a campground. Those features lying within the downstream damage zone reported by the Corps of Engineers, St. Louis District, were verified by the inspection team.

e. Ownership. The lake and dam are owned by Mrs. Catherine Straatmann. Mrs. Straatmann's address is Box 55, Route 1, Villa Ridge, Missouri 63089.

f. Purpose of Dam. The dam impounds water for recreational use. The property is operated on a commercial basis by Mrs. Straatmann and is available for picnicking, camping, and fishing. Mrs. Straatmann and family reside on the property where the dam is located.

g. Design and Construction History. According to Mrs. Straatmann, the dam was constructed in 1954 by Arthur Tyree, an earth excavating contractor, from St. Clair, Missouri. Mr. Tyree is deceased, and no records of the design or construction of the dam are known to exist.

h. Normal Operational Procedure. The lake level is unregulated. Lake outflow is governed by the capacities of the principal and emergency spillways.

1.3 PERTINENT DATA

a. Drainage Area. With the exception of the hillside east of the lake which is tree covered, the area tributary to the lake is essentially meadowland. The watershed above the dam amounts to approximately 175 acres. The watershed area is outlined on Plate 2.

b. Discharge at Damsite.

(1) Estimated known maximum flood at damsite ... 26 cfs* (W.S.Elev. 600.6)

(2) Spillway capacity

a. Principal ... 12 cfs (W.S.Elev. 600.4)

b. Principal + emergency ... 242 cfs (W.S.Elev. 601.9)

c. Elevation (Ft. above MSL). The following elevations were determined by survey and are based on topographic data shown on the 1969 Moselle, Missouri, Quadrangle Map, 7.5 Minute Series.

(1) Observed pool ... 598.5

(2) Normal pool ... 600.0

(3) Spillway crest

a. Principal ... 600.0

b. Emergency ... 600.4

(4) Maximum experienced pool ... 600.6*

(5) Top of dam ... 601.9 (min.)

(6) Streambed at centerline of dam ... 576± (Est.)

(7) Maximum tailwater ... *Unknown*

(8) Observed tailwater ... None

d. Reservoir.

(1) Length at normal pool (Elev. 600.0) ... 700 ft.

(2) Length at maximum pool (Elev. 601.9) ... 800 ft.

e. Storage.

(1) Normal pool ... 53 ac. ft.

(2) Top of dam (incremental) ... 16 ac. ft.

*Based on an estimate of maximum lake level as reported by Mrs. Straatmann.

f. Reservoir Surface.

(1) Normal pool ... 8 acres

(2) Top of dam (incremental) ... 1 acre

g. Dam. The height of the dam is defined to be the overall vertical distance from the lowest point of foundation surface at the downstream toe of the barrier to the top of the dam.

(1) Type ... Earthfill

(2) Length ... 597 ft.

(3) Height ... 27 ft.

(4) Top width ... 10 ft.

(5) Side slopes

a. Upstream ... 1v on 2.2h (above waterline)

b. Downstream ... 1v on 2.4h

(6) Cutoff ... Core trench*

(7) Slope protection

a. Upstream ... Grass

b. Downstream ... Grass

h. Principal Spillway.

(1) Type ... Uncontrolled, excavated earth, trapezoidal section

(2) Location ... Left abutment

(3) Crest elevation ... 600.0

(4) Approach channel ... Lake

(5) Outlet channel ... Excavated earth, trapezoidal section

*Per Mrs. Straatmann.

i. Emergency Spillway.

(1) Type ... Uncontrolled, excavated earth, dish-shaped section

(2) Location ... Right abutment

(3) Crest elevation ... 600.4

(4) Approach channel ... Lake

(5) Outlet channel ... Excavated earth, trapezoidal section

j. Lake Drawdown Facility.

(1) Type ... 3-Inch steel pipe

(2) Location ... Station 2+62

(3) Control ... 3-Inch gate valve

(4) Outlet elevation ... 578.4 (75 ft. from center of dam)

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

No data relating to the design of the dam are known to exist.

2.2 CONSTRUCTION

As previously stated, the dam was constructed in 1954 by Arthur Tyree (deceased), an earth excavating contractor from St. Clair, Missouri. No records of the construction are known to exist. According to the Owner, Mrs. Catherine Straatmann, (Mr. Straatmann is deceased), a core trench was excavated to rock along the axis of the dam. Mrs. Straatmann recalled that the material used to backfill the trench and construct the dam was clay, obtained from the area to be occupied by the lake. No other information regarding construction activities was available.

2.3 OPERATION

The lake level is uncontrolled and governed by the elevation of the crest of the principal spillway. An emergency spillway with a crest elevation approximately 0.4 foot higher than the crest of the principal spillway and about 1.5 feet lower than the top of the dam at its lowest point, also serves as an outlet for lake surcharge. No indication was found that the dam has been overtopped. Mrs. Straatmann, who resides on the lake property, reported that the dam has never been overtopped and that the highest lake level observed produced a depth of flow at the emergency spillway on the order of 0.2 foot.

2.4 EVALUATION

a. Availability. Engineering data for assessing the design of the dam and spillways were unavailable.

b. Adequacy. No data available. 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.

ɛCTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. A visual inspection of the Rainbow Lake Dam was made by Horner & Shifrin engineering personnel, R. E. Sauthoff, Civil Engineer, H. B. Lockett, Hydrologist, and A. B. Becker, Jr., Civil and Soils Engineer, on 28 August 1980. An examination of the dam site was also made by an engineering geologist, Jerry D. Higgins, Ph.D., a consultant retained by Horner & Shifrin for the purpose of assessing the area geology. Also examined at the time of the inspection were the areas and features below the dam within the potential flood damage zone. Photographs of the dam taken at the time of the inspection are included on pages A-1 through A-5 of Appendix A. The locations of the photographs taken during the inspection are indicated on Plate 3.

b. Site Geology. The dam area is located within the Salem Plateau Section of the Ozark Plateaus Physiographic Province near the border with the Dissected Till Plains Section of the Central Lowlands Province. The topography is rolling, with a maximum of approximately 160 feet of relief between the reservoir and the surrounding drainage divides. The bedrock consists of gently northward-dipping Ordovician-age sedimentary strata of the Jefferson City-Cotter formation. No faults were observed or have been reported in the vicinity of the site. The Jefferson City-Cotter is a light brown, medium-to-finely crystalline dolomite. It is thin- to medium-bedded, often argillaceous, and cherty. Solution-enlargement of joints and bedding planes frequently occur in the dolomite, and the contact between bedrock, and the overlying surficial materials is usually an irregular surface. These solution features are commonly the cause of reservoir leakage when the soil cover is thin. The Jefferson City-Cotter is exposed in the spillway channel.

The unconsolidated surficial materials are composed primarily of residual clays overlain by loessal soils. The residual soils, formed from the in-place weathering of bedrock, consist of stony, blocky, silty clays which are somewhat permeable and often cause seepage from reservoirs. The loessal soils consist of deep, moderately well-drained silts and silty clays. In general, these soils grade from light brown silts near the surface to a friable silty clay with depth, and are generally low in permeability but susceptible to erosion. According to the Unified Soil Classification, these soils are classified as CL or CL-ML materials and are generally suitable for small reservoirs if they are not too thin and protected from erosion. The soils in the general area of the reservoir are thin, however, and at least some seepage through bedrock should be expected.

It appears that the most significant geologic problem at the site is the erodibility of the silty soils; however, this does not appear to affect the stability of the dam embankment at the present time.

c. Dam. The visible portions of the upstream and downstream faces of the dam, as well as the dam crest (see Photos 1 and 2), were examined and, except as noted herein, found to be in sound condition. Erosion of the unprotected (no riprap) upstream face of the dam has created a near vertical bank about 12-to-18 inches high (see Photo 9) at the normal waterline. No cracking of the surface, sloughing of the embankment slopes, or undue settlement of the dam crest was noticed, although the top of the dam was found to be quite irregular and wavey across the crest. For the most part, the top of the dam was covered by grass up to 24 inches high; however, there was evidence that the crest had been used as a roadway, and the grass along the vehicle tracks was very thin and offered little protection. The slopes of the dam were well covered with grass, sericea lespedeza, and weeds that were about 3 feet high throughout. In some areas, undergrowth, including small trees and dense brush, also covered the downstream face of the dam. No animal burrows were noticed; however, due to the dense growth of vegetative cover on the slopes, not all areas could be thoroughly examined, and it cannot be stated that none exist. No significant erosion of the embankment at the junctions with the abutments was observed. Examination of a soil sample obtained from the downstream face of the embankment near the center of the dam indicated the material to be a grey-brown, silty, lean clay (CL) of low-to-medium plasticity.

A marshy area approximately 35 feet square (see Photo 10), as evidenced by cattails and soft, wet ground, was noticed in the area just downstream of the toe of the dam opposite station 5+00. Since flow in the area was indistinguishable, an estimate of seepage quantity could not be made. A second marshy area, with small willow trees, high grass, and wet, soft ground also existed in the area just downstream of and opposite the center of the dam. It could not be determined if this marshy condition was due primarily to seepage or to leakage of the valve on the lake drawdown pipe. The main valve (see Photo 8) on the drawdown pipe was leaking at a rate of about 1 gpm at the time of the inspection, and flow from the pipe was entering the area. However, since the marshy condition extended to a point about 90 feet east of the valve, it is believed that the dam is experiencing some seepage in this area and that the marshy condition is a result of both dam seepage and valve leakage. The marshy area extended to the upstream end of the culvert that crosses beneath the road (see Photo 7) at about station 3+50. Due to the collapsed condition of the culvert headwalls, flow at this location was difficult to estimate; however, it appeared to be also on the order of 1 gpm.

The crest and exit sections of the principal spillway (see Photos 3 and 4) were found to be in satisfactory condition with no significant erosion of the bedrock invert or earthen banks, although a few small trees on the order of 1 inch in diameter were present within the channel at the downstream end of the crest section.

The crest section of the emergency spillway (see Photo 5) was also found to be in satisfactory condition without signs of erosion damage. Some erosion of the banks of the emergency spillway outlet channel through the exit section was observed; however, loss of material at this location did not appear to be significant at this time. Just downstream of the crest section (see Photo 6), the channel was congested with small-to-medium size trees and dense brush.

As previously mentioned, the main valve on the 3-inch lake drawdown pipe (see Photo 8) was leaking at a rate of about 1 gpm. An attempt to tighten the valve did not reduce the flow. A small gulley, on the order of 12 inches deep and 15 inches wide, was eroded in the area just downstream of the valve. The 1-inch valve on the line that connects to the 3-inch diameter pipe just upstream of the valve was not leaking and appeared to be in satisfactory condition. The portion of the 3-inch pipe exposed to view also appeared to be in satisfactory condition.

d. Appurtenant Structures. No appurtenant structures were observed at this dam site.

e. Downstream Channel. The channel downstream of the dam is unimproved. The channel section is irregular and for the most part, lined with trees. The stream joins Pin Oak Creek at a point about 1.3 miles downstream of the dam; Pin Oak Creek joins the Bourbeuse River nearly 2 miles downstream of the dam.

f. Reservoir. The area surrounding the lake is for the most part covered with grass and well maintained. No significant erosion of the lake banks was noted. At the time of the inspection, the lake water was clear and about 1.5 feet below normal pool level. The amount of sediment within the lake could not be determined during the inspection; however, due to the fact that the drainage area is well covered with vegetation, and that several small ponds, which will prevent sediment from entering the lake, are located on the tributaries just upstream of the lake, it is not expected to be significant.

3.2 EVALUATION

The deficiencies observed during this inspection and noted herein are not considered of significant importance to warrant immediate remedial action. It is recommended that the leaking valve on the lake drawdown pipe be repaired. It is also recommended that measures be taken to control the seepage evident in the areas just downstream of the dam, and that the upstream face of the dam be restored and provisions made to prevent future erosion.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

The spillways are uncontrolled. The lake surface level is governed by precipitation runoff, evaporation, seepage, and the capacities of the uncontrolled principal and emergency spillways.

4.2 MAINTENANCE OF DAM

According to the Owner, Mrs. Catherine Straatmann, the grass on the downstream side of the dam is burned off in the spring of the year, and muskrats in the vicinity of the dam are trapped during the winter. No other dam maintenance work is performed. Mrs. Straatmann also reported that the lake drawdown system originally had a perforated pipe riser section on the upstream end which projected above the normal level of the lake, but that several years ago, this section was pulled over and now lies on the bottom of the lake.

4.3 MAINTENANCE OF OUTLET OPERATING FACILITIES

With the exception of the valves on the lake drawdown pipe, no outlet facilities requiring operation exist at this dam. There is no reservoir regulation plan.

4.4 DESCRIPTION OF ANY WARNING SYSTEMS IN EFFECT

The inspection did not reveal the existence of a dam failure warning system.

4.5 EVALUATION

Lack of or inadequate maintenance is considered detrimental to the safety of a dam. It is recommended that maintenance of the dam and spillways be undertaken on a regular basis and that records be kept of all major items of maintenance work performed. It is also recommended that a detailed inspection of the dam be instituted on a regular basis by an engineer experienced in the design and construction of dams and that records be kept of all inspections made and remedial measures taken.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. Design data are not available.

b. Experience Data. The drainage area and lake surface area were determined from the 1969 USGS Moselle, Missouri, Quadrangle Map. The proportions and dimensions of the spillways and dam were developed from surveys made during the inspection. Records of rainfall, streamflow, or flood data for the watershed were not available.

Due to the fact that the watershed for this reservoir is small and since there is no history of excessive reservoir leakage that would adversely affect the normal operating level of the lake, the lake level was assumed to be at normal pool as a result of antecedent storms prior to occurrence of the PMF and the probabilistic storms.

According to the St. Louis District, Corps of Engineers, the estimated flood damage zone, should failure of the dam occur, extends two miles downstream of the dam.

c. Visual Observations.

(1) The dam has both a principal and an emergency spillway.

(2) The principal spillway, an excavated earth, trapezoidal section, is located at the left, or east, abutment.

(3) The emergency spillway, an excavated earth, dish-shaped section, is located at the left, or west, abutment.

(4) The principal and emergency spillway outlet channels join the original stream channel at a point approximately 170 feet downstream of the dam.

(5) A 3-inch pipe with a valve at the outlet end is provided for lake drawdown.

(6) Several small (less than 1 acre surface area) ponds are located in e watershed area upstream of Rainbow Lake. Due to their small areas and limited storage capacities, these ponds are considered hydrologically insignificant and are ignored in the hydraulic/h ro.ogic analysis.

d. Overtopping Potential. The spillway is inadequate to pass the probable maximum flood, 1/2 the probable max m flood, or the 1 percent chance flood without overtopping the dam. The spillway is adequate, however, to pass the 10 percent chance (10-year frequency) flood without overtopping the dam. The results of the dam overtopping analyses are as follows:

(Note: The data appearing in the following table were extracted from the computer output data appearing in Appendix B. Decimal values have been rounded to the nearest one-tenth in order to prevent assumption of unwarranted accuracy.)

Ratio of PMF	Q-Peak Outflow (cfs)	Max. Lake W.S. Elev.	Max. Depth (Ft.) of Flow over Dam (Elev. 601.9)	Duration of Overtopping of Dam (Hours)
0.50	1,673	603.1	1.2	4.5
1.00	3,692	603.8	1.9	6.6
100-Yr.Flood	419	602.3	0.4	0.5
10-Yr. Flood	133	601.5	0.0	0.0

Elevation 601.9 was found to be the lowest point in the dam crest. The flow safely passing the spillway just prior to overtopping was determined to be approximately 242 cfs, which is the routed outflow corresponding to about 12 percent of the probable maximum flood inflow. This flow is less than the outflow from the 1 percent chance (100-year frequency) flood but greater than the outflow from the 10 percent chance (10-year frequency) flood. During peak flow of the probable maximum flood, the greatest depth of flow over the dam is

projected to be 1.9 feet and overtopping will extend across the entire length of the dam.

e. Evaluation. Experience with embankments constructed of similar material (a silty lean clay of low-to-medium plasticity) to that used to construct this dam has shown evidence that under certain conditions, such as high velocity flow, the material can be very erodible. Such a condition exists during the PMF when large lake outflow, accompanied by high flow velocities, occurs. For the PMF condition where the depth of flow over the dam crest, a maximum of 1.9 feet, and the duration of flow over the dam, 6.6 hours, are considerable, damage by erosion to the crest and downstream face of the dam is expected. The extent of these damages is not predictable within the scope of this investigation; however, there is a possibility that they could result in failure by erosion of the dam.

f. References. Procedures and data for determining the probable maximum flood, the 100-year and 10-year frequency floods, and the discharge rating curve for flow passing the spillways and dam crest are presented on pages B-1 thru B-3 of the Appendix. Listings of the HEC-1 (Dam Safety Version) input data for both the probable maximum flood, and the probabilistic floods, are shown on pages B-4 through B-8. Computer output data, including unit hydrograph ordinates, tabulation of PMF rainfall, loss and inflow data are shown on pages B-9 through B-12; tabulation of lake surface area, elevation and storage volume is shown on page B-13; tabulations titled "Summary of Dam Safety Analysis" for the PMF, 1 percent chance (100-year frequency) and 10 percent chance (10-year frequency) floods are also shown on pages B-13 and B-14 of Appendix B.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

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

b. Design and Construction Data. No design or construction data relating to the structural stability of the dam are known to exist. 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. Operating Records. No appurtenant structures or facilities requiring operation exist at this dam. According to the Owner, Mrs. Catherine Straatmann, no records are kept of the lake level, spillway discharge, dam settlement, or seepage.

d. Post Construction Changes. According to Mrs. Straatmann, no post construction changes have been made which would affect the structural stability of the dam.

e. Seismic Stability. The dam is located within a Zone II seismic probability area. An earthquake of the magnitude that might occur in this area would not be expected to cause structural damage to a well constructed earth dam of this size provided that static stability conditions are satisfactory and conventional safety margins exist. However, it is recommended that the prescribed seismic loading for this zone be applied in any stability analyses performed for this dam.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. A hydraulic analysis indicated that the spillways (principal plus emergency) are capable of passing lake outflow of about 242 cfs without the level of the lake exceeding the low point in the top of the dam. A hydrologic analysis of the lake watershed area, as discussed in Section 5, paragraph 5.1d, indicates that for storm runoff of probable maximum flood magnitude, the lake outflow would be about 3,692 cfs, and that for the 1 percent chance (100-year frequency) flood, the lake outflow would be about 419 cfs. A similar analysis indicated that the lake outflow for the 10 percent chance (10-year frequency) flood would be on the order of 133 cfs.

Seepage and stability analyses of the dam were not available for review, and therefore, no judgment could be made with respect to the structural stability of the dam.

Several items were noticed during the inspection that could adversely affect the safety of the dam. These items include high grass and brush on the dam slopes, seepage, and a leaking valve on the lake drawdown outlet pipe.

b. Adequacy of Information. Due to lack of design and construction data, the assessments reported herein were based on external conditions as determined during the visual inspection. The assessments of the hydrology of the watershed and capacities of the spillways were based on a hydrologic/hydraulic study as indicated in Section 5. Seepage and stability analyses comparable to the requirements of "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

c. Urgency. The remedial measures recommended in paragraph 7.2 for the items concerning the safety of the dam noted in paragraph 7.1a should be accomplished without undue delay. The item recommended in paragraph 7.2a regarding the provision of additional spillway capacity should be pursued on a high priority basis since the existing spillways are considered to be seriously inadequate.

d. <u>Necessity for Phase II</u>. Based on the results of the Phase I inspection, a Phase II investigation is not recommended.

e. <u>Seismic Stability</u>. The dam is located within a Zone II seismic probability area. An earthquake of the magnitude that might occur in this area would not be expected to cause structural damage to a well constructed earth dam of this size provided that static stability conditions are satisfactory and conventional safety margins exist. However, it is recommended that the prescribed seismic loading for this zone be applied in any stability analyses performed for this dam.

7.2 REMEDIAL MEASURES

a. <u>Recommendations</u>. The following actions are recommended:

1. Based upon criteria set forth in the recommended guidelines, spillway size and/or height of dam should be increased in order to pass lake outflow resulting from a storm of probable maximum flood magnitude. In either case, the spillways should be protected to prevent erosion.

2. Obtain the necessary soil data and perform dam seepage and stability analyses in order to determine the structural stability of the dam for all operational conditions. Seepage and stability analyses should be performed by a qualified professional engineer experienced in the design and construction of earthen dams.

b. <u>Operations and Maintenance (O & M) Procedures</u>. The following O & M Procedures are recommended:

1. Provide some means of controlling seepage evident in the areas adjacent to the downstream toe of the dam. Uncontrolled seepage can lead to a piping condition which could result in failure of the dam. Drainage of the areas affected by seepage including elimination of the marshy areas just downstream of the dam should be one of the objectives of the seepage control measures since saturation of the soil weakens the foundation which could impair the stability of the dam. It is also recommended that the leaking

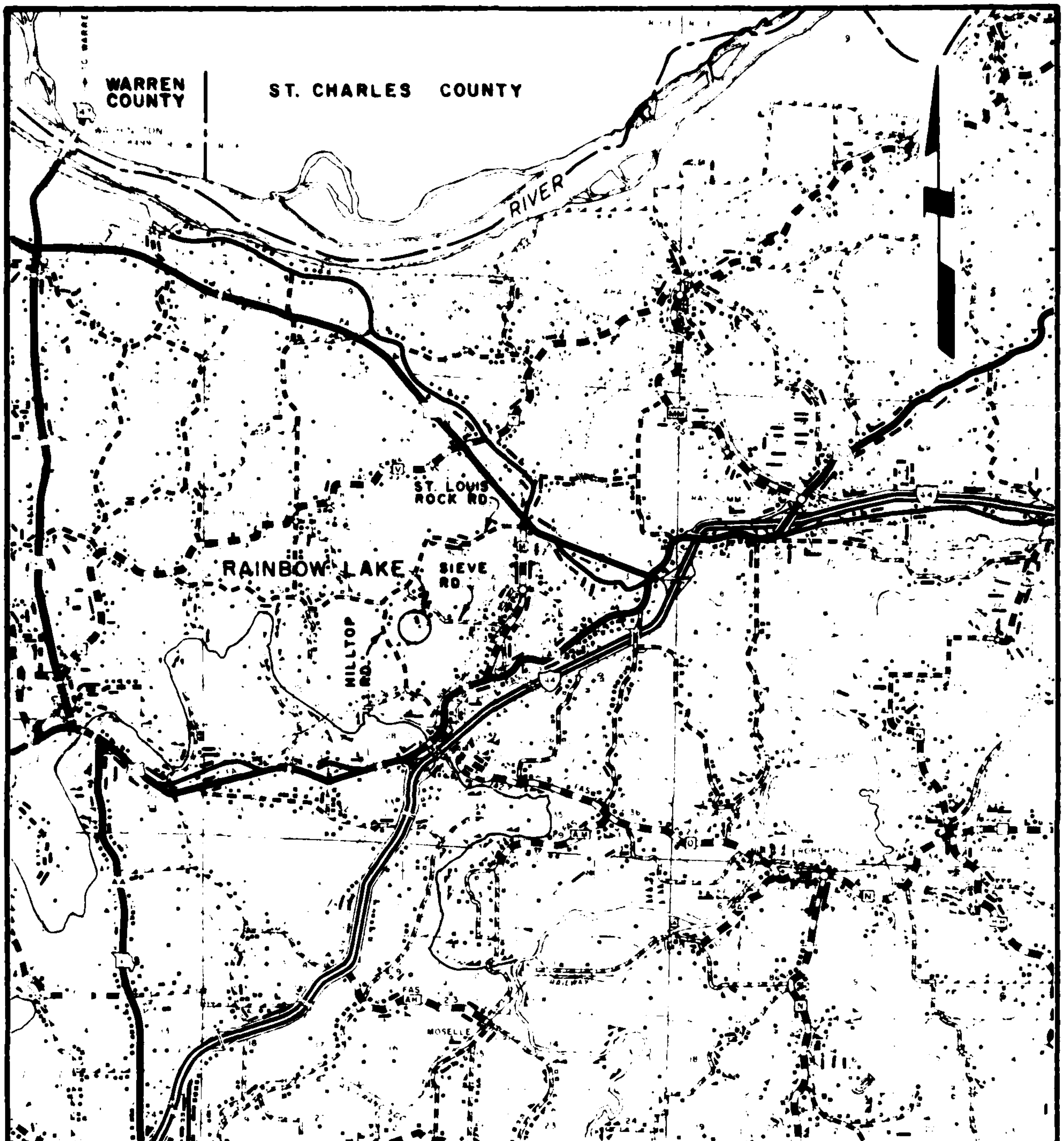
valve on the lake drawdown facility be repaired since flow from the pipe is contributing to the wet condition adjacent to the dam.

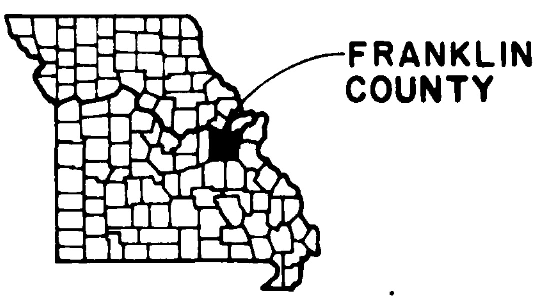
2. Restore the eroded areas of the embankment and provide some form of protection (other than grass) at the upstream face of the dam at and above the normal waterline in order to prevent erosion by wave action or by fluctuations of the lake level. A grass covered slope is not considered adequate protection to prevent erosion of the embankment by wave action or by a fluctuating lake level. Loss of material can impair the stability of the dam.

3. Maintain the turf cover on the embankment at a height that will not hinder inspection of the dam or provide cover for burrowing animals. Animal burrows can also provide passageways for lake seepage that can develop into a piping condition.

4. Provide maintenance of all areas of the dam and spillways on a regularly scheduled basis in order to insure features of being in satisfactory operational condition.

5. A detailed inspection of the dam should be instituted on a regular basis by an engineer experienced in the design and construction of dams. It is also recommended, for future reference, that records be kept of all inspections made and remedial measures taken.



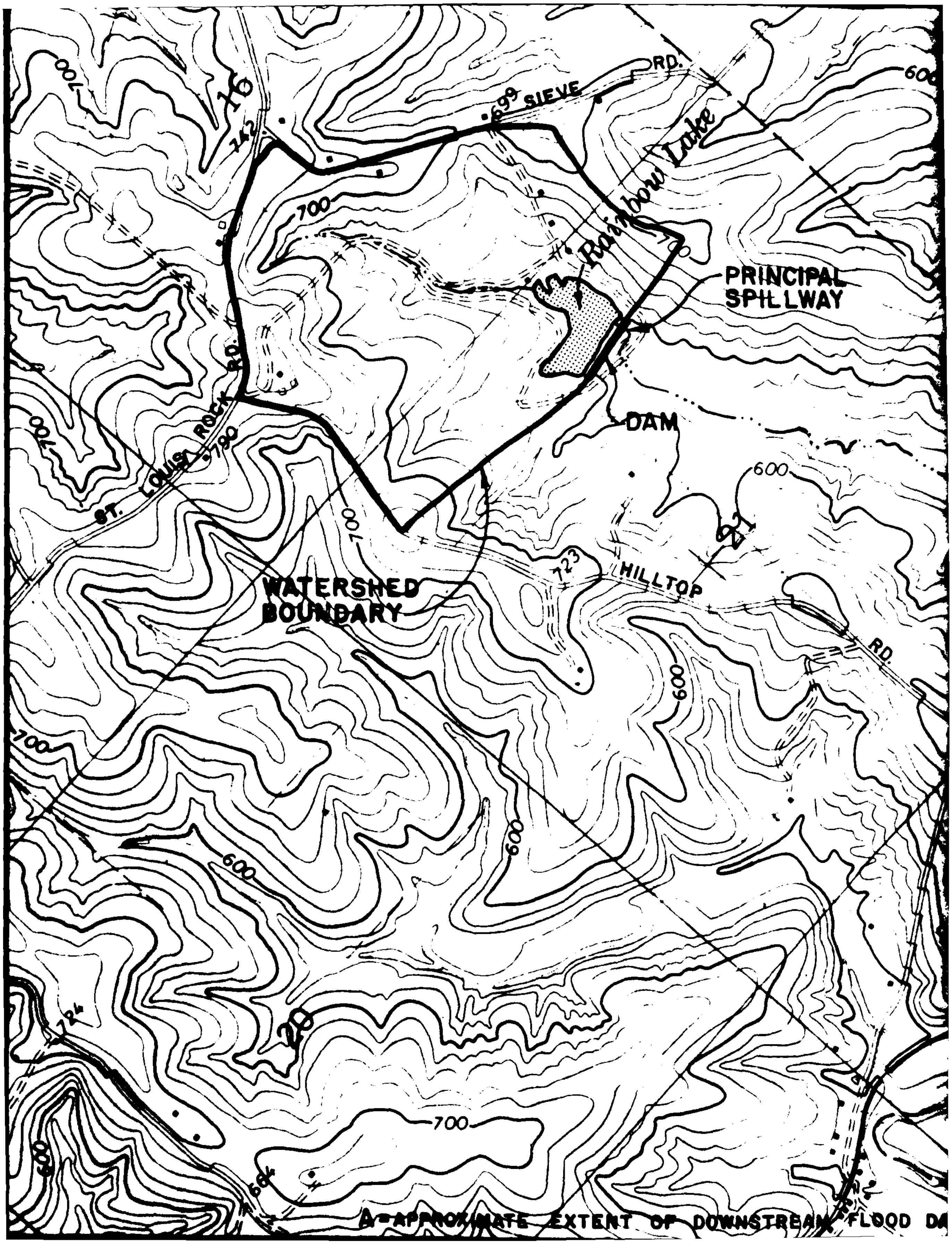


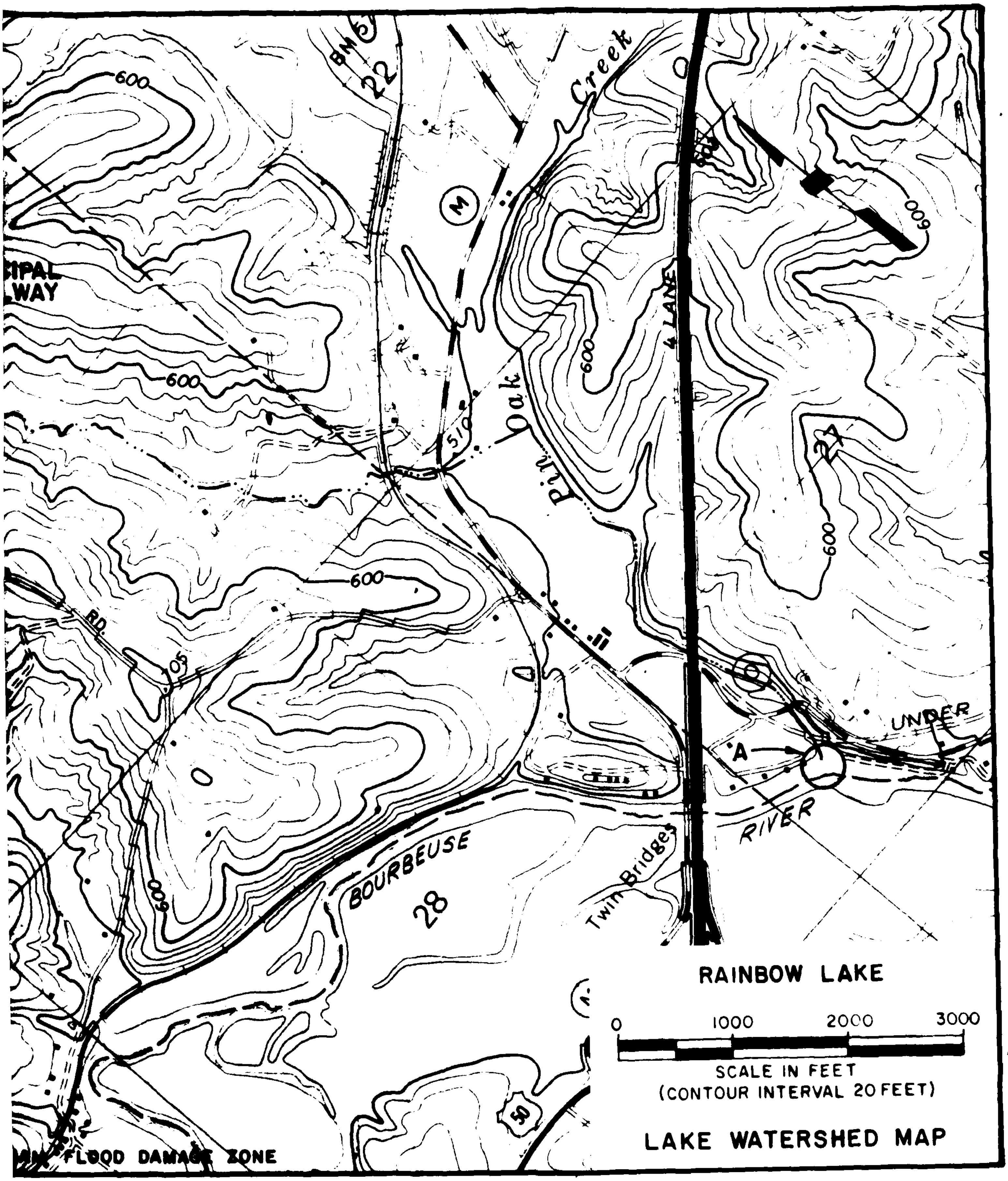
LOCATION MAP

RAINBOW LAKE

REGIONAL VICINITY MAP

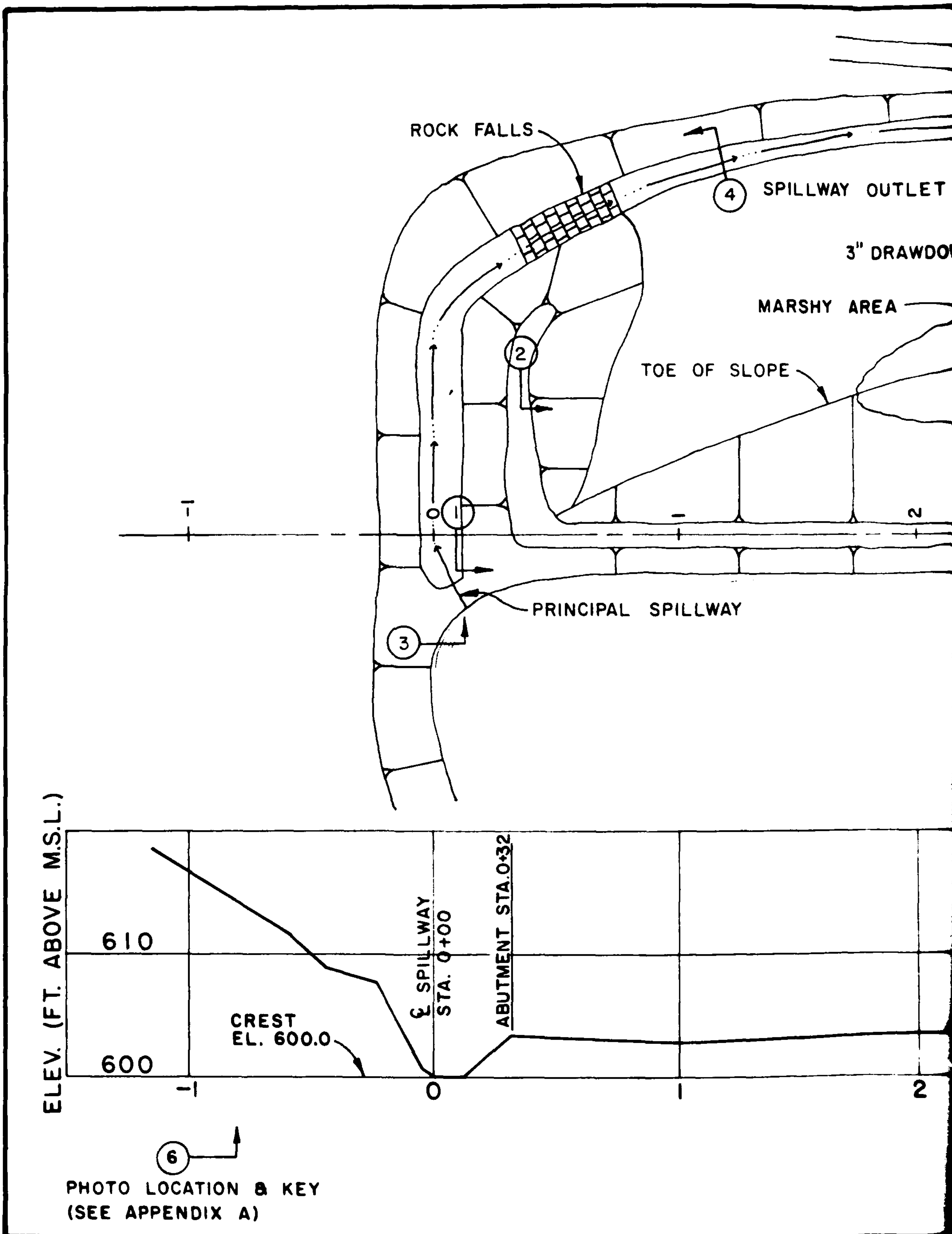
PLATE 1

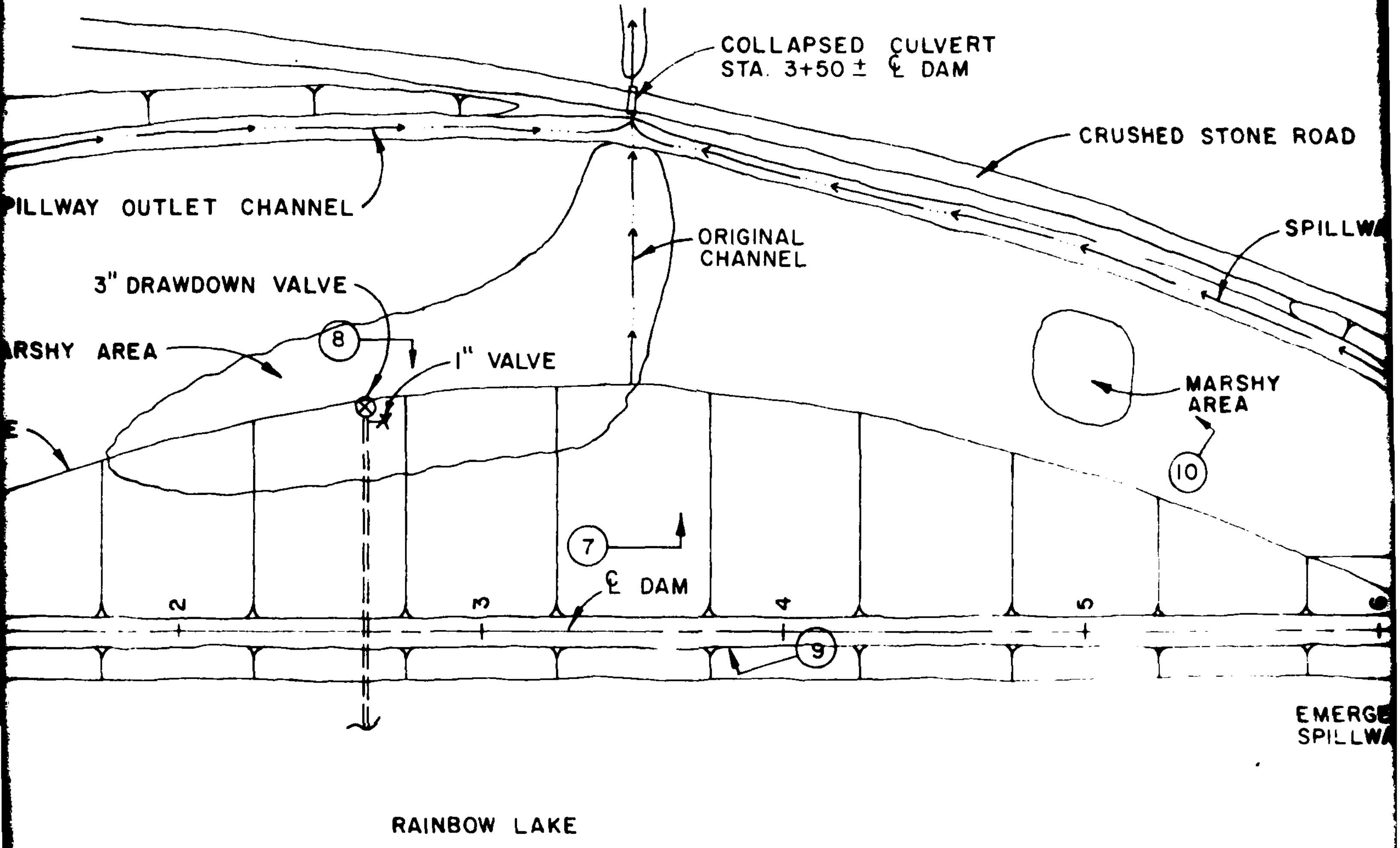

SIEVE RD.
Rainbow Lake
PRINCIPAL SPILLWAY
DAM
ST. LOUIS ROCK RD.
WATERSHED BOUNDARY
HILLTOP RD.
700
600
A=APPROXIMATE EXTENT OF DOWNSTREAM FLOOD DA



600
22
Creek
M
Oak
4 LANE
510
27
RD.
UNDER
A
RIVER
BOURBEUSE
28
Twin Bridges
50
FLOOD DAMAGE ZONE
RAINBOW LAKE
0
1000
2000
3000
SCALE IN FEET
(CONTOUR INTERVAL 20 FEET)
LAKE WATERSHED MAP

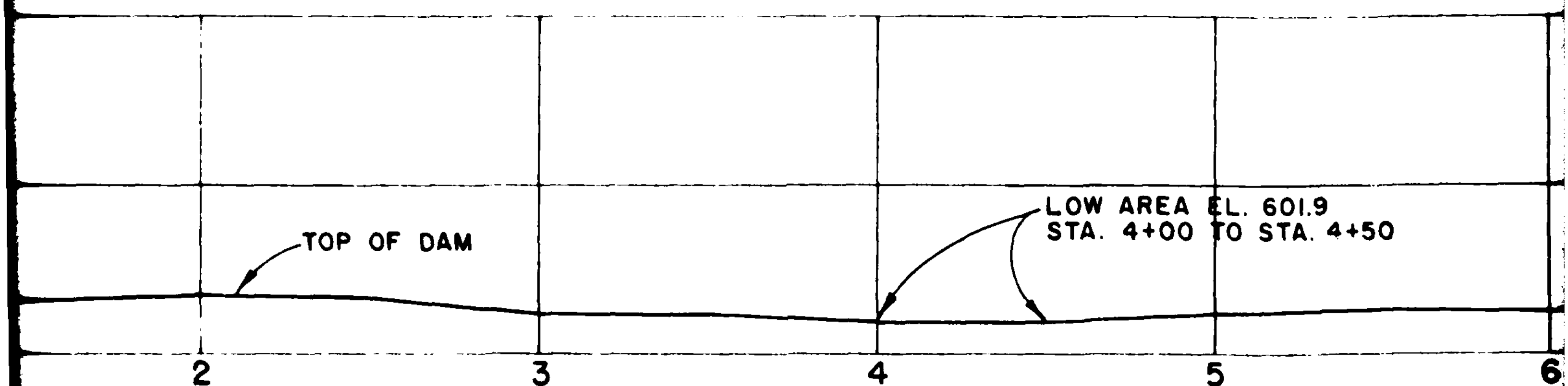
PLATE 2


ROCK FALLS
SPILLWAY OUTLET
3" DRAWDOW
MARSHY AREA
TOE OF SLOPE
PRINCIPAL SPILLWAY
ELEV. (FT. ABOVE M.S.L.)
610
600
CREST
EL. 600.0
℄ SPILLWAY
STA. 0+00
ABUTMENT STA.0+32
-1
0
1
2
PHOTO LOCATION & KEY
(SEE APPENDIX A)



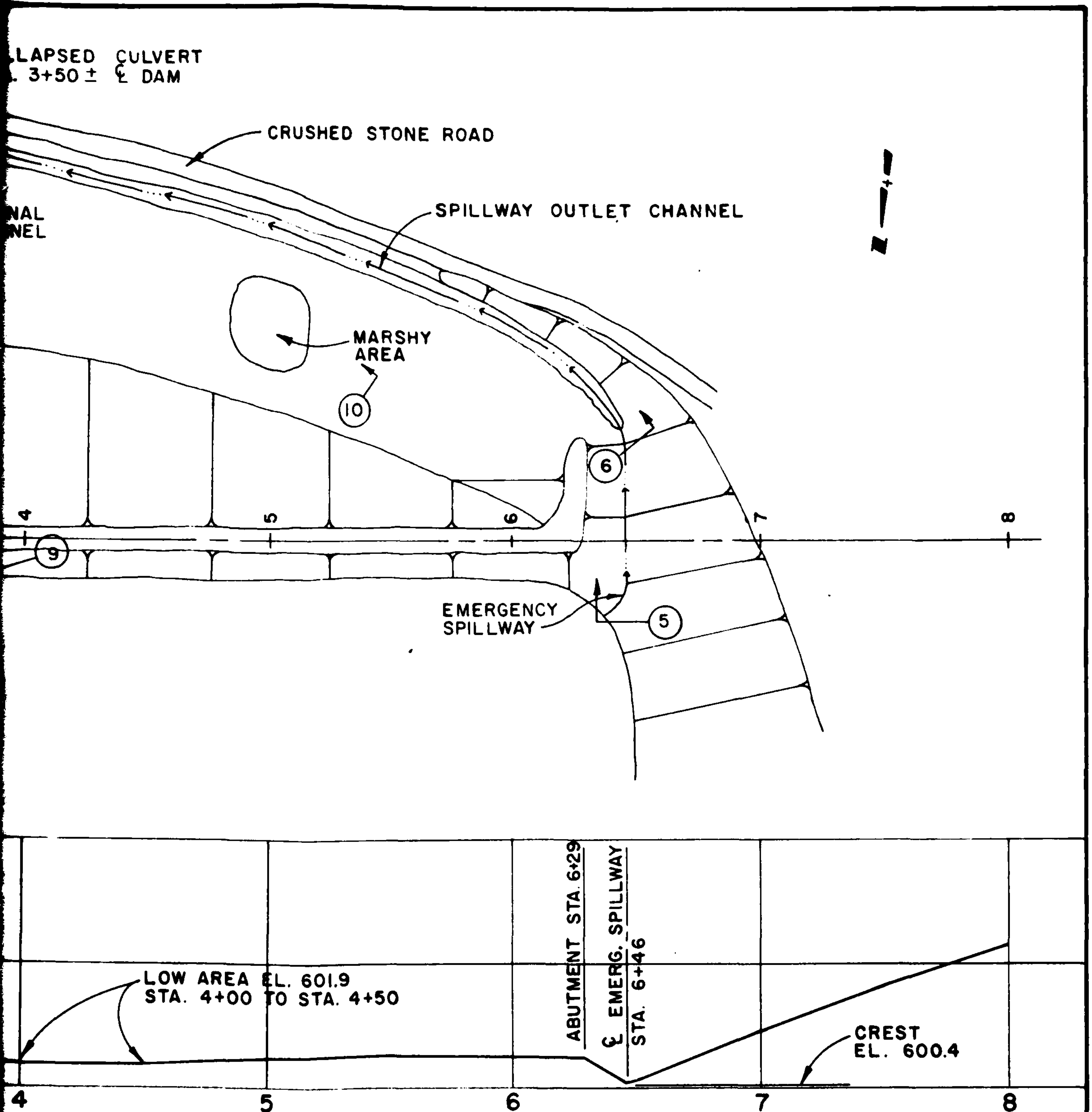
GENERAL PLAN OF DAM

SCALE: 1" = 50'



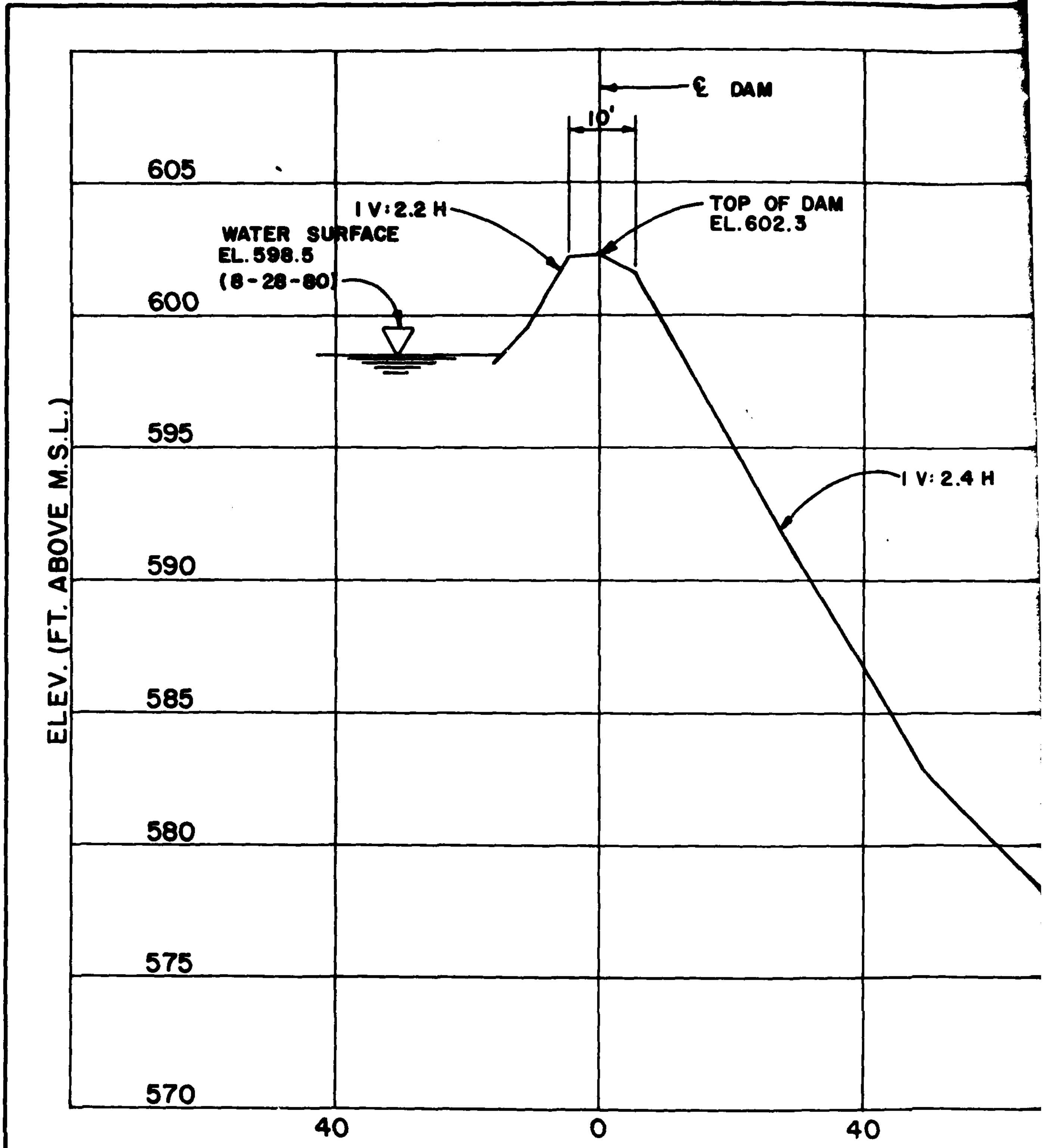
PROFILE DAM CREST

SCALES: 1" = 10' V., 1" = 50' H.



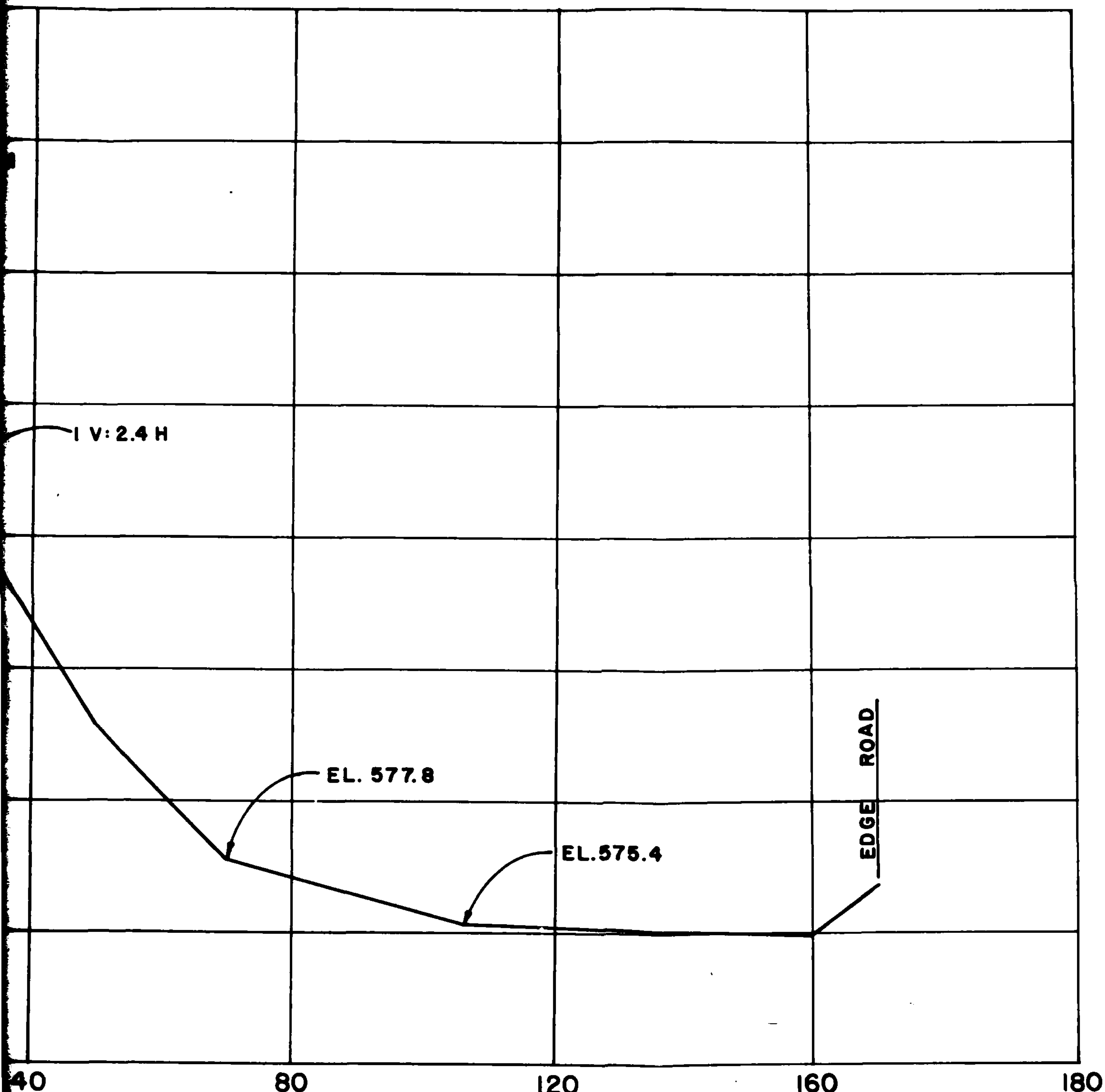
RAINBOW LAKE
DAM PLAN & PROFILE

Horner & Shifrin, Inc. Sept. 1980



DAM CROSS-SECTIO

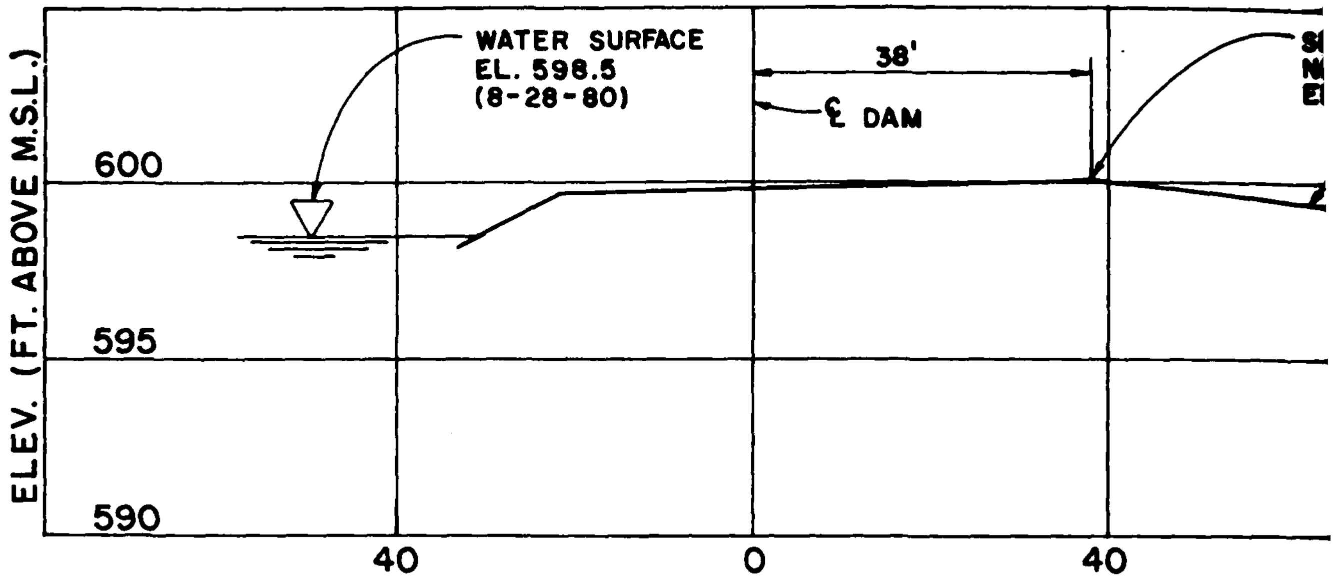
SCALE: 1" = 5' V.,



CROSS-SECTION STA. 3+50
SCALE: 1" = 5' V., 1" = 20' H.

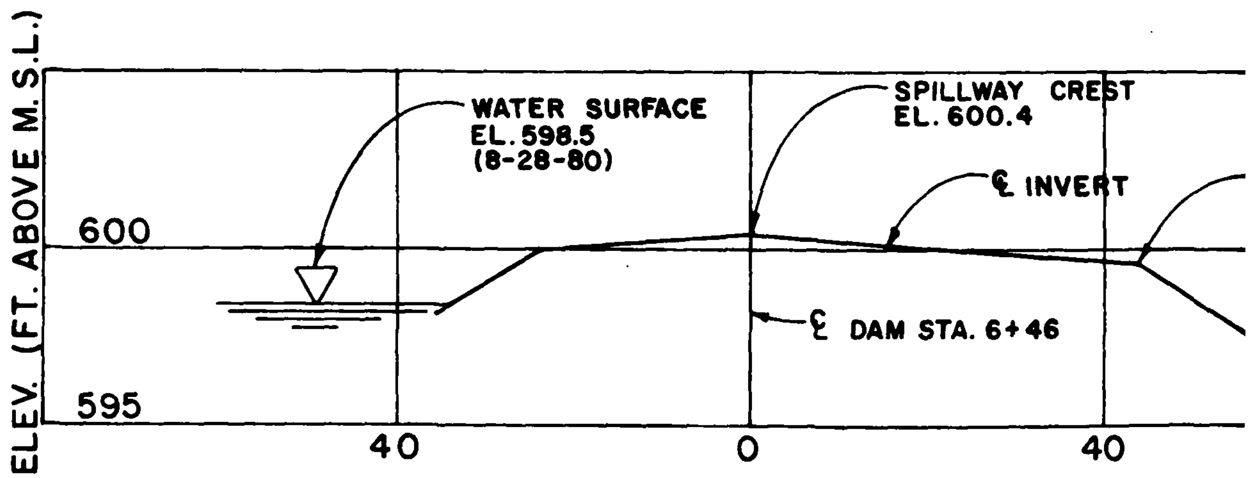
RAINBOW LAKE
DAM CROSS-SECTION
Horner & Shifrin, Inc. Sept. 1980

PLATE 4



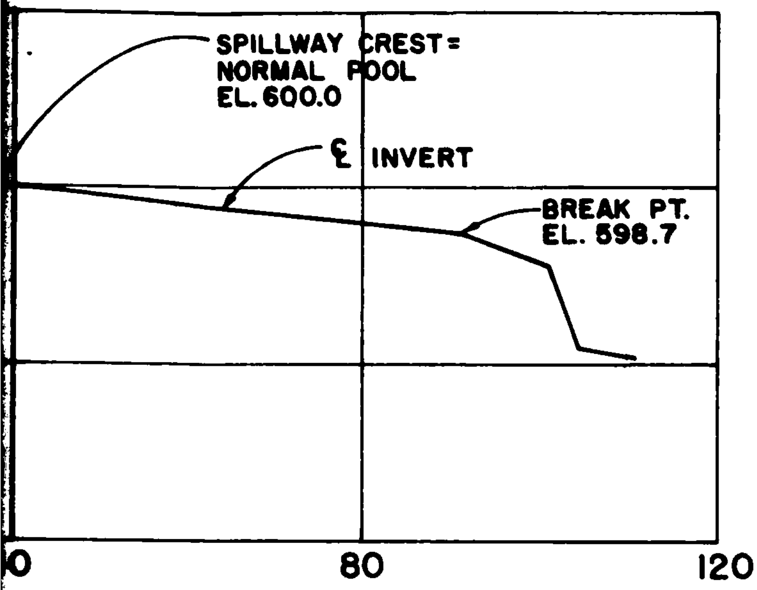
PROFILE – PRINCIPAL SPILLWAY

SCALE: 1"=5' V., 1"=20' H.

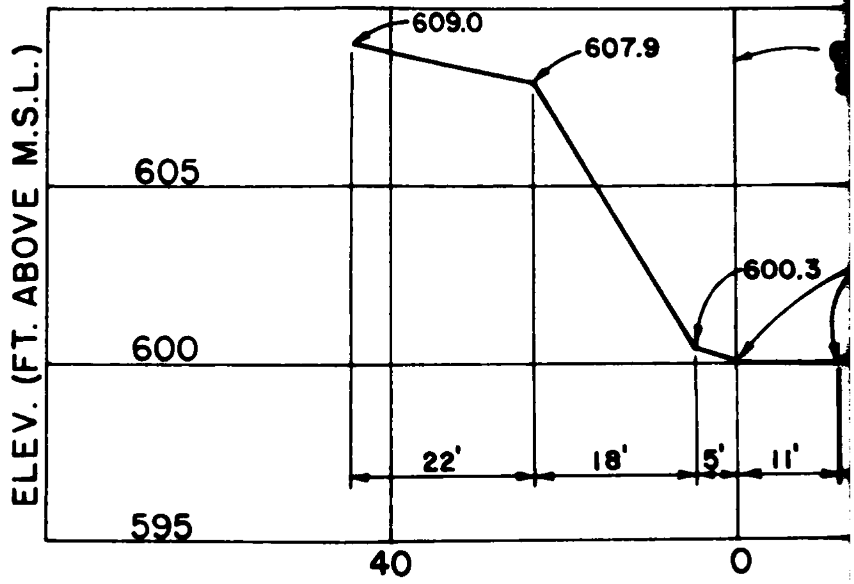


PROFILE – EMERGENCY SPILLWAY

SCALE: 1"=5'V., 1"=20'H.

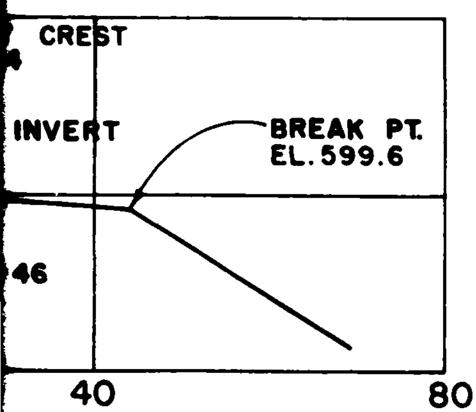


ILLWAY

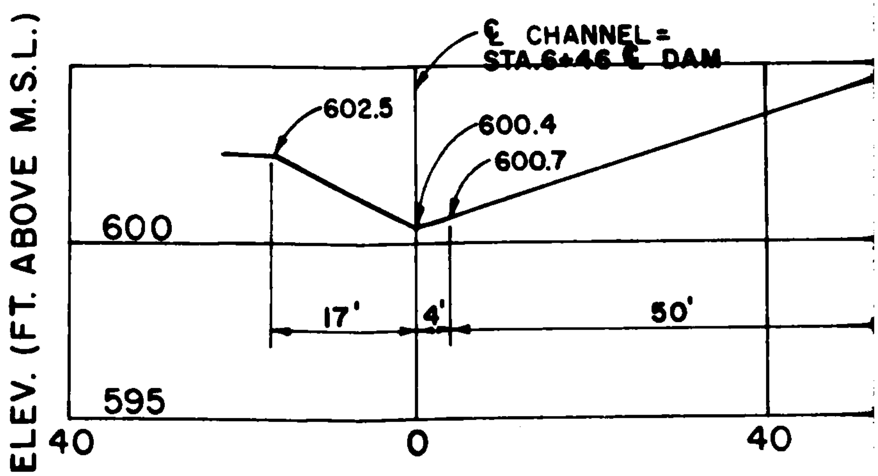


CROSS-SECTION PRINCIPAL SPILL

SCALE: 1" = 5' V., 1" = 20' H.



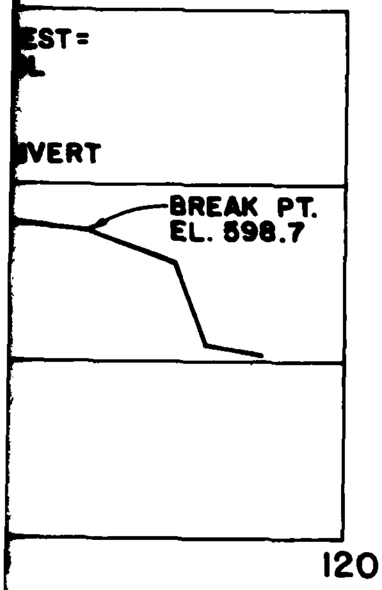
AY

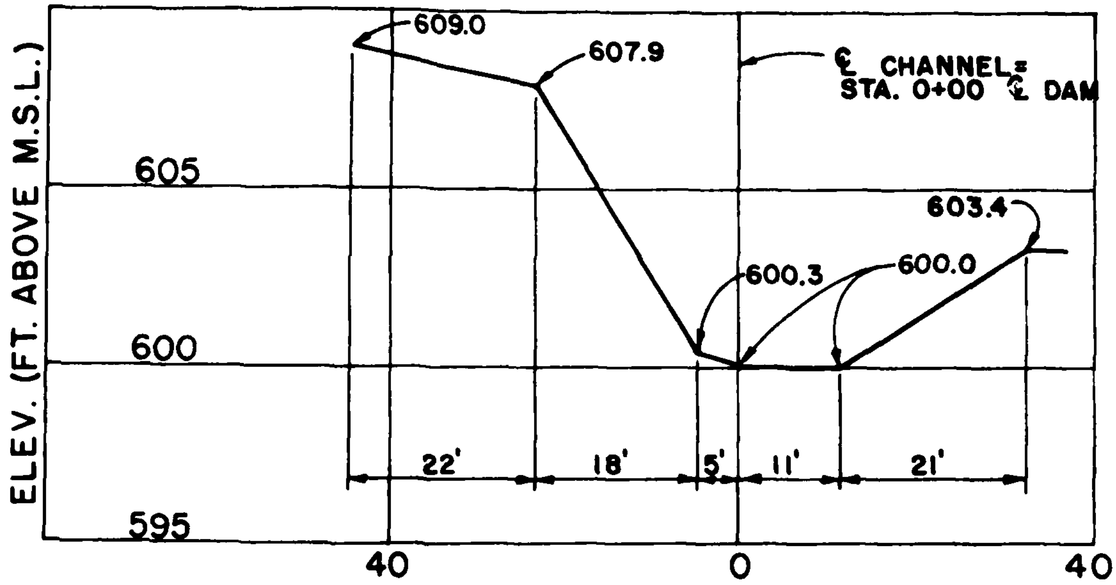


CROSS-SECTION EMERGENCY SPILL

SCALE: 1" = 5' V., 1" = 20' H.

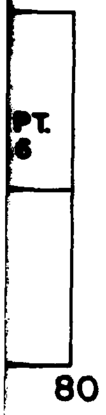
RAINBO
SPILLWAY
& CROSS
Horner & Shifrin,

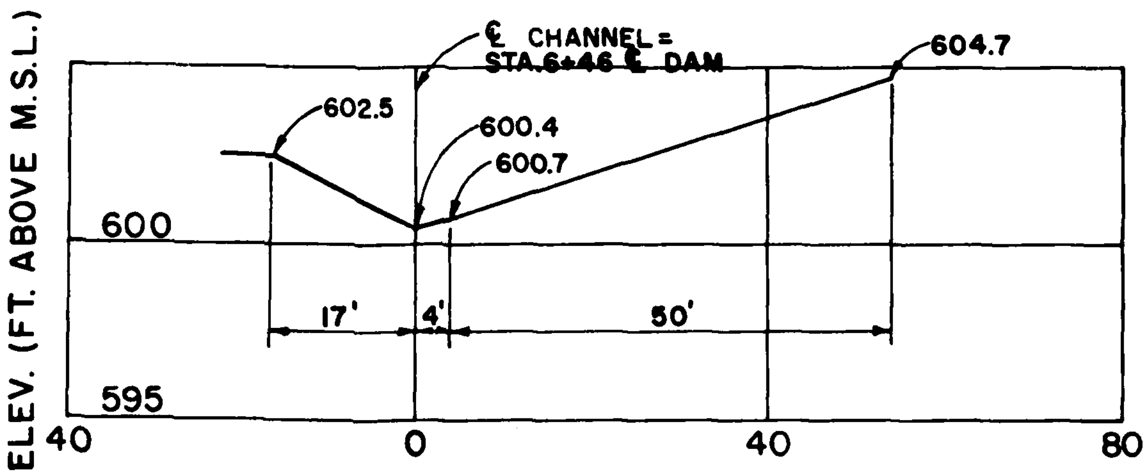




CROSS-SECTION PRINCIPAL SPILLWAY

SCALE: 1" = 5' V., 1" = 20' H.





CROSS-SECTION EMERGENCY SPILLWAY

SCALE: 1" = 5' V., 1" = 20' H.

RAINBOW LAKE
SPILLWAY PROFILES
& CROSS-SECTIONS

Horner & Shifrin, Inc. Sept. 1980

PLATE 5

APPENDIX A

INSPECTION PHOTOGRAPHS

NO. 1: CREST AND UPSTREAM FACE OF DAM

NO. 2: DOWNSTREAM FACE OF DAM

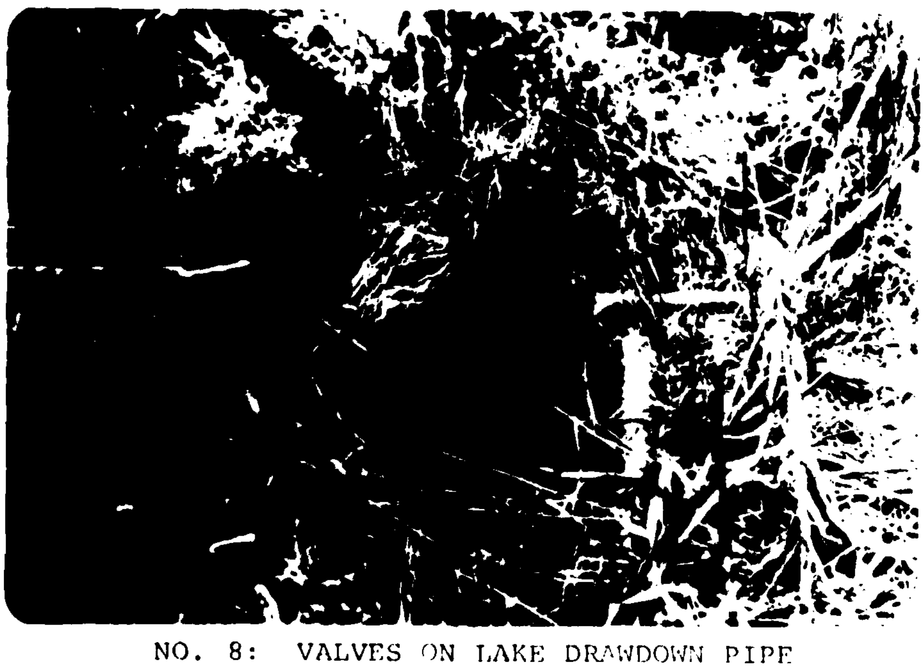
NO. 3: CREST SECTION OF PRINCIPAL SPILLWAY

NO. 4: PRINCIPAL SPILLWAY OUTLET CHANNEL - LOOKING UPSTREAM AT EXIT SECTION

NO. 5: CREST SECTION OF EMERGENCY SPILLWAY

NO. 6: EMERGENCY SPILLWAY OUTLET CHANNEL - LOOKING DOWNSTREAM FROM CREST AREA

NO. 7: AREA UPSTREAM OF CULVERT AT STATION 3+50$\pm$



NO. 8: VALVES ON LAKE DRAWDOWN PIPE

NO. 9: EMBANKMENT EROSION AT UPSTREAM FACE OF DAM

NO. 10: MARSHY AREA DOWNSTREAM OF DAM

APPENDIX B

HYDROLOGIC AND HYDRAULIC ANALYSES

HYDROLOGIC AND HYDRAULIC COMPUTATIONS

1. The HEC-1 Dam Safety Version (July 1978, Modified 26 February 1979) program was used to develop inflow and outflow hydrographs and dam overtopping analyses, with hydrologic inputs as follows:

a. Probable maximum precipitation (200 sq. mile, 24-hour value equals 25.4 inches) from Hydrometeorological Report No. 33. The precipitation data used in the analysis of the 1 percent chance (100-year frequency) and the 10 percent chance (10-year frequency) floods were provided by the St. Louis District, Corps of Engineers.

b. Drainage area = 0.273 square miles = 175 acres.

c. SCS parameters:

Time of Concentration (T_c) = $\left(\frac{11.9L^3}{H}\right)^{0.385}$ = 0.177 hours

Where: T_c = Travel time of water from hydraulically most distant point to point of interest, hours.

L = Length of longest watercourse = 0.511 miles.

H = Elevation difference = 142 feet.

The time of concentration (T_c) was obtained using method C as described in Fig. 30, "Design of Small Dams", by the United States Department of the Interior, Bureau of Reclamation, and was verified using average channel velocity estimates and watercourse lengths.

Lag time = 0.106 hours (0.60 T_c)

Hydrologic Soil Group = C (Predominantly Bucklick and Gatewood Series, per unpublished SCS Soil Survey Report)

Soil type CN = 71 (AMC II, 100-yr flood)
= 86 (AMC III, PMF condition)

2. The principal spillway consists of a broad-crested trapezoidal section and the emergency spillway section consists of a broad-crested, dish-shaped section, either for which conventional weir formulas do not apply.

Spillway release rates were determined as follows:

a. Spillway crest section properties (areas, "a", and top width, "t") were computed f[illegible] various depths, "d".

b. It was assumed that flow over the spillway crest would occur at critical depth. Flow at critical depth Q_c was computed as $Q_c = \left(\frac{a^3 g}{t}\right)^{0.5}$ for the various depths, "d". Corresponding velocities (v_c) and velocity heads (H_{vc}) were determined using conventional formulas.* Reference "Handbook of Hydraulics", Fifth Edition, by King & Brater, page 8-7.

c. Static lake levels corresponding to the various flow values passing the spillway were computed as critical depths plus critical velocity heads ($d_c + H_{vc}$), and the relationship between lake level and spillway discharge was thus obtained. The procedure neglects the minor insignificant friction losses across the length of the spillway.

d. The discharges for the principal and emergency spillways for equal elevations were summated for entry on the Y4 and Y5 cards.

3. The profile of the dam crest is irregular and flow over the dam cannot be determined by application of conventional weir formulas. Crest length and elevation data for the dam crest proper were entered into the HEC-1 Program on the $L and $V cards. The program assumes that flow over the

* $v_c = \frac{Qc}{a}$; $Hvc = \frac{{v_c}^2}{2g}$

dam crest occurs at critical depth and computes internally the flow passing the dam crest and adds this flow to the flow passing the spillways as entered on the Y4 and Y5 cards.

```
A1       ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
A2       HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF RAINBOW LAKE DAM
A3       RATIOS OF PMF ROUTED THROUGH RESERVOIR
B      288       0       5       0       0       0       0       0       0       0
B1       5
J        1       4       1
J1    0.12    0.13    0.50    1.00
K        0  INFLOW                                       1
K1       INFLOW HYDROGRAPH
M        1       2   0.273                   1.0                                 1
P        0    25.4     102     120     130
T                                                       -1     -86
W2            0.106
X   [illegible]    -.10     2.0
K        1     DAM                                       1
K1       RESERVOIR ROUTING BY MODIFIED PULS
Y                                1       1
Y1       1                                           53.20       1
Y4   600.0   600.4  600.85  601.40  602.07  602.73  603.38  604.02  604.54  605.25
Y4  605.97  606.67  607.38  608.08  607.47  610.00
Y5       0      12      44     121     288     520     853    1264    1651    2200
Y5    3078    3865    4800    5842    7013    8298    9355
$A       0     7.6    14.0    22.5    33.5
$E     579     600     610     620     630
$$   600.0
$D   601.9
$L      50     200     235     281     349     354     512     597     598
$V   601.9   602.3   602.5   602.6   602.7   602.8   603.3   603.4   608.0
K       99
```

```
A1       ANALYSIS OF DAM OVERTOPPING USING 100-YR FLOOD
A2      HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF RAINBOW LAKE DAM
A3      100-YR FLOOD ROUTED THROUGH RESERVOIR
B     288       0       5                                               4
B1      5
J       1       1       1
J1   1.00
K       0  INFLOW                                       1
K1      INFLOW HYDROGRAPH
M       0       2   0.273                   1.0                         1
O     288   7.224
O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007    .007    .007    .007    .007    .007    .007    .007    .007    .007
O1   .007    .007    .014    .014    .014    .014    .014    .014    .014    .014
O1   .014    .014    .014    .014    .014    .014    .014    .014    .014    .014
O1   .014    .014    .014    .014    .014    .014    .014    .014    .014    .014
O1   .014    .014    .014    .014    .014    .014    .014    .014    .022    .022
O1   .022    .022    .022    .022    .022    .022    .022    .022    .022    .022
O1   .022    .022    .022    .022    .022    .022    .031    .031    .031    .031
O1   .031    .031    .061    .061    .061    .061    .061    .061    .132    .132
O1   .132    .252    .252    .552    .826    .384    .252    .132    .132    .132
O1   .061    .061    .061    .061    .061    .061    .031    .031    .031    .031
O1   .031    .031    .022    .022    .022    .022    .022    .022    .022    .022
O1   .022    .022    .022    .022    .022    .022    .022    .022    .022    .022
O1   .014    .014    .014    .014    .014    .014    .014    .014    .014    .014
```

100-YR. FLOOD (Cont'd)

```
O1   .014   .014   .014   .014   .014   .014   .014   .014   .014   .014
O1   .014   .014   .014   .014   .014   .014   .014   .014   .014   .014
O1   .014   .014   .014   .014   .014   .014   .007   .007   .007   .007
O1   .007   .007   .007   .007   .007   .007   .007   .007   .007   .007
O1   .007   .007   .007   .007   .007   .007   .007   .007   .007   .007
O1   .007   .007   .007   .007   .007   .007   .007   .007   .007   .007
O1   .007   .007   .007   .007   .007   .007   .007   .007   .007   .007
O1   .007   .007   .007   .007   .007   .007   .007   .007   .007   .007
O1   .007   .007   .007   .007   .007   .007   .007   .007   .007   .007
O1   .007   .007   .007   .007   .007   .007   .007   .007
T                                                 -1    -71
W2          0.106
X    -1.0   -.10    2.0
K       1    DAM                                   1
K1      RESERVOIR ROUTING BY MODIFIED PULS
Y                          1      1
Y1      1                                      53.20     -1
Y4  600.0  600.4 600.85 601.40 602.07 602.73 603.38 604.02 604.54 605.25
Y4605.97 606.27 607.38 608.08 608.78 609.47 610.00
Y5      0     12     44    121    283    526    853   1264   1651   2280
Y5   3028   3865   4800   5842   7013   8298   9355
$A      0    7.6   14.0   22.5   33.5
$E    579    600    610    620    630
$$  600.0
$D  601.9
$L     50    200    235    281    349    354    512    597    598
$V  601.9  602.3  602.5  602.6  602.7  602.8  603.3  603.4  608.0
K      99
```

`1A1	ANALYSIS OF DAM OVERTOPPING USING 10-YR FLOOD									
A2	HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF RAINBOW LAKE DAM									
A3	10-YR FLOOD ROUTED THROUGH RESERVOIR									
B	288	0	5						4	
B1	5									
J	1	1	1							
J1	1.00									
K	0	INFLOW					1			
K1	INFLOW HYDROGRAPH									
M	0	2	0.273			1.0			1	
O	288	5.114								
O1	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
O1	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
O1	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
O1	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
O1	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
O1	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
O1	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
O1	.005	.005	.010	.010	.010	.010	.010	.010	.010	.010
O1	.010	.010	.010	.010	.010	.010	.010	.010	.010	.010
O1	.010	.010	.010	.010	.010	.010	.010	.010	.010	.010
O1	.010	.010	.010	.010	.010	.010	.010	.010	.015	.015
O1	.015	.015	.015	.015	.015	.015	.015	.015	.015	.015
O1	.015	.015	.015	.015	.015	.015	.031	.031	.031	.031
O1	.031	.031	.049	.049	.049	.049	.049	.049	.086	.086
O1	.086	.164	.164	.377	.587	.262	.164	.086	.086	.086
O1	.049	.049	.049	.049	.049	.049	.031	.031	.031	.031
O1	.031	.031	.015	.015	.015	.015	.015	.015	.015	.015
O1	.015	.015	.015	.015	.015	.015	.015	.015	.015	.015
O1	.010	.010	.010	.010	.010	.010	.010	.010	.010	.010

10-YR. FLOOD (Cont'd)

```
O1  .010   .010   .010   .010   .010   .010   .010   .010   .010   .010
O1  .010   .010   .010   .010   .010   .010   .010   .010   .010   .010
O1  .010   .010   .010   .010   .010   .010   .005   .005   .005   .005
O1  .005   .005   .005   .005   .005   .005   .005   .005   .005   .005
O1  .005   .005   .005   .005   .005   .005   .005   .005   .005   .005
O1  .005   .005   .005   .005   .005   .005   .005   .005   .005   .005
O1  .005   .005   .005   .005   .005   .005   .005   .005   .005   .005
O1  .005   .005   .005   .005   .005   .005   .005   .005   .005   .005
O1  .005   .005   .005   .005   .005   .005   .005   .005   .005   .005
O1  .005   .005   .005   .005   .005   .005   .005   .005
T                                              -1    -71
W2          0.106
X   -1.0   -.10    2.0
K      1    DAM                                 1
K1     RESERVOIR ROUTING BY MODIFIED PULS
Y                          1      1
Y1     1                                     53.20     -1
Y4 600.0  600.4 600.85 601.40 602.07 602.73 603.38 604.02 604.54 605.25
Y4605.97 606.27 607.38 608.08 608.78 609.47 610.00
Y5     0     12     44    121    283    526    853   1264   1651   2280
Y5  3023   3865   4800   5842   7013   8298   9355
$A     0    7.6   14.0   22.5   33.5
$E   579    600    610    620    630
$$ 600.0
$D 601.9
$L    50    200    235    281    349    354    512    597    598
$V 601.9  602.3  602.5  602.6  602.7  602.8  603.3  603.4  608.0
K     99
^
```

```
ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF RAINBOW LAKE DAM
RATIOS OF PMF ROUTED THROUGH RESERVOIR

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

                     MULTI-PLAN ANALYSES TO BE PERFORMED
                       NPLAN= 1 NRTIO= 4 LRTIO= 1
     RTIOS=    .12    .13    .50   1.00

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

                          SUB-AREA RUNOFF COMPUTATION

     INFLOW HYDROGRAPH

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

                               HYDROGRAPH DATA
     IHYDG   IUHG  TAREA   SNAP  TRSDA  TRSPC  RATIO  ISNOW  ISAME  LOCAL
         1      2    .27   0.00    .27   1.00  0.000      0      1      0

                                 PRECIP DATA
              SPFE     PMS      R6     R12     R24     R48     R72     R96
              0.00   25.40  102.00  120.00  130.00    0.00    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 -86.00   0.00   0.00

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

                            UNIT HYDROGRAPH DATA
                          TC=  0.00    LAG=   .11

                               RECESSION DATA
                  STRTQ=   -1.00   QRCSN=    -.10   RTIOR= 2.00

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

     UNIT HYDROGRAPH  8 END OF PERIOD ORDINATES, TC=    0.00 HOURS, LAG=    .11  VOL= 1.00
  534.     877.     421.     171.      67.      27.      11.       4.
```

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	0.00	.01	0.	1.01	12.05	145	.22	.20	.01	204.
1.01	.10	2	.01	0.00	.01	0.	1.01	12.10	146	.22	.20	.01	331.
1.01	.15	3	.01	0.00	.01	0.	1.01	12.15	147	.22	.21	.01	392.
1.01	.20	4	.01	0.00	.01	0.	1.01	12.20	148	.22	.21	.01	418.
1.01	.25	5	.01	0.00	.01	0.	1.01	12.25	149	.22	.21	.01	429.
1.01	.35	7	.01	0.00	.01	0.	1.01	12.35	151	.22	.21	.01	437.
1.01	.40	8	.01	0.00	.01	0.	1.01	12.40	152	.22	.21	.01	438.
1.01	.45	9	.01	0.00	.01	0.	1.01	12.45	153	.22	.21	.01	439.
1.01	.50	10	.01	0.00	.01	0.	1.01	12.50	154	.22	.21	.01	440.
1.01	.55	11	.01	0.00	.01	0.	1.01	12.55	155	.22	.21	.01	441.
1.01	1.00	12	.01	0.00	.01	0.	1.01	13.00	156	.22	.21	.01	442.
1.01	1.05	13	.01	0.00	.01	0.	1.01	13.05	157	.26	.25	.01	465.
1.01	1.10	14	.01	0.00	.01	0.	1.01	13.10	158	.26	.25	.01	502.
1.01	1.15	15	.01	0.00	.01	0.	1.01	13.15	159	.26	.25	.01	521.
1.01	1.20	16	.01	0.00	.01	0.	1.01	13.20	160	.26	.25	.01	528.
1.01	1.25	17	.01	0.00	.01	0.	1.01	13.25	161	.26	.25	.01	532.
1.01	1.30	18	.01	0.00	.01	0.	1.01	13.30	162	.26	.25	.01	534.
1.01	1.35	19	.01	0.00	.01	0.	1.01	13.35	163	.26	.25	.01	535.
1.01	1.40	20	.01	0.00	.01	0.	1.01	13.40	164	.26	.25	.01	536.
1.01	1.45	21	.01	0.00	.01	0.	1.01	13.45	165	.26	.25	.01	536.
1.01	1.50	22	.01	0.00	.01	0.	1.01	13.50	166	.26	.25	.00	537.
1.01	1.55	23	.01	0.00	.01	0.	1.01	13.55	167	.26	.25	.00	537.
1.01	2.00	24	.01	.00	.01	0.	1.01	14.00	168	.26	.25	.00	538.
1.01	2.05	25	.01	.00	.01	0.	1.01	14.05	169	.32	.32	.01	572.
1.01	2.10	26	.01	.00	.01	1.	1.01	14.10	170	.32	.32	.01	628.
1.01	2.15	27	.01	.00	.01	1.	1.01	14.15	171	.32	.32	.00	656.
1.01	2.20	28	.01	.00	.01	2.	1.01	14.20	172	.32	.32	.00	667.
1.01	2.25	29	.01	.00	.01	2.	1.01	14.25	173	.32	.32	.00	672.
1.01	2.30	30	.01	.00	.01	3.	1.01	14.30	174	.32	.32	.00	674.
1.01	2.35	31	.01	.00	.01	3.	1.01	14.35	175	.32	.32	.00	675.
1.01	2.40	32	.01	.00	.01	3.	1.01	14.40	176	.32	.32	.00	676.
1.01	2.45	33	.01	.00	.01	4.	1.01	14.45	177	.32	.32	.00	676.
1.01	2.50	34	.01	.00	.01	4.	1.01	14.50	178	.32	.32	.00	676.
1.01	2.55	35	.01	.00	.01	5.	1.01	14.55	179	.32	.32	.00	677.
1.01	3.00	36	.01	.00	.01	5.	1.01	15.00	180	.32	.32	.00	677.
1.01	3.05	37	.01	.00	.01	5.	1.01	15.05	181	.20	.20	.00	610.
1.01	3.10	38	.01	.00	.01	6.	1.01	15.10	182	.39	.39	.00	604.
1.01	3.15	39	.01	.00	.01	6.	1.01	15.15	183	.39	.39	.00	723.
1.01	3.20	40	.01	.00	.01	7.	1.01	15.20	184	.59	.57	.00	838.
1.01	3.25	41	.01	.00	.01	7.	1.01	15.25	185	.69	.68	.01	1137.
1.01	3.30	42	.01	.00	.01	7.	1.01	15.30	186	1.67	1.66	.01	1837.
1.01	3.35	43	.01	.00	.01	8.	1.01	15.35	187	2.76	2.74	.02	3351.
1.01	3.40	44	.01	.00	.01	8.	1.01	15.40	188	1.08	1.08	.01	3352.
1.01	3.45	45	.01	.00	.01	8.	1.01	15.45	189	.69	.69	.00	2819.
1.01	3.50	46	.01	.00	.01	9.	1.01	15.50	190	.59	.59	.00	1977.
1.01	3.55	47	.01	.00	.01	9.	1.01	15.55	191	.39	.39	.00	1438.
1.01	4.00	48	.01	.00	.01	9.	1.01	16.00	192	.39	.39	.00	1086.
1.01	4.05	49	.01	.00	.01	9.	1.01	16.05	193	.30	.30	.00	883.
1.01	4.10	50	.01	.00	.01	10.	1.01	16.10	194	.30	.30	.00	739.
1.01	4.15	51	.01	.00	.01	10.	1.01	16.15	195	.30	.30	.00	673.
1.01	4.20	52	.01	.01	.01	10.	1.01	16.20	196	.30	.30	.00	650.
1.01	4.25	53	.01	.01	.01	11.	1.01	16.25	197	.30	.30	.00	641.

END-OF-PERIOD FLOW (Cont'd)

1.01	4.30	54	.01	.01	.01	11.	1.01	16.30	198	.30	.30	.00	636.
1.01	4.35	55	.01	.01	.01	11.	1.01	16.35	199	.30	.30	.00	637.
1.01	4.40	56	.01	.01	.01	11.	1.01	16.40	200	.30	.30	.00	637.
1.01	4.45	57	.01	.01	.01	12.	1.01	16.45	201	.30	.30	.00	637.
1.01	4.50	58	.01	.01	.01	12.	1.01	16.50	202	.30	.30	.00	637.
1.01	4.55	59	.01	.01	.01	12.	1.01	16.55	203	.30	.30	.00	637.
1.01	5.00	60	.01	.01	.01	12.	1.01	17.00	204	.30	.30	.00	637.
1.01	5.05	61	.01	.01	.01	13.	1.01	17.05	205	.24	.24	.00	602.
1.01	5.10	62	.01	.01	.01	13.	1.01	17.10	206	.24	.24	.00	546.
1.01	5.15	63	.01	.01	.01	13.	1.01	17.15	207	.24	.24	.00	518.
1.01	5.20	64	.01	.01	.01	13.	1.01	17.20	208	.24	.24	.00	507.
1.01	5.25	65	.01	.01	.01	13.	1.01	17.25	209	.24	.24	.00	503.
1.01	5.30	66	.01	.01	.01	14.	1.01	17.30	210	.24	.24	.00	501.
1.01	5.35	67	.01	.01	.01	14.	1.01	17.35	211	.24	.24	.00	501.
1.01	5.40	68	.01	.01	.01	14.	1.01	17.40	212	.24	.24	.00	500.
1.01	5.45	69	.01	.01	.01	14.	1.01	17.45	213	.24	.24	.00	500.
1.01	5.50	70	.01	.01	.01	14.	1.01	17.50	214	.24	.24	.00	501.
1.01	5.55	71	.01	.01	.01	15.	1.01	17.55	215	.24	.24	.00	501.
1.01	6.00	72	.01	.01	.01	15.	1.01	18.00	216	.24	.24	.00	501.
1.01	6.05	73	.06	.03	.03	29.	1.01	18.05	217	.02	.02	.00	365.
1.01	6.10	74	.06	.03	.03	52.	1.01	18.10	218	.02	.02	.00	359.
1.01	6.15	75	.06	.04	.03	66.	1.01	18.15	219	.02	.02	.00	335.
1.01	6.20	76	.06	.04	.03	73.	1.01	18.20	220	.02	.02	.00	313.
1.01	6.25	77	.06	.04	.02	77.	1.01	18.25	221	.02	.02	.00	292.
1.01	6.30	78	.06	.04	.02	80.	1.01	18.30	222	.02	.02	.00	272.
1.01	6.35	79	.06	.04	.02	83.	1.01	18.35	223	.02	.02	.00	254.
1.01	6.40	80	.06	.04	.02	86.	1.01	18.40	224	.02	.02	.00	237.
1.01	6.45	81	.06	.04	.02	88.	1.01	18.45	225	.02	.02	.00	221.
1.01	6.50	82	.06	.04	.02	90.	1.01	18.50	226	.02	.02	.00	206.
1.01	6.55	83	.06	.04	.02	92.	1.01	18.55	227	.02	.02	.00	193.
1.01	7.00	84	.06	.05	.02	94.	1.01	19.00	228	.02	.02	.00	180.
1.01	7.05	85	.06	.05	.02	95.	1.01	19.05	229	.02	.02	.00	168.
1.01	7.10	86	.06	.05	.02	97.	1.01	19.10	230	.02	.02	.00	156.
1.01	7.15	87	.06	.05	.02	98.	1.01	19.15	231	.02	.02	.00	146.
1.01	7.20	88	.06	.05	.02	100.	1.01	19.20	232	.02	.02	.00	136.
1.01	7.25	89	.06	.05	.01	101.	1.01	19.25	233	.02	.02	.00	127.
1.01	7.30	90	.06	.05	.01	102.	1.01	19.30	234	.02	.02	.00	119.
1.01	7.35	91	.06	.05	.01	104.	1.01	19.35	235	.02	.02	.00	111.
1.01	7.40	92	.06	.05	.01	105.	1.01	19.40	236	.02	.02	.00	103.
1.01	7.45	93	.06	.05	.01	106.	1.01	19.45	237	.02	.02	.00	96.
1.01	7.50	94	.06	.05	.01	107.	1.01	19.50	238	.02	.02	.00	90.
1.01	7.55	95	.06	.05	.01	108.	1.01	19.55	239	.02	.02	.00	84.
1.01	8.00	96	.06	.05	.01	109.	1.01	20.00	240	.02	.02	.00	78.
1.01	8.05	97	.06	.05	.01	109.	1.01	20.05	241	.02	.02	.00	73.
1.01	8.10	98	.06	.05	.01	110.	1.01	20.10	242	.02	.02	.00	68.
1.01	8.15	99	.06	.05	.01	111.	1.01	20.15	243	.02	.02	.00	64.
1.01	8.20	100	.06	.05	.01	112.	1.01	20.20	244	.02	.02	.00	59.
1.01	8.25	101	.06	.05	.01	112.	1.01	20.25	245	.02	.02	.00	55.
1.01	8.30	102	.06	.05	.01	113.	1.01	20.30	246	.02	.02	.00	52.
1.01	8.35	103	.06	.05	.01	114.	1.01	20.35	247	.02	.02	.00	48.
1.01	8.40	104	.06	.05	.01	114.	1.01	20.40	248	.02	.02	.00	45.

END-OF-PERIOD FLOW (Cont'd)

1.01	8.45	105	.06	.05	.01	115.	1.01	20.45	249	.02	.02	.00	45.
1.01	8.50	106	.06	.05	.01	115.	1.01	20.50	250	.02	.02	.00	45.
1.01	8.55	107	.06	.06	.01	116.	1.01	20.55	251	.02	.02	.00	45.
1.01	9.00	108	.06	.06	.01	117.	1.01	21.00	252	.02	.02	.00	45.
1.01	9.05	109	.06	.06	.01	117.	1.01	21.05	253	.02	.02	.00	45.
1.01	9.10	110	.06	.06	.01	117.	1.01	21.10	254	.02	.02	.00	45.
1.01	9.15	111	.06	.06	.01	118.	1.01	21.15	255	.02	.02	.00	45.
1.01	9.20	112	.06	.06	.01	118.	1.01	21.20	256	.02	.02	.00	45.
1.01	9.25	113	.06	.06	.01	119.	1.01	21.25	257	.02	.02	.00	45.
1.01	9.30	114	.06	.06	.01	119.	1.01	21.30	258	.02	.02	.00	45.
1.01	9.35	115	.06	.06	.01	120.	1.01	21.35	259	.02	.02	.00	45.
1.01	9.40	116	.06	.06	.01	120.	1.01	21.40	260	.02	.02	.00	45.
1.01	9.45	117	.06	.06	.01	120.	1.01	21.45	261	.02	.02	.00	45.
1.01	9.50	118	.06	.06	.01	121.	1.01	21.50	262	.02	.02	.00	45.
1.01	9.55	119	.06	.06	.01	121.	1.01	21.55	263	.02	.02	.00	45.
1.01	10.00	120	.06	.06	.01	121.	1.01	22.00	264	.02	.02	.00	45.
1.01	10.05	121	.06	.06	.01	122.	1.01	22.05	265	.02	.02	.00	45.
1.01	10.10	122	.06	.06	.01	122.	1.01	22.10	266	.02	.02	.00	45.
1.01	10.15	123	.06	.06	.01	122.	1.01	22.15	267	.02	.02	.00	45.
1.01	10.20	124	.06	.06	.01	122.	1.01	22.20	268	.02	.02	.00	45.
1.01	10.25	125	.06	.06	.01	123.	1.01	22.25	269	.02	.02	.00	45.
1.01	10.30	126	.06	.06	.01	123.	1.01	22.30	270	.02	.02	.00	45.
1.01	10.35	127	.06	.06	.01	123.	1.01	22.35	271	.02	.02	.00	45.
1.01	10.40	128	.06	.06	.00	123.	1.01	22.40	272	.02	.02	.00	45.
1.01	10.45	129	.06	.06	.00	124.	1.01	22.45	273	.02	.02	.00	45.
1.01	10.50	130	.06	.06	.00	124.	1.01	22.50	274	.02	.02	.00	45.
1.01	10.55	131	.06	.06	.00	124.	1.01	22.55	275	.02	.02	.00	45.
1.01	11.00	132	.06	.06	.00	124.	1.01	23.00	276	.02	.02	.00	45.
1.01	11.05	133	.06	.06	.00	125.	1.01	23.05	277	.02	.02	.00	45.
1.01	11.10	134	.06	.06	.00	125.	1.01	23.10	278	.02	.02	.00	45.
1.01	11.15	135	.06	.06	.00	125.	1.01	23.15	279	.02	.02	.00	45.
1.01	11.20	136	.06	.05	.00	125.	1.01	23.20	280	.02	.02	.00	45.
1.01	11.25	137	.06	.06	.00	125.	1.01	23.25	281	.02	.02	.00	45.
1.01	11.30	138	.06	.06	.00	125.	1.01	23.30	282	.02	.02	.00	45.
1.01	11.35	139	.06	.06	.00	126.	1.01	23.35	283	.02	.02	.00	45.
1.01	11.40	140	.06	.06	.00	126.	1.01	23.40	284	.02	.02	.00	45.
1.01	11.45	141	.06	.06	.00	126.	1.01	23.45	285	.02	.02	.00	45.
1.01	11.50	142	.06	.06	.00	126.	1.01	23.50	286	.02	.02	.00	45.
1.01	11.55	143	.06	.06	.00	126.	1.01	23.55	287	.02	.02	.00	45.
1.01	12.00	144	.06	.06	.00	126.	1.02	0.00	288	.02	.02	.00	45.

SUM	33.02	31.14	1.88	68877.
	(839.)	(791.)	(48.)	(1950.38)

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	3852.	747.	239.	239.	68841.
CMS	109.	21.	7.	7.	1949.
INCHES		25.47	32.58	32.58	32.58
MM		646.89	827.51	827.51	827.51
AC-FT		371.	474.	474.	474.
THOUS CU M		457.	585.	585.	585.

SURFACE AREA=	0.	0.	14.	23.	34.
CAPACITY=	0.	53.	160.	340.	619.
ELEVATION=	579.	600.	610.	620.	630.

SUMMARY OF DAM SAFETY ANALYSIS

PMF

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	600.00	600.00	601.90
STORAGE	53.	53.	69.
OUTFLOW	0.	0.	242.

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
.12	601.83	0.00	68.	224.	0.00	15.83	0.00
.13	601.92	.02	69.	247.	.17	15.83	0.00
.50	603.14	1.24	80.	1673.	4.50	15.67	0.00
1.00	603.82	1.92	86.	3692.	6.58	15.67	0.00

SUMMARY OF DAM SAFETY ANALYSIS

100-YR. FLOOD

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	600.00	600.00	601.90
STORAGE	53.	53.	69.
OUTFLOW	0.	0.	242.

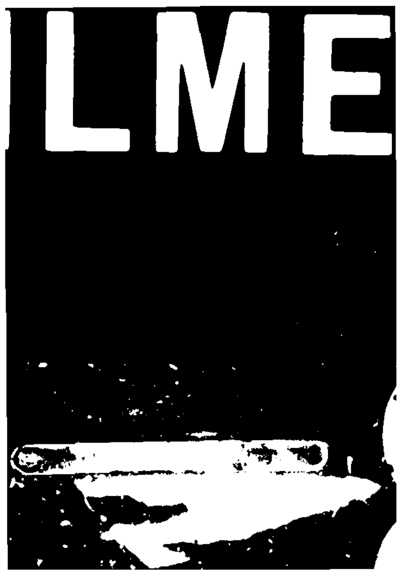
RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	602.26	.36	72.	419.	.50	12.30	0.00

SUMMARY OF DAM SAFETY ANALYSIS

10-YR. FLOOD

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	600.00	600.00	601.90
STORAGE	53.	53.	69.
OUTFLOW	0.	0.	242.

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	601.45	0.00	65.	133.	0.00	12.50	0.00


LME