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MISSOURI - KANSAS CITY BASIN

LONGSTREET LAKE DAM

WARREN COUNTY, MISSOURI

MO 30832

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

SEPTEMBER 1980

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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

LONGSTREET LAKE DAM
WARREN COUNTY, MISSOURI
MO 30832

PHASE 1 INSPECTION REPORT
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PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
FOR: STATE OF MISSOURI

SEPTEMBER 1980

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

REPLY TO
ATTENTION OF

LMSED-P

SUBJECT: Longstreet Lake Dam, MO 30832, Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Longstreet Lake Dam (MO 30832):

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

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

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

2) Overtopping of the dam could result in failure of the dam.

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

SUBMITTED BY: SIGNED — Chief, Engineering Division — 15 OCT 1980 — Date

APPROVED BY: SIGNED — Colonel, CE, District Engineer — 15 OCT 1980 — Date

LONGSTREET LAKE DAM

MISSOURI INVENTORY NO. 30832

WARREN 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

SEPTEMBER 1980

HS-8011

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam:	Longstreet Lake Dam
State Located:	Missouri
County Located:	Warren
Stream:	Tributary of Massie Creek
Date of Inspection	18 June 1980

Longstreet 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 these hydrologic/hydraulic investigations, the present general condition of the dam is considered to be somewhat 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. 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 vertical bank up to about 12 inches high at the normal waterline. Riprap is not provided at this location, and a grass covered slope is not considered adequate protection to prevent erosion of the embankment by wave action or fluctuations of the lake level.

2. Depressions in the embankment believed to be old animal burrows were noted at 4 locations along the upstream face of the dam at the waterline. Animal burrows can provide passageways for seepage that could develop into a piping condition (progressive internal erosion) that can lead to failure of the dam.

3. Several small trees and brushy undergrowth that could conceal animal burrows are present on the downstream face of the dam. Tree roots can also provide passageways for seepage that can result in a piping condition.

4. A minor erosion rill was noted in the lower reach of the dam at the junction of the downstream face and the left abutment, and an eroded area has developed at the downstream toe of the dam below the outlet end of the spillway pipe. Loss of embankment material by erosion can be detrimental to the structural stability of the dam.

5. A deep gully believed to be result of erosion by spillway flow exists at the downstream end of the emergency spillway outlet channel. While not immediately endangering the stability of the dam, the progress of this erosion should be monitored.

According to the criteria set forth in the recommended guidelines, the magnitude of the spillway design flood for the Longstreet Lake Dam, which is classified as intermediate in size and of high hazard potential, is specified to be the Probable Maximum Flood (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.

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 without overtopping the dam. The spillways are capable, however, of passing lake outflow resulting from the one percent chance (100-year frequency) flood and the outflow corresponding to about 28 percent of the PMF. 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 three miles. Accordingly, within the possible damage zone are five dwellings and several farm buildings.

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

It is recommended that the Owner take the necessary action in the near future to correct or control the deficiencies and safety defects reported herein. Priority should be given to increasing the spillway capacity.

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 LONGSTREET LAKE DAM

PHASE 1 INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

LONGSTREET LAKE DAM - MO 30832

TABLE OF CONTENTS

LIST OF PLATES

APPENDIX A - INSPECTION PHOTOGRAPHS

APPENDIX B - HYDROLOGIC AND HYDRAULIC ANALYSES

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

LONGSTREET LAKE DAM - MO 30832

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 Longstreet 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 above 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 Longstreet Lake Dam is an earthfill type embankment rising approximately 41 feet above the original streambed. The embankment has an upstream slope (above the waterline) of approximately 1v on 2.5h, a crest width of about 15 feet, and a downstream slope on the order of 1v on 3.1h. The length of the dam is approximately 450 feet. A plan and profile of the dam are shown on Plate 3 and a cross-section of the dam is shown on Plate 4. At normal pool level, the reservoir impounded by the dam occupies approximately 10 acres. The dam has both a principal and an emergency spillway. There is no drawdown facility to dewater the lake.

The principal spillway, which is located to the right of the center of the dam, consists of a 24-inch diameter steel, drop inlet, type pipe with an antivortex plate (see Photo 3) and a 10-inch diameter steel outlet pipe. The spillway outlet pipe discharges to the original stream channel at the toe of the dam.

The emergency spillway, a riprap lined trapezoidal section, is located at the right, or south, abutment. The spillway outlet channel, an excavated grass-lined earthen trapezoidal section, is cut into the hillside with an earthen berm constructed on the downhill, or left, side to confine flow to the channel. The channel extends about 170 feet from the centerline of the dam and discharges into a natural draw which joins the original stream channel approximately 300 feet below the dam. The profile and cross-section of the emergency spillway are shown on Plate 5.

b. Location. The dam is located on an unnamed tributary of Massie Creek, about 3.5 miles south of Jonesburg, Missouri, as shown on the Regional Vicinity Map, Plate 1. The dam is located in the southwest quadrant of Section 25, Township 47 North, Range 4 West, within Warren County.

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

d. Hazard Classification. Longstreet 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 three miles downstream of the dam. Within the possible damage zone are five dwellings and several farm buildings. 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 William H. Longstreet. Mr. Longsteet's address is: 350 Gray Avenue, Webster Groves, Missouri 63119.

f. Purpose of Dam. The dam impounds water for recreational use.

g. Design and Construction History. According to the Owner, the dam was constructed in 1970 by Russell Bolinger, a local excavating and grading contractor and builder of earthen type dams. Mr. Bolinger is deceased. The Owner reported that the drop inlet spillway was installed in 1977.

h. Normal Operational Procedure. The lake level is unregulated. Lake outflow is governed by the combined capacities of the drop inlet type spillway and the overflow type emergency spillway.

1.3 PERTINENT DATA

a. Drainage Area. The drainage area tributary to the lake is for the most part in a native state covered with timber. The watershed above the dam amounts to approximately 68 acres. The watershed area is outlined on Plate 2.

b. Discharge at Damsite.

(1) Estimated known maximum flood at damsite ... 10 cfs* (W.S. Elev. 701.0)

(2) Spillway capacity

a. Principal ... 10 cfs (W.S. Elev. 701.0)

b. Principal + Emergency ... 164 cfs (W.S. Elev. 702.3)

c. Elevation (Ft. above MSL). Except where otherwise indicated, the following elevations were determined by survey and are based on topographic data shown on the 1973 Jonesburg, Missouri, Quadrangle Map, 7.5 Minute Series.

*Based on an estimate of depth of flow at principal spillway as observed by the Owner.

(1) Observed pool ... 699.9

(2) Normal pool ... 700.0

(3) Spillway Crest

a. Principal ... 700.0

b. Emergency ... 701.0

(4) Maximum experienced pool ... 701.0*

(5) Top of dam ... 702.3 (min.)

(6) Streambed at centerline of dam ... 662± (Est.)

(7) Maximum tailwater ... Unknown

(8) Observed tailwater ... None

d. Reservoir.

(1) Length at normal pool (Elev. 700.0) ... 1,350 ft.

(2) Length at maximum pool (Elev. 702.3) ... 1,400 ft.

e. Storage.

(1) Normal pool ... 112 ac. ft.

(2) Top of dam (incremental) ... 23 ac. ft.

f. Reservoir Surface.

(1) Normal pool ... 10 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.

*Based on an estimate of depth of flow at principal spillway as observed by the Owner.

(1) Type ... Earthfill, clay core*

(2) Length ... 450 ft.

(3) Height ... 41 ft.

(4) Top width ... 15 ft.

(5) Side slopes

a. Upstream ... 1v on 2.5h (above waterline)

b. Downstream ... 1v on 3.1h

(6) Cutoff ... Clay core*

(7) Slope protection

a. Upstream ... Grass

b. Downstream ... Grass

h. Principal Spillway.

(1) Type ... Uncontrolled, drop inlet, 24-inch diameter steel pipe

(2) Location ... Station 1 + 60, 16 feet upstream

(3) Crest ... Elevation 700.0

(4) Outlet pipe ... 10-inch diameter steel pipe

i. Emergency Spillway.

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

(2) Location ... Right abutment

(3) Crest ... Elevation 701.0

(4) Approach channel ... Lake

(5) Exit channel ... Grass-lined earth, trapezoidal section

j. Lake Drawdown Facility. ... None

* Per Owner

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

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

2.2 CONSTRUCTION

No formal records were maintained during construction of the dam. However, as previously stated, the dam was constructed in 1970 by Russell Bolinger, an excavating and grading contractor from Wright City, Missouri. Mr. Bolinger is deceased. The Owner stated that a core trench was excavated and that the dam was constructed with clay excavated from the adjacent hillsides, and that compaction was obtained by running earth moving equipment over the fill material. According to the Owner, the pipe spillway was installed in the dam in 1977.

2.3 OPERATION

The lake level is uncontrolled and governed by the crest elevation of the drop inlet spillway located near the center of the dam. An emergency spillway located in the hillside at the right abutment provides relief for lake surcharge greater than the capacity of the drop inlet. No indication was found that the dam had been overtopped. The Owner reported that the dam has never been overtopped and that the maximum flood experienced by the dam occurred in April of 1979 when a storm produced a depth of flow at the inlet estimated to be about 12 inches.

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.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. A visual inspection of the Longstreet Lake Dam was made by Horner & Shifrin engineering personnel, T. K. Dedlens, Geological Engineer, and H. B. Lockett, Civil Engineer and Hydrologist, on 15 June 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 site 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-4 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 near the northern edge of the Ozark Plateaus Physiographic Province, near the border with the Dissected Till Plains Section of the Central Lowlands Province.

The topography is moderately to steeply sloping in the reservoir area. The relief between the reservoir and the surrounding drainage divides ranges up to a maximum of approximately 125 feet. No bedrock exposures were noted at the reservoir site; however, exposures along Massie Creek indicate the dam is most probably underlain by Ordovician-age sedimentary strata of the Plattin formation. The bedrock dips gently to the north, and no faults were observed or are reported to be present in this area.

The Plattin formation consists of evenly-bedded, gray, finely crystalline to micritic limestone which often contains minor amounts of intercalated shale. Brown, dark gray, and white chert nodules and layers are found throughout much of the formation. The limestones are subject to solution weathering. Solution-enlarged joints or bedding planes, sinkholes, and an irregular contact between bedrock and the overlying soils are common. Solution features such as these are often the source of significant reservoir leakage. However, bedrock outcrops in the general area were insufficient to assess the extent of solution features, and no surface expression of these features was noted.

The dam and reservoir are underlain primarily by soils of the Cedargap, Gasconade, and the Lindley series. The Cedargap soils blanket the valley floor under the dam site. These deposits consist of deep, somewhat excessively drained soils formed in alluvium. These soils are a dark grayish-brown, cherty silt at the surface and become more cherty and clayey with depth. According to the Unified Soil Classification System, these soils are classified as ML to GC materials, are permeable, and may cause seepage. The more silty material may be subject to piping. The Gasconade soils cover the south abutment and part of the south valley wall. This series consists of shallow, somewhat excessively drained soils derived from weathering of limestone and thinly interbedded shale. They consist of dark grayish-brown, stoney (limestone and chert fragments), silty clays near the surface and grade to dark brown, silty clay with depth. The soils range in classification from CL to GC, are moderately permeable and may allow seepage into shallow bedrock. The Lindley soils cover most of the valley slopes surrounding the reservoir and dam. These are deep, well-drained soils formed on glacial till. The soil is typically a silty clay at the surface, becoming more clayey with depth. Chert fragments from the reworked residual soils are common. The soils are classified as CL-ML to CL materials, exhibit moderately low permeability, and are generally considered favorable for impoundments and embankments. Keswick soils reportedly cover the higher valley slopes well above the reservoir. The soils around the north abutment of the dam are a combination of the Keswick and Lindley series and exhibit engineering properties similar to the Lindley soils. However, these soils are more silty and may be susceptible to erosion on slopes.

The most significant geologic condition at the dam site is the severe erosion of residuum in the spillway channel. No other geologic factors were noted that would appear to significantly affect the performance of the dam or reservoir.

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 inspected and appeared to be in sound condition, although erosion of the unprotected upstream slope had created a vertical face up to 12 inches high at the normal lake level waterline. Riprap was not provided along the upstream face of the dam. The presence of small trees and brush (see Photos 1 and 2) was noted on the downstream face of the dam.

At the normal waterline the remains of what appeared to be old animal burrows (see Photo 7) were found at four locations along the upstream face of the dam. No settlement or horizontal misalignment of the dam crest, or sloughing of the dam slopes was noticed. No seepage was noted on the downstream face of the dam or in the valley areas just downstream of the dam. A minor erosion rill was noted in the lower reach of the dam at the junction of the downstream face and the left abutment. An examination of a soil sample obtained from the downstream face of the dam indicated the material to be a yellow-brown silty lean clay (CL) of medium plasticity.

The 24-inch diameter drop inlet (see Photo 3) and the 10-inch diameter steel outlet pipe were inspected and found to be in satisfactory condition. However, an eroded area (see Photo 4) about five feet in diameter and approximately 1.5 feet deep has developed below the outlet of the 10-inch pipe at the junction of the downstream toe of the dam and the original stream channel.

The grass-lined outlet channel (see Photo 5) for the emergency spillway was examined and found to be in good condition; however, a deep gully (see Photo 6) approximately 10 feet deep and 20 feet wide has been eroded at the downstream end of the channel at a point about 170 feet from the centerline of the dam.

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

e. Downstream Channel. The channel within the potential dam failure damage zone downstream of the dam is unimproved and extends approximately 1,500 feet before joining Massie Creek, which is also unimproved.

f. Reservoir. The area adjacent to the lake is for the most part in a natural state and wooded. At the time of the inspection the lake water surface elevation was about 0.1 foot below normal pool and the water within the reservoir was essentially clear. The amount of sediment within the lake at the time of inspection could not be determined; however, due to the vegetation covering the surrounding area, it is believed to be insignificant.

3.2 EVALUATION

The deficiencies observed during the inspection and noted herein, are not considered of significant importance to warrant immediate remedial action. It is recommended, however, that restoration of the eroded areas of the embankment be assigned a high priority.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

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

4.2 MAINTENANCE OF DAM

With the exception of several locations where erosion has occurred, the embankment and areas immediately adjacent thereto appeared as if they receive routine maintenance. According to the Owner, the grass on the dam is cut periodically during the growing season.

4.3 MAINTENANCE OF OUTLET OPERATING FACILITIES

No outlet facilities requiring operation exist at this dam, and 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

It is recommended that the eroded areas of the dam be restored and that riprap be added to the upstream face of the dam to prevent erosion by wave action or fluctuations of the lake level. 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 - HYDROLOGIC/HYDRAULIC

5.1 EVALUATION OF FEATURES

a. Design Data. Design data are not available.

b. Experience Data. The drainage area and lake surface area were developed from the 1973 USGS Jonesburg, 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 are not available.

Due to the fact that the watershed for this reservoir is small, 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 storm.

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

c. Visual Observations.

(1) The principal spillway, a 24-inch diameter drop inlet, is located to the right of the center of the dam. The 24-inch steel pipe drop inlet is about 3 feet deep. A steel antivortex plate and a welded reinforcing bar grate that serves as a trash screen are provided at the top of the inlet.

(2) A 10-inch diameter steel outlet pipe extends from the drop inlet to the toe of the dam at the downstream channel.

(3) The emergency spillway, a riprap lined broad-crested trapezoidal section, is located at the right, or south, abutment.

(4) The emergency spillway outlet channel, an excavated grass lined earthen trapezoidal section, is cut into the hillside with an earthen bank constructed on the downhill, or left, side to confine flow to the channel.

(5) The original stream channel abuts the dam.

d. Overtopping Potential. The spillways (principal and emergency) are inadequate to pass the probable maximum flood, or 1/2 the probable maximum flood, without overtopping the dam. The results of the dam overtopping analysis are as follows:

(Note: The data appearing in the following table have been 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. 702.3)	Duration of Overtopping of Dam (Hrs.)
0.50	482	702.9	0.6	1.2
1.00	1,412	703.6	1.3	5.2

Elevation 702.3 was found to be the lowest point in the dam crest. The flow safely passing the spillways just prior to overtopping amounts to approximately 164 cfs, which is the routed outflow corresponding to about 28 percent of the probable maximum flood inflow. During peak flow of the probable maximum flood, the greatest depth of flow over the dam is projected to be 1.3 feet and overtopping will extend across the entire length of the dam.

e. Evaluation. Experience with embankments constructed of similar material (a yellow-brown silty lean clay of medium plasticity) to that used to construct this dam have shown evidence that the material under certain conditions, such as high velocity flow, can be very erodible. An example of such erosion is apparent at the emergency spillway outlet channel. 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 1.3 feet, and the duration of flow over the dam, 5.2 hours, are substantial, damage by erosion to the crest and downstream face of the dam is expected. The extent of these damages is not predictable; however, there is a possibility that they could result in failure by erosion of the dam.

f. Reference. Procedures and data for determining the probable maximum flood, the 100-year frequency flood, and the discharge rating curve for flow passing the spillways and dam crest are presented on pages B-1 through B-3 of the Appendix. Listings of the HEC-1 (Dam Safety Version) input data for both the probable maximum flood and the 100-year frequency flood are shown on pages B-4 through B-6. Computer output data, including unit hydrograph ordinates, tabulation of PMF rainfall, loss and inflow data are shown on pages B-7 through B-10; tabulation of lake surface area, elevation and storage volume is shown on page B-11 and tabulation titled "Summary of Dam Safety Analysis" for the PMF and 1 percent chance (100-year frequency) flood are also shown on page B-11.

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, no records are kept of the lake level, spillway discharge, dam settlement, or seepage.

d. Post Construction Changes. With the exception of the installation of the drop inlet spillway in 1977, the Owner reported that no post construction changes have been made or have occurred which would affect the structural stability of the dam.

e. Seismic Stability. The dam is located in an area close to the boundary separating the Zone I and Zone II seismic probability areas. 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 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 164 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 1,412 cfs, and that for the 1 percent chance (100-year frequency) flood, the lake outflow would be about 35 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 old animal burrows on the upstream face of the embankment, the areas of erosion, small trees and undergrowth, and the lack of adequate slope protection to prevent erosion of the upstream face of the dam.

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 in the near future. The item concerning increasing spillway capacity should be pursued on a high priority basis.

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

e. Seismic Stability. The dam is located in an area close to the boundary separating the Zone I and Zone II seismic probability areas. 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 be applied in any stability analyses performed for this dam.

7.2 REMEDIAL MEASURES

a. Recommendations. 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 spillway 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. Operations and Maintenance (O & M) Procedures. The following O & M Procedures are recommended:

(1) Provide some form of protection other than grass for the upstream face of the dam at and above the normal waterline in order to prevent erosion. A grass covered slope is not considered adequate protection to prevent erosion by wave action or by a fluctuating lake level.

(2) Restore the eroded areas of the dam and provide some means of preventing future erosion by spillway pipe discharges and overland drainage. Loss of section due to erosion can impair the structural stability of the dam.

(3) Restore the embankment at the old animal burrows along the upstream face of the dam. Animal burrows can provide a passageway for lake seepage which could lead to a piping condition (progressive internal erosion) and subsequent failure of the dam.

(4) Remove the small trees and undergrowth from the downstream face of the dam. Holes from tree roots can provide passageways for seepage that could lead to a piping condition.

(5) Monitor progress of channel erosion at the lower end of the emergency spillway outlet channel. Measures should be taken at the appropriate time to prevent a condition where erosion of the channel affects the operation of the reservoir.

(6) 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.

(7) 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.

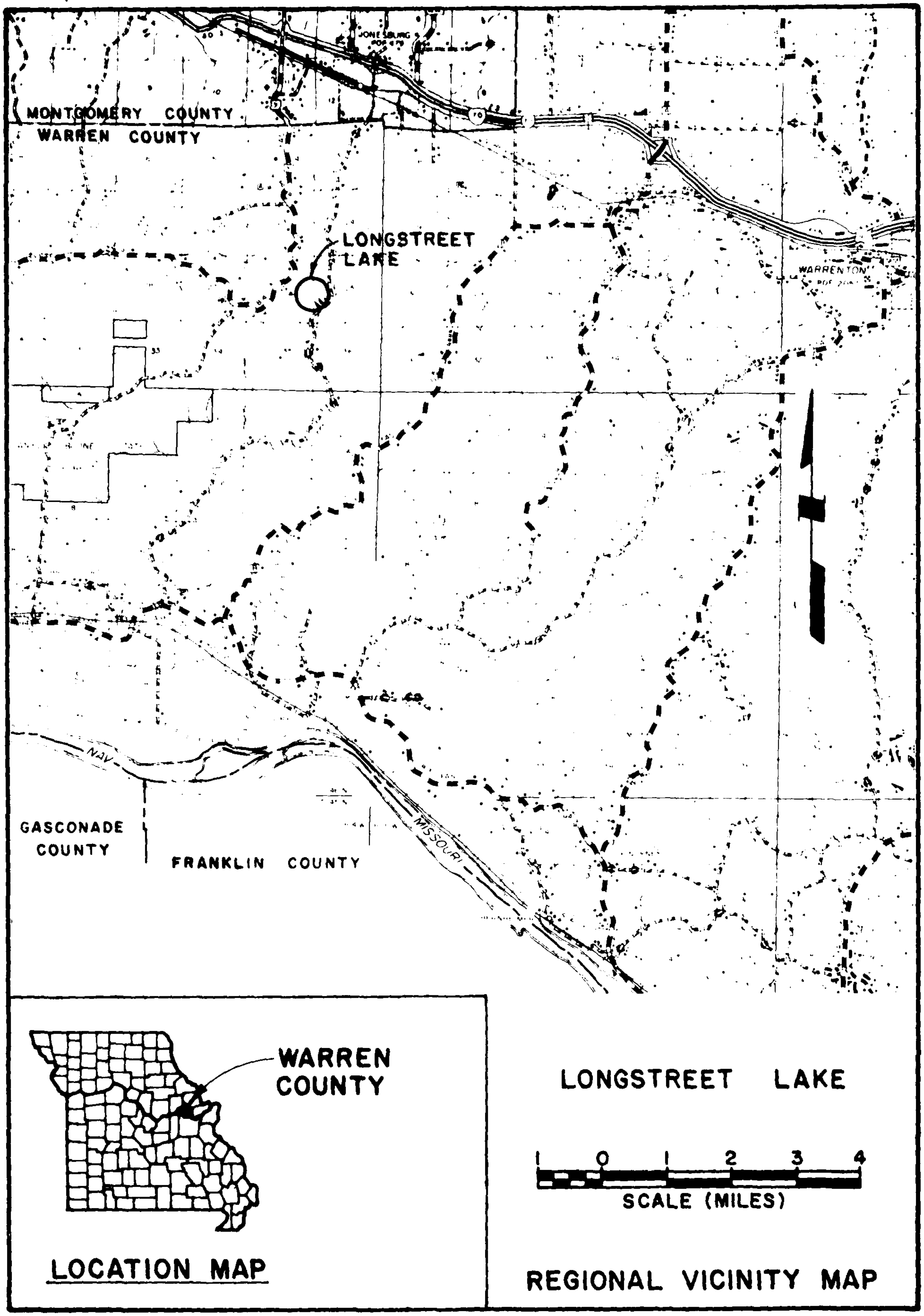
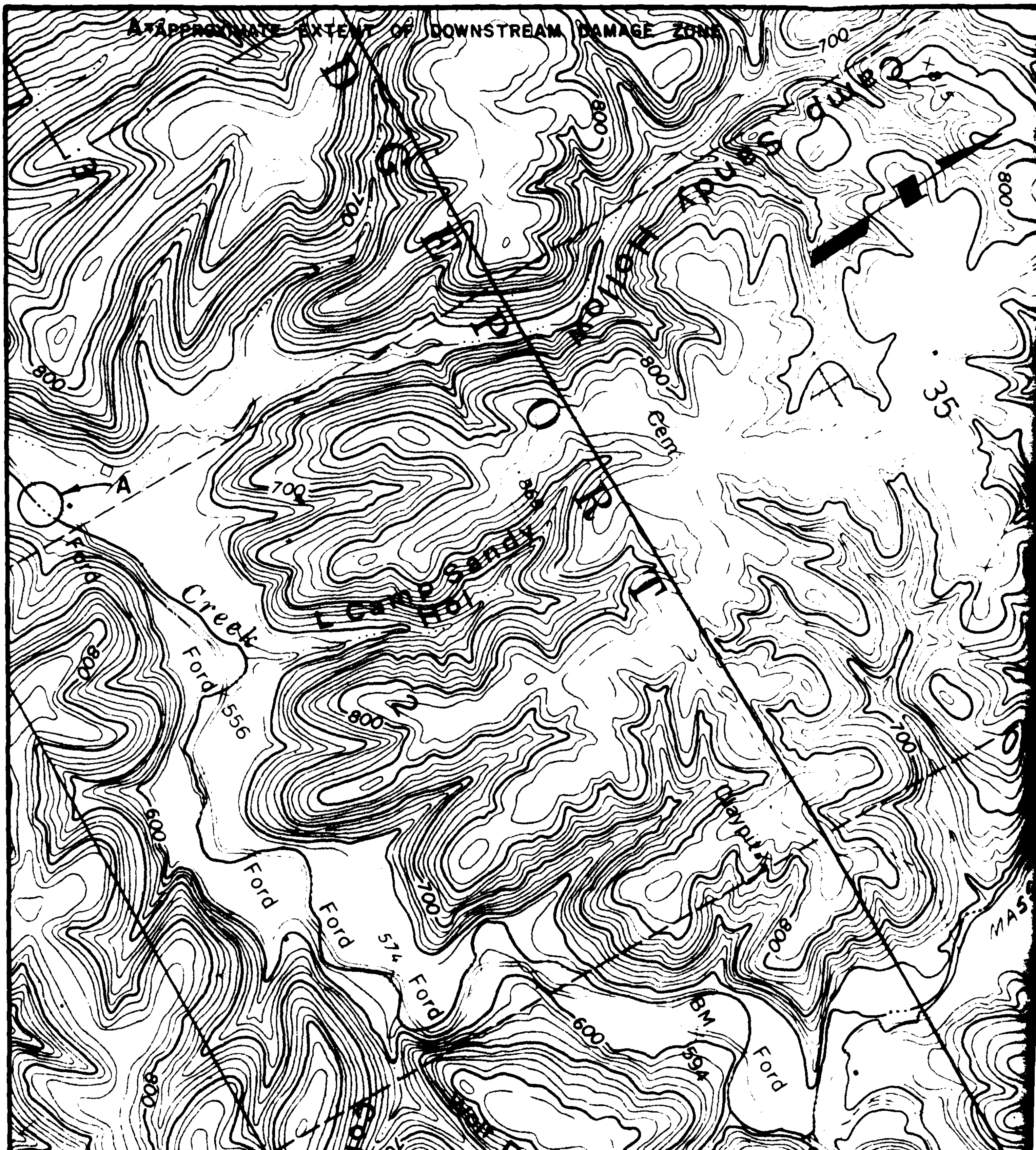

MONTGOMERY COUNTY
WARREN COUNTY
JONESBURG
LONGSTREET LAKE
WARRENTON
NAV
MISSOURI
GASCONADE COUNTY
FRANKLIN COUNTY
WARREN COUNTY
LOCATION MAP
LONGSTREET LAKE
1 0 1 2 3 4
SCALE (MILES)
REGIONAL VICINITY MAP

PLATE I



APPROXIMATE EXTENT OF DOWNSTREAM DAMAGE ZONE
A
Creek
Ford
556
Ford
Ford
574
Ford
BM
594
Ford
Cem
Claypit
800
700
600
35
MAS

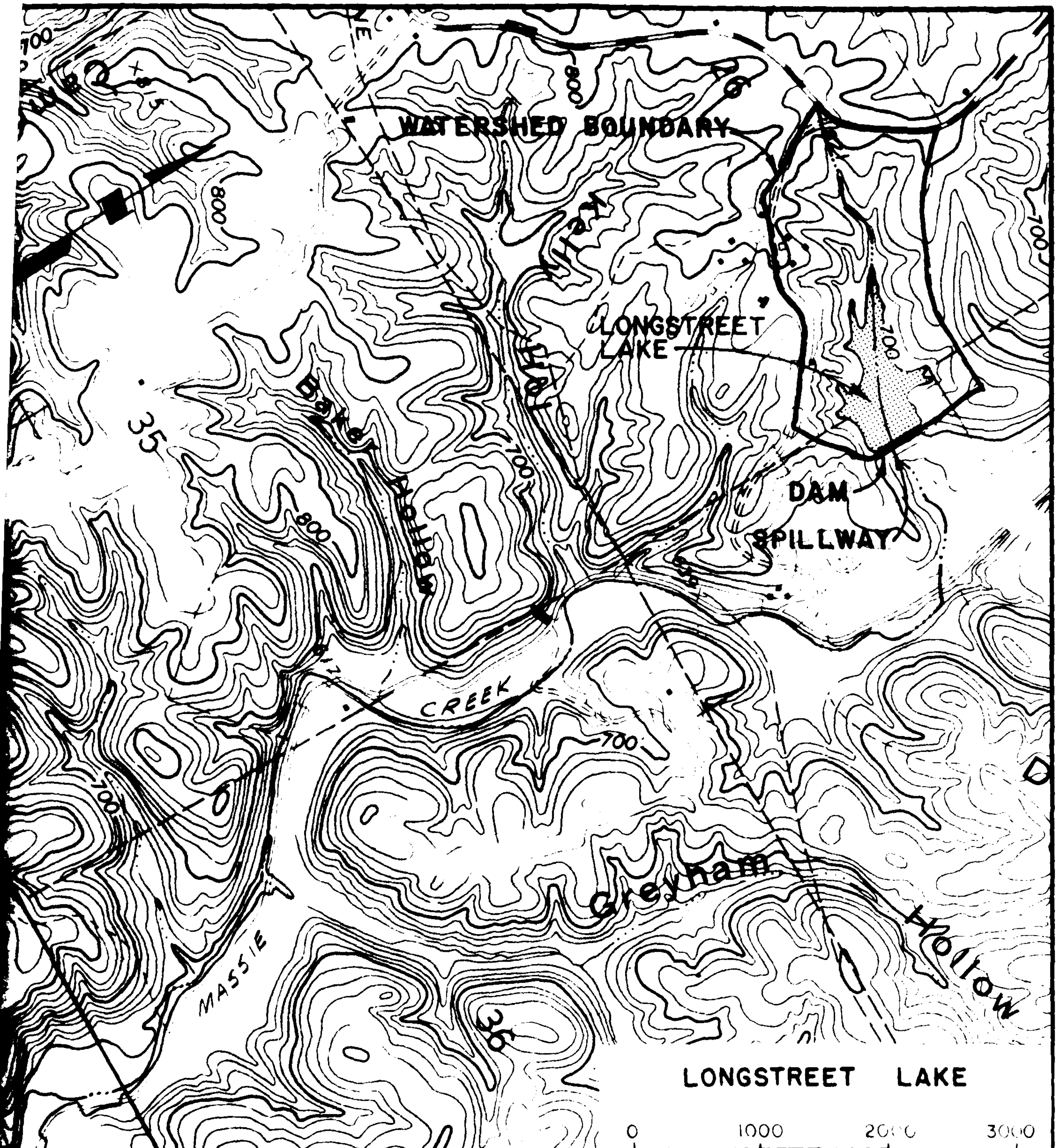
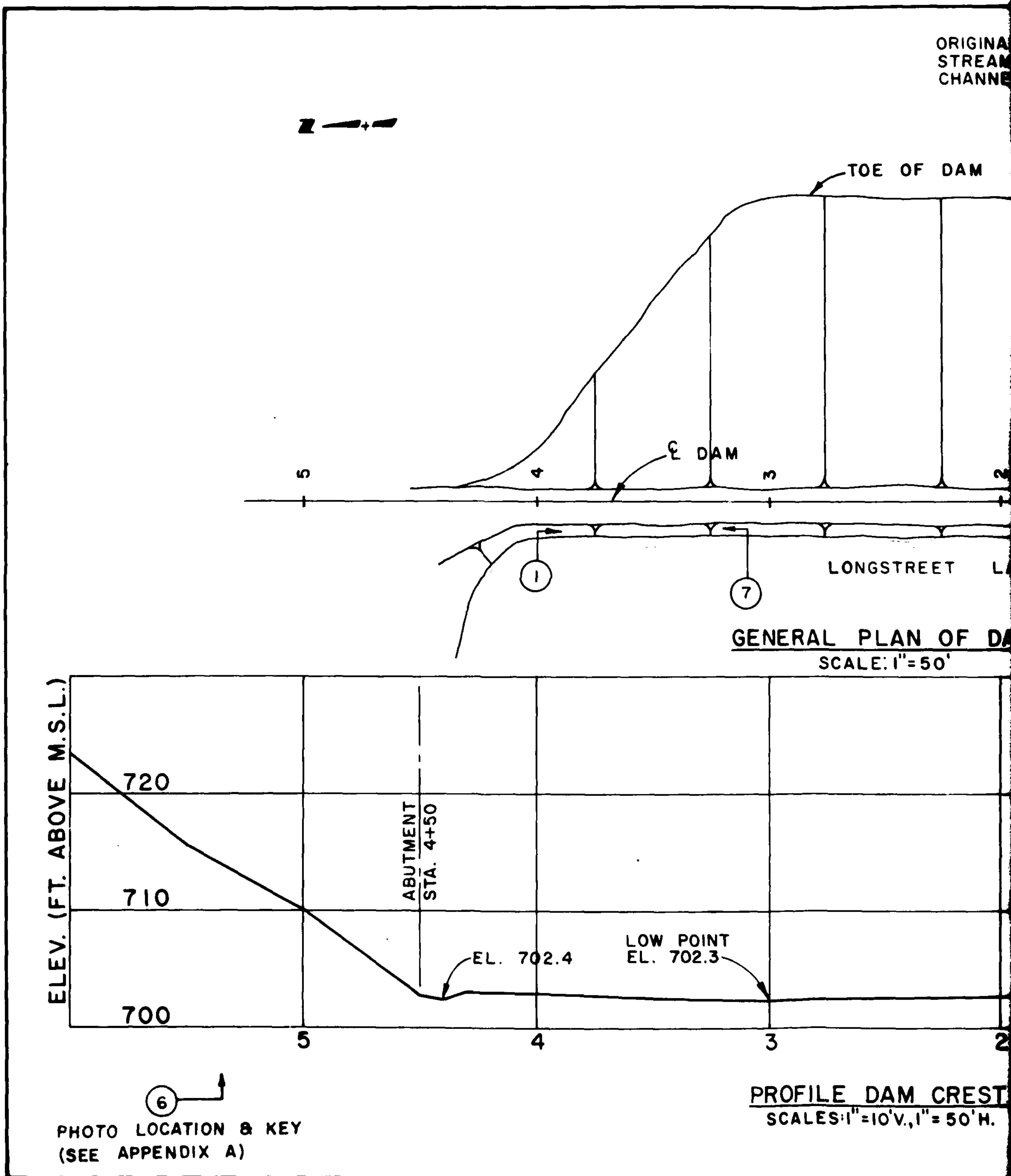

WATERSHED BOUNDARY
LONGSTREET LAKE
DAM
SPILLWAY
Bake Hollow
Greyham Hollow
CREEK
MASSIE
700
800
35
36
LONGSTREET LAKE
0 1000 2000 3000
SCALE IN FEET
(CONTOUR INTERVAL 20 FEET)
LAKE WATERSHED MAP

PLATE 2


ORIGINA
STREAM
CHANNE
TOE OF DAM
℄ DAM
5
4
3
2
LONGSTREET L
1
7
GENERAL PLAN OF DA
SCALE: 1"=50'
ELEV. (FT. ABOVE M.S.L.)
720
710
700
ABUTMENT
STA. 4+50
EL. 702.4
LOW POINT
EL. 702.3
5
4
3
2
6
PHOTO LOCATION & KEY
(SEE APPENDIX A)
PROFILE DAM CREST
SCALES: 1"=10'V., 1"= 50'H.

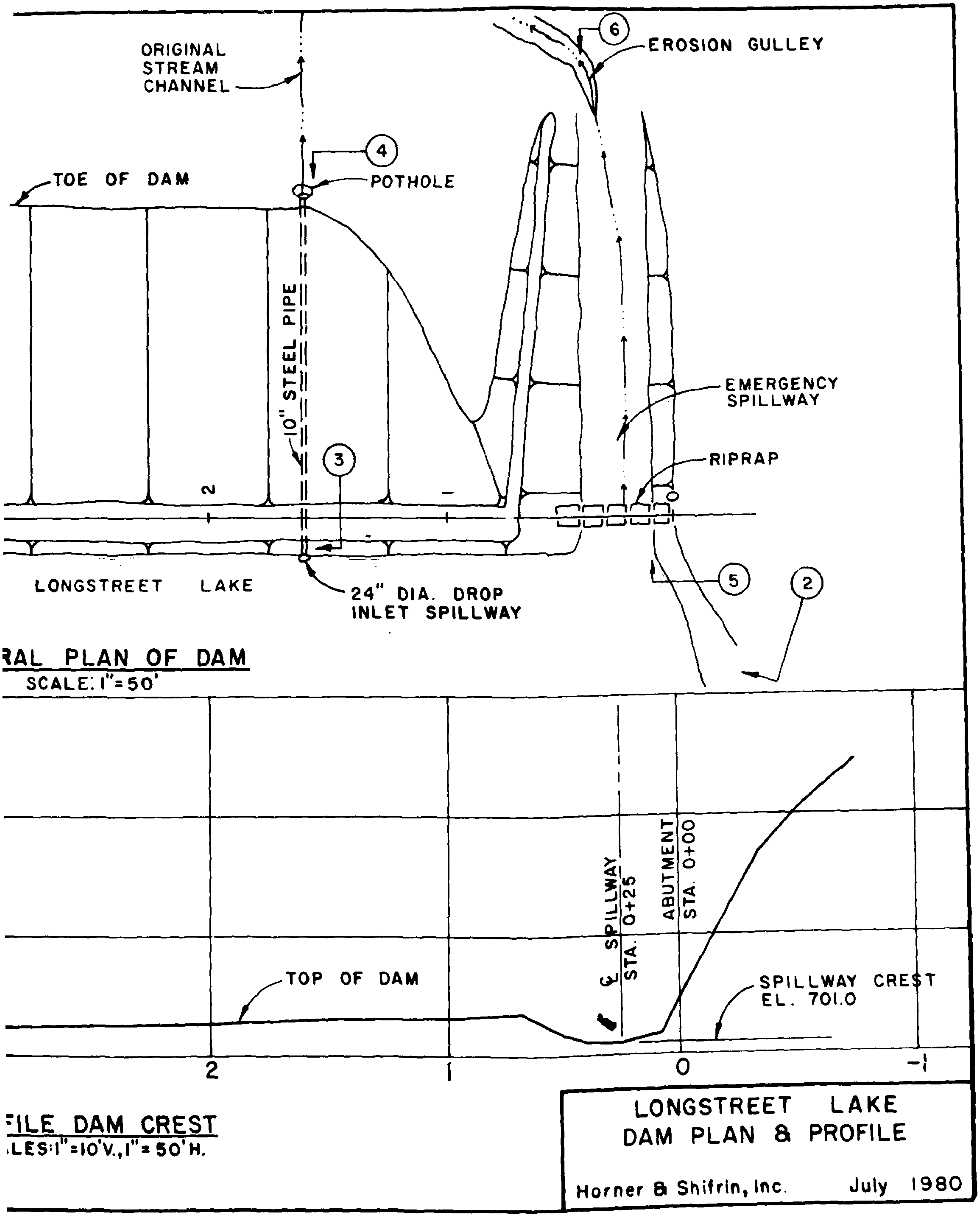
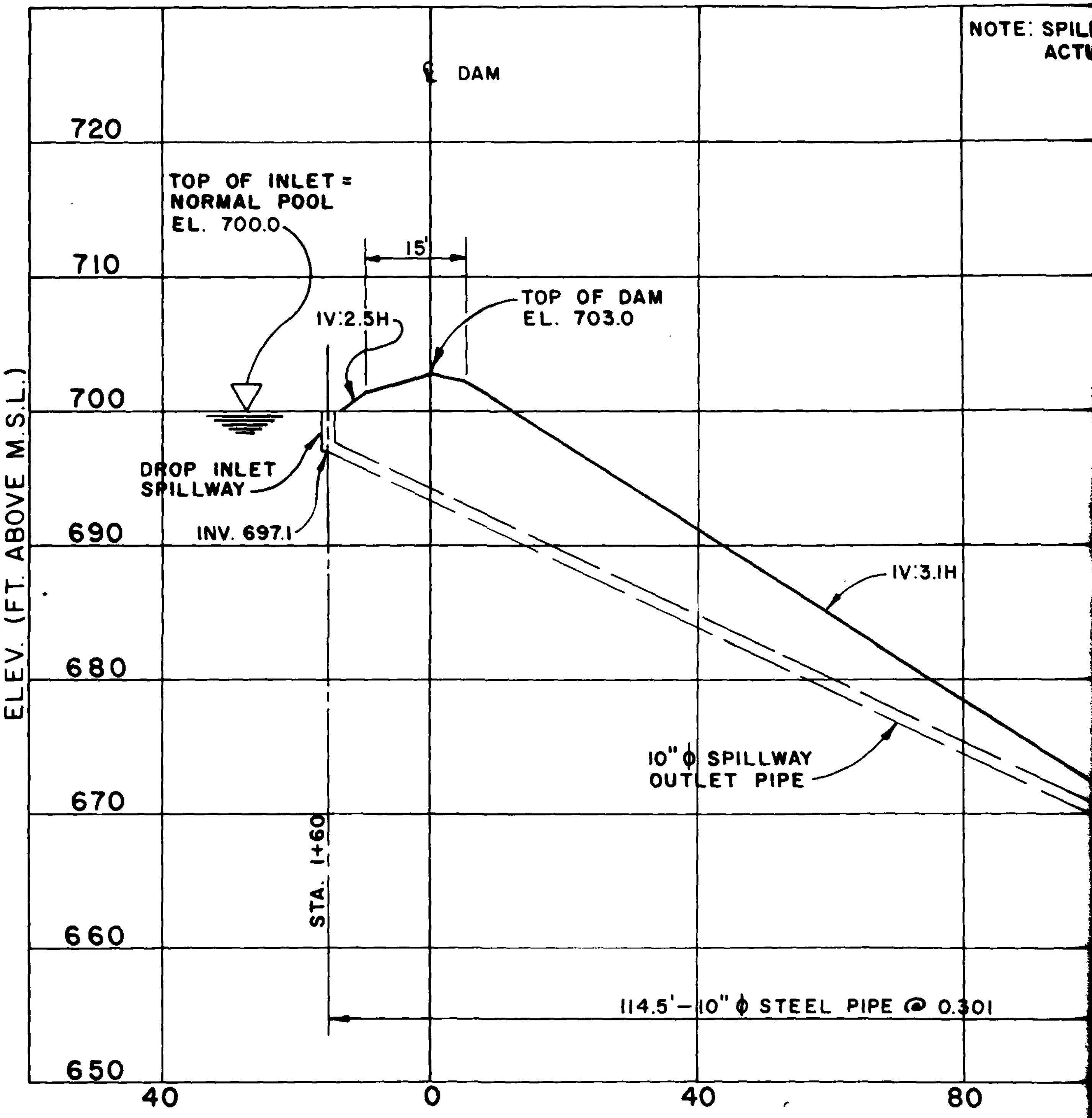
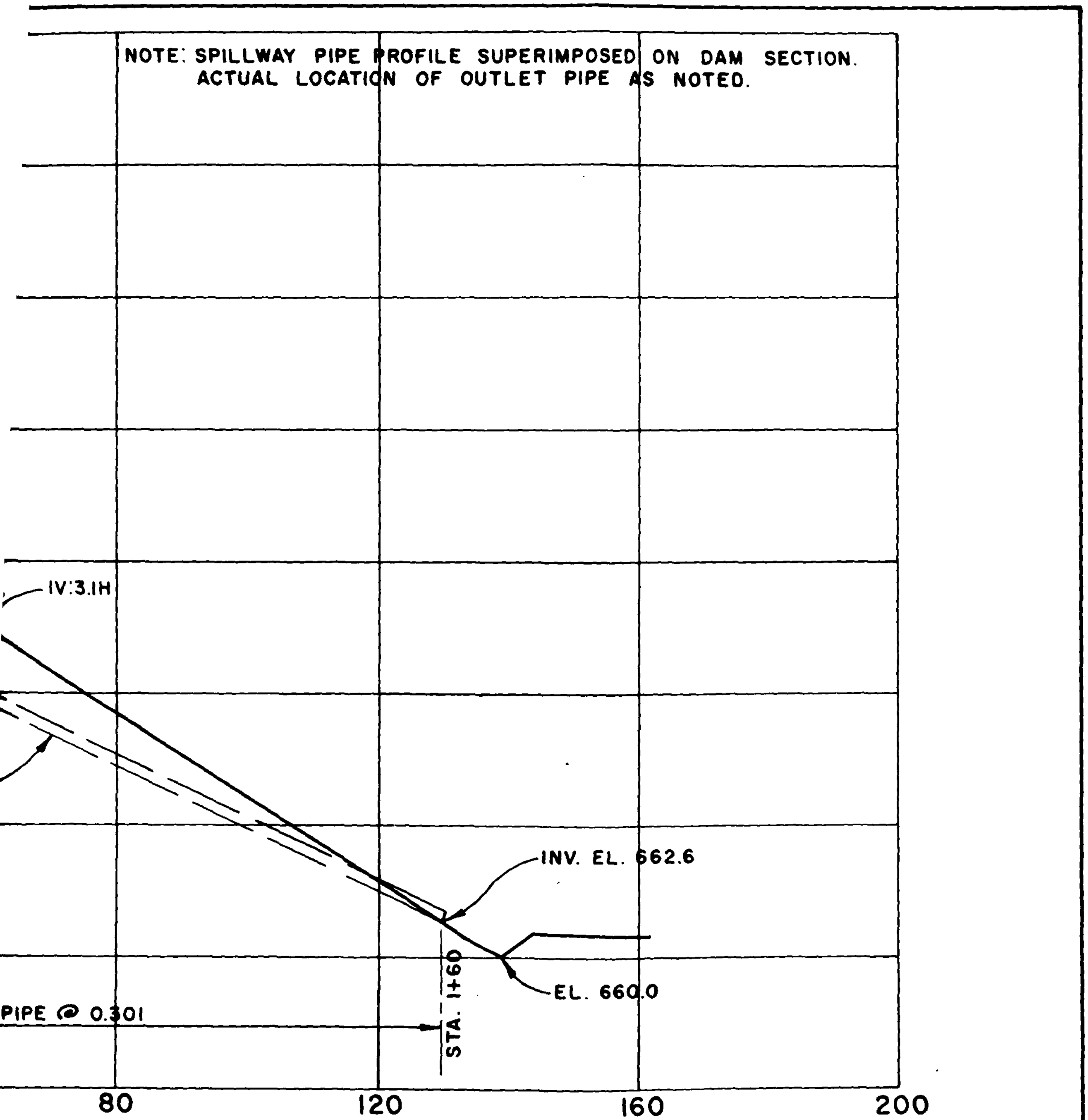

ORIGINAL STREAM CHANNEL
EROSION GULLEY
6
4
TOE OF DAM
POTHOLE
10" STEEL PIPE
EMERGENCY SPILLWAY
3
RIPRAP
2
1
0
LONGSTREET LAKE
24" DIA. DROP INLET SPILLWAY
5
2
RAL PLAN OF DAM
SCALE: 1"=50'
℄ SPILLWAY STA. 0+25
ABUTMENT STA. 0+00
TOP OF DAM
SPILLWAY CREST EL. 701.0
2
1
0
-1
FILE DAM CREST
LES: 1"=10'V., 1"=50'H.
LONGSTREET LAKE
DAM PLAN & PROFILE
Horner & Shifrin, Inc.
July 1980

PLATE 3



DAM CROSS-SECTION STA. 1+

SCALES: 1"=10'V., 1"=20' H.

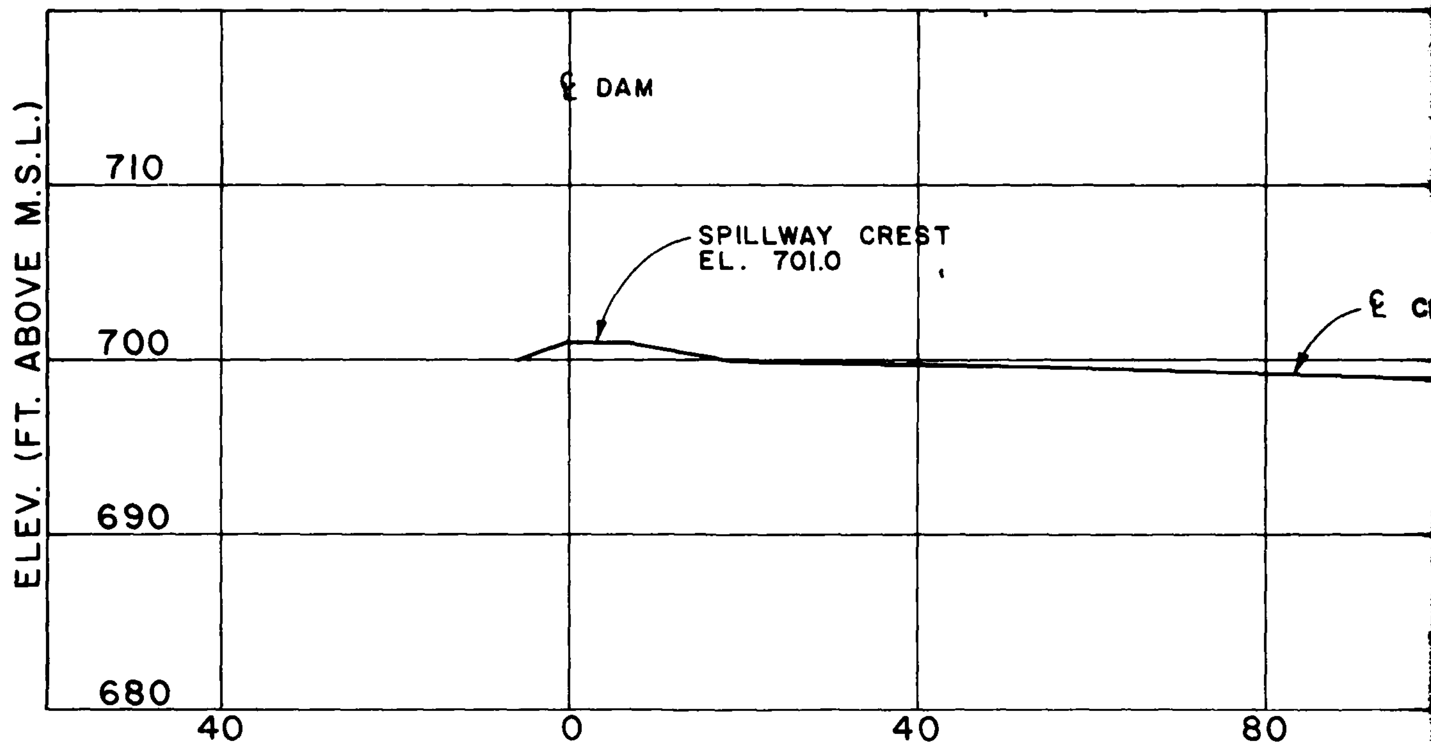


SECTION STA. 1+50
"=10'V.,1"=20' H.

LONGSTREET LAKE
DAM CROSS-SECTION

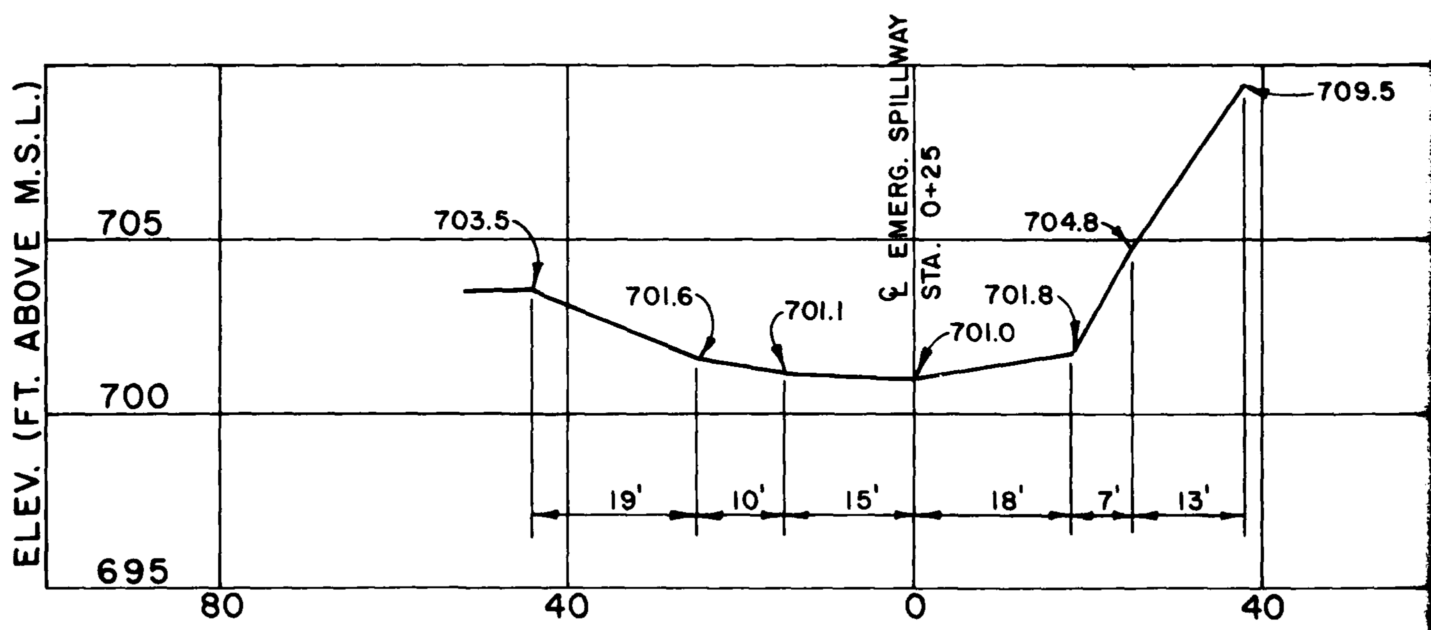
Horner & Shifrin, Inc. July 1980

PLATE 4



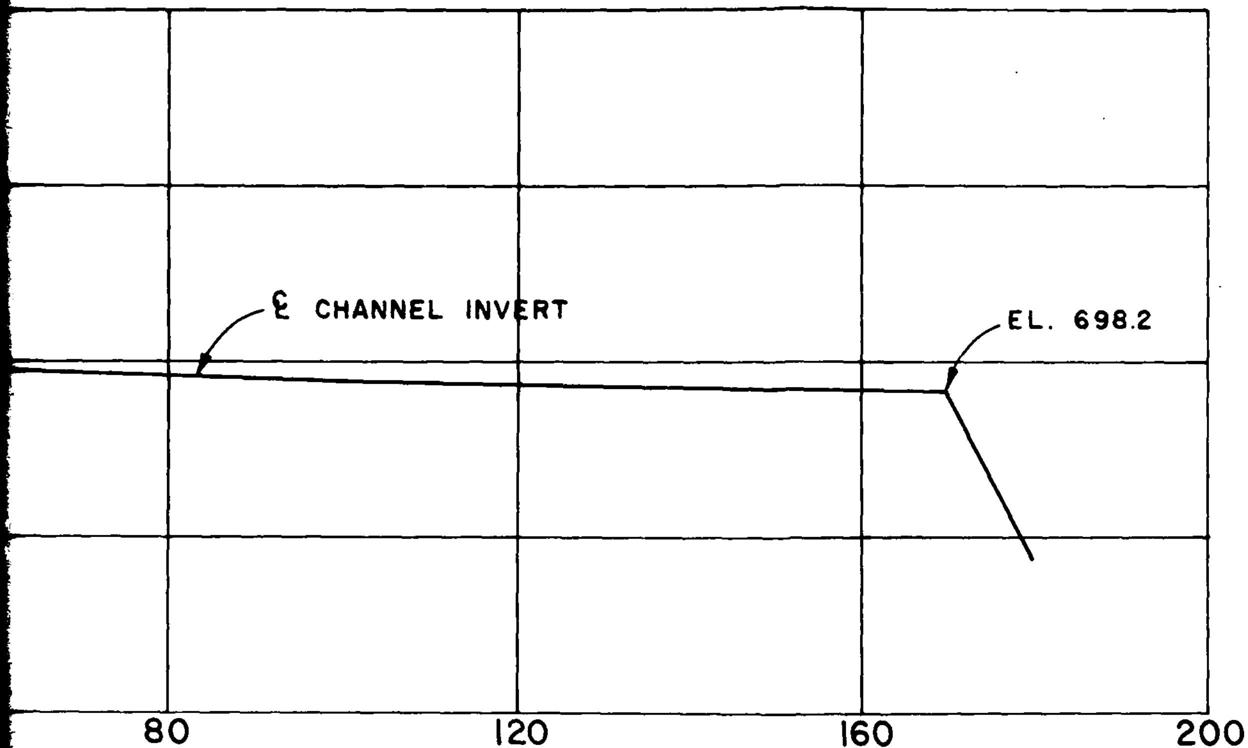
PROFILE EMERGENCY SPILLW

SCALES: 1"=10'V., 1"=20'H.

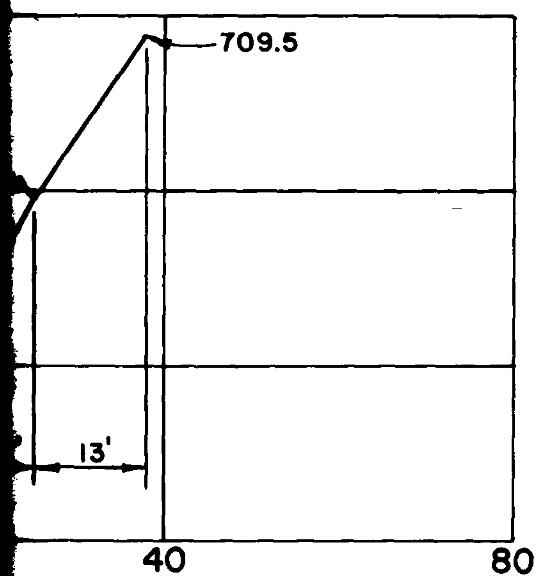


CROSS-SECTION EMERGENCY SPILLWAY-℄ DAM

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



ERGENCY SPILLWAY
: 1"=10'V., 1"=20'H.



Y-℄ DAM

LONGSTREET LAKE
PROFILE & CROSS-SECTION
EMERGENCY SPILLWAY
Horner & Shifrin, Inc. July 1980

APPENDIX A

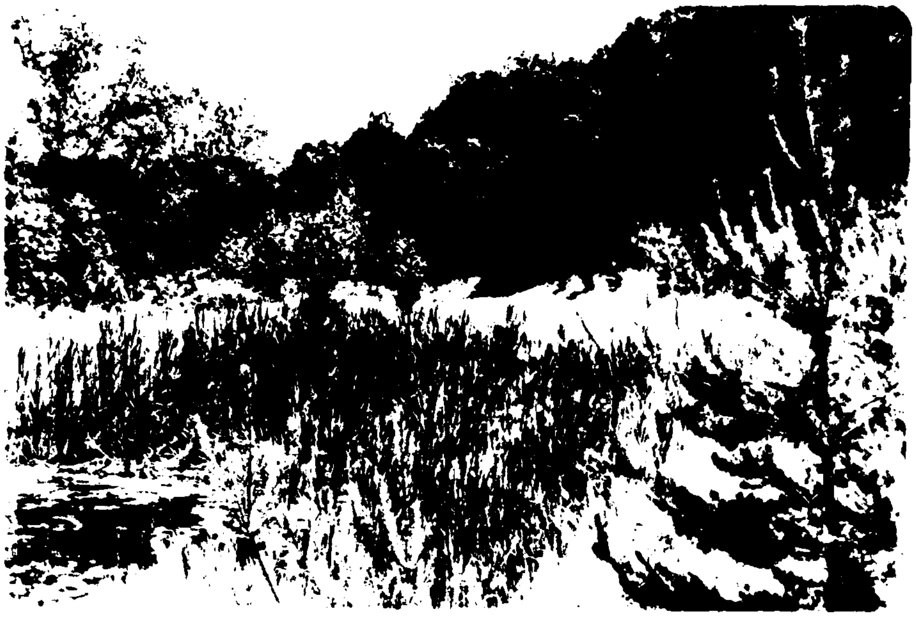
INSPECTION PHOTOGRAPHS

NO. 1: CREST AND UPSTREAM FACE OF DAM

NO. 2: CREST AND LEFT ABUTMENT OF DAM

NO. 3: DROP INLET SPILLWAY

NO. 4: PIPE OUTLET AND EROSION AT DOWNSTREAM TOE OF DAM



NO. 5: EMERGENCY SPILLWAY CREST AND OUTLET CHANNEL

NO. 6: ERODED AREA AT DOWNSTREAM END
OF EMERGENCY SPILLWAY CHANNEL

NO. 7: ANIMAL BURROW IN UPSTREAM FACE 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 25.0 inches) from Hydrometeorological Report No. 33. The precipitation data used in the analysis of the 1 percent (100-year flood) was provided by the St. Louis District, Corps of Engineers.

b. Drainage area = 0.106 square miles = 68 acres.

c. SCS parameters:

Time of Concentration (T_c) = $\left(\frac{11.9L^3}{H}\right)^{0.385}$ = 0.088 hours

Where: T_c = Travel time of water from hydraulically most distant point to point of interest, hours.
L = Length of longest watercourse = 0.265 miles.
H = Elevation difference = 121 feet.

The time of concentration (T_c) was obtained using Method C as described in Figure 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 = 0.053 hours (0.60 Tc)
Hydrologic soil group = 50% C (Lindley Series) and 50% D (Gasconade and Keswick Series) per SCS County Soil Report.
Soil type CN = 76 (AMC II, 100-yr flood condition)
= 89 (AMC III, PMF condition)

2. Spillway releases for the drop inlet spillway were computed utilizing equations and nomographs presented in "Design of Small Dams" by the U. S. Department of the Interior (USDI) for drop inlet type spillways. The rise of the nappe above the elevation of the crest lip was considered negligible. The following equation was used for crest control:

$$Q = C_o (2 \quad R_s) H_o^{3/2}$$

where "C_o" is a coefficient obtained from Figure 283 of the above reference, expressed in terms of H_o/R_s, "R_s" is the radius of the spillway crest, 1.0 feet, and "H_o" is the depth of flow over the crest.

When the ratio H_o/R_s reached a value of 1.00, inflow was determined by assuming flow was over a sharp edge submerged orifice. The following equation was used: $Q = Ca\ (2gh)^{0.5}$, where "C" is a coefficient assumed to be 0.6, "a" is the area of the orifice, 3.14 sf, "h" is the height of flow above the orifice, and "g" is acceleration due to gravity. Reference "Handbook of Hydraulics", Fifth Edition, by King and Brater, page 4-3.

Flow through the 10-inch diameter outlet pipe was determined using Bernoulli's equation for pressure flow in pipes. A pipe friction factor (n) of 0.013 was used. Losses, including entrance, turn, pipe and exit losses totaled 6.36 velocity heads. Reference "Handbook of Hydraulics", Fifth Edition, by King and Brater, pages 8-5 and 8-6.

Discharge quantities, determined by the methods described herein were plotted versus corresponding lake water surface elevations to determine the discharge rating curve for the drop inlet spillway.

3. The emergency spillway section consists of a broad-crested, trapezoidal section 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 for 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

$Qc = (\frac{a^3 g}{t})^{0.5}$ 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, King and Brater, page 8-7.

c. Static lake levels corresponding to the various 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.

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

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

```
A1       ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
A2       HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF LONGSTREET 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   0.28     0.29     0.50     1.00
K       0   INFLOW                                            1
K1       INFLOW HYDROGRAPH
M       1        2    0.106                       1.0                          1
P       0     25.0      102      120      130
T                                                             1       89
W2              0.053
X    -1.0     -.10      2.0
K       1      DAM                                            1
Y1       RESERVOIR ROUTING BY MODIFIED PULS
Y                                    1        1
Y1      1                                                112.00        1
Y4  700.0    700.7    701.0    701.1    701.8    702.1    702.6    703.2    703.7    704.4
Y4  705.1    705.7    706.3    707.0    707.7    708.4    709.1    709.9
Y5      0       10       10       11       62      170      290      400      590      800
Y5   1201     1641     2071     2527     3061     3641     4261     5071
$A      0      9.6     14.1     18.4     22.5
$E    665      700      710      720      730
$$  700.0
$D  702.3
$L      0      107      172      256      301      352      385      431
$V  702.3    702.4    702.7    703.0    703.1    703.2    703.5    710.1
K      99
```

```
A1       ANALYSIS OF DAM OVERTOPPING USING 100-YR FLOOD
A2       HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF LONGSTREET 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   0.106                       1.0                     1
O     288   7.074
01   .006    .006    .006    .006    .006    .006    .006    .006    .006    .006
01   .006    .006    .006    .006    .006    .006    .006    .006    .006    .006
01   .006    .006    .006    .006    .006    .006    .006    .006    .006    .006
01   .006    .006    .006    .006    .006    .006    .006    .006    .006    .006
01   .006    .006    .006    .006    .006    .006    .006    .006    .006    .006
01   .006    .006    .006    .006    .006    .006    .006    .006    .006    .006
01   .006    .006    .006    .006    .006    .006    .006    .006    .006    .006
01   .006    .006    .014    .014    .014    .014    .014    .014    .014    .014
01   .014    .014    .014    .014    .014    .014    .014    .014    .014    .014
01   .014    .014    .014    .014    .014    .014    .014    .014    .014    .014
01   .014    .014    .014    .014    .014    .014    .014    .014    .024    .024
01   .024    .024    .024    .024    .024    .024    .024    .024    .024    .024
01   .024    .024    .024    .024    .024    .024    .029    .029    .029    .029
01   .029    .029    .060    .060    .060    .060    .060    .060    .127    .129
01   .130    .247    .247    .546    .826    .380    .247    .130    .130    .129
01   .060    .060    .060    .060    .060    .060    .029    .029    .029    .029
01   .029    .029    .024    .024    .024    .024    .024    .024    .024    .024
01   .024    .024    .024    .024    .024    .024    .024    .024    .024    .024
01   .014    .014    .014    .014    .014    .014    .014    .014    .014    .014
01   .014    .014    .014    .014    .014    .014    .014    .014    .014    .014
```

100-YR. FLOOD (Cont'd)

01	.014	.014	.014	.014	.014	.014	.014	.014	.014	.014
01	.014	.014	.014	.014	.014	.014	.006	.006	.006	.006
01	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
01	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
01	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
01	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
01	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
01	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
01	.006	.006	.006	.006	.006	.006	.006	.006		
T							-1	-76		
W2		0.053								
X	-1.0	-.10	2.0							
K	1	DAM					1			
K1	RESERVOIR ROUTING BY MODIFIED PULS									
Y				1	1					
Y1	1						112.00	1		
Y4	700.0	700.7	701.0	701.1	701.8	702.1	702.4	703.2	703.7	704.4
Y4	705.1	705.7	706.3	707.0	707.7	708.4	709.1	709.8		
Y5	0	10	10	11	62	120	230	400	500	900
Y5	1281	1641	2021	2527	3061	3641	4261	5021		
$A	0	9.6	14.1	18.4	22.5					
$E	665	700	710	720	730					
$$	700.0									
$D	702.3									
$L	0	107	172	256	301	352	385	431		
$V	702.3	702.6	702.7	703.0	703.1	703.2	703.5	710.1		
K	99									

ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
HYDROLOGIC HYDRAULIC ANALYSIS OF SAFETY OF LONGSTREET 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= .23 .29 .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	.11	0.00	.11	1.00	0.000	0	1	0

PRECIP DATA

SPFE	PMS	R6	R12	R24	R48	R72	R96
0.00	25.00	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	-89.00	0.00	0.00

CURVE NO = -89.00 WETNESS = 1.00 EFFECT CN = 89.00

UNIT HYDROGRAPH DATA
TC= 0.00 LAG= .05

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

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

UNIT HYDROGRAPH 5 END OF PERIOD ORDINATES, TC= 0.00 HOURS, LAG= .05 VOL= 1.00
526. 224. 54. 13. 3.

END-OF PERIOD FLOW

0 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	.21	.21	.01	126.
1.01	.10	2	.01	0.00	.01	0.	1.01	12.10	146	.21	.21	.01	153.
1.01	.15	3	.01	0.00	.01	0.	1.01	12.15	147	.21	.21	.01	166.
1.01	.20	4	.01	0.00	.01	0.	1.01	12.20	148	.21	.21	.01	169.
1.01	.25	5	.01	0.00	.01	0.	1.01	12.25	149	.21	.21	.01	169.
1.01	.30	6	.01	0.00	.01	0.	1.01	12.30	150	.21	.21	.01	170.
1.01	.35	7	.01	0.00	.01	0.	1.01	12.35	151	.21	.21	.01	170.
1.01	.40	8	.01	0.00	.01	0.	1.01	12.40	152	.21	.21	.00	170.
1.01	.45	9	.01	0.00	.01	0.	1.01	12.45	153	.21	.21	.00	170.
1.01	.50	10	.01	0.00	.01	0.	1.01	12.50	154	.21	.21	.00	171.
1.01	.55	11	.01	0.00	.01	0.	1.01	12.55	155	.21	.21	.00	171.
1.01	1.00	12	.01	0.00	.01	0.	1.01	13.00	156	.21	.21	.00	171.
1.01	1.05	13	.01	0.00	.01	0.	1.01	13.05	157	.26	.25	.00	193.
1.01	1.10	14	.01	0.00	.01	0.	1.01	13.10	158	.26	.25	.00	203.
1.01	1.15	15	.01	0.00	.01	0.	1.01	13.15	159	.26	.25	.00	205.
1.01	1.20	16	.01	0.00	.01	0.	1.01	13.20	160	.26	.25	.00	206.
1.01	1.25	17	.01	0.00	.01	0.	1.01	13.25	161	.26	.25	.00	206.
1.01	1.30	18	.01	.00	.01	0.	1.01	13.30	162	.26	.25	.00	206.
1.01	1.35	19	.01	.00	.01	0.	1.01	13.35	163	.26	.25	.00	206.
1.01	1.40	20	.01	.00	.01	0.	1.01	13.40	164	.26	.25	.00	206.
1.01	1.45	21	.01	.00	.01	1.	1.01	13.45	165	.26	.25	.00	207.
1.01	1.50	22	.01	.00	.01	1.	1.01	13.50	166	.26	.25	.00	207.
1.01	1.55	23	.01	.00	.01	1.	1.01	13.55	167	.26	.25	.00	207.
1.01	2.00	24	.01	.00	.01	1.	1.01	14.00	168	.26	.25	.00	207.
1.01	2.05	25	.01	.00	.01	1.	1.01	14.05	169	.32	.32	.00	240.
1.01	2.10	26	.01	.00	.01	2.	1.01	14.10	170	.32	.32	.00	254.
1.01	2.15	27	.01	.00	.01	2.	1.01	14.15	171	.32	.32	.00	258.
1.01	2.20	28	.01	.00	.01	2.	1.01	14.20	172	.32	.32	.00	259.
1.01	2.25	29	.01	.00	.01	2.	1.01	14.25	173	.32	.32	.00	259.
1.01	2.30	30	.01	.00	.01	2.	1.01	14.30	174	.32	.32	.00	259.
1.01	2.35	31	.01	.00	.01	3.	1.01	14.35	175	.32	.32	.00	259.
1.01	2.40	32	.01	.00	.01	3.	1.01	14.40	176	.32	.32	.00	260.
1.01	2.45	33	.01	.00	.01	3.	1.01	14.45	177	.32	.32	.00	260.
1.01	2.50	34	.01	.00	.01	3.	1.01	14.50	178	.32	.32	.00	260.
1.01	2.55	35	.01	.00	.01	3.	1.01	14.55	179	.32	.32	.00	260.
1.01	3.00	36	.01	.00	.01	3.	1.01	15.00	180	.32	.32	.00	260.
1.01	3.05	37	.01	.00	.01	4.	1.01	15.05	181	.19	.19	.00	195.
1.01	3.10	38	.01	.00	.01	4.	1.01	15.10	182	.39	.39	.00	268.
1.01	3.15	39	.01	.00	.01	4.	1.01	15.15	183	.39	.39	.00	305.
1.01	3.20	40	.01	.00	.01	4.	1.01	15.20	184	.58	.58	.00	415.
1.01	3.25	41	.01	.01	.01	4.	1.01	15.25	185	.68	.68	.00	511.
1.01	3.30	42	.01	.01	.01	4.	1.01	15.30	186	1.65	1.64	.01	1051.
1.01	3.35	43	.01	.01	.01	4.	1.01	15.35	187	2.71	2.70	.01	1834.
1.01	3.40	44	.01	.01	.01	4.	1.01	15.40	188	1.07	1.06	.00	1265.
1.01	3.45	45	.01	.01	.01	5.	1.01	15.45	189	.68	.68	.00	764.
1.01	3.50	46	.01	.01	.01	5.	1.01	15.50	190	.58	.58	.00	555.
1.01	3.55	47	.01	.01	.01	5.	1.01	15.55	191	.39	.39	.00	393.
1.01	4.00	48	.01	.01	.01	5.	1.01	16.00	192	.39	.39	.00	334.
1.01	4.05	49	.01	.01	.01	5.	1.01	16.05	193	.30	.30	.00	273.

END-OF-PERIOD FLOW (Cont'd)

1.01	4.10	50	.01	.01	.01	5.	1.01	16.10	194	.30	.30	.00	251.
1.01	4.15	51	.01	.01	.01	5.	1.01	16.15	195	.30	.30	.00	245.
1.01	4.20	52	.01	.01	.01	5.	1.01	16.20	196	.30	.30	.00	244.
1.01	4.25	53	.01	.01	.01	5.	1.01	16.25	197	.30	.30	.00	244.
1.01	4.30	54	.01	.01	.01	6.	1.01	16.30	198	.30	.30	.00	244.
1.01	4.35	55	.01	.01	.01	6.	1.01	16.35	199	.30	.30	.00	244.
1.01	4.40	56	.01	.01	.01	6.	1.01	16.40	200	.30	.30	.00	244.
1.01	4.45	57	.01	.01	.01	6.	1.01	16.45	201	.30	.30	.00	244.
1.01	4.50	58	.01	.01	.01	6.	1.01	16.50	202	.30	.30	.00	244.
1.01	4.55	59	.01	.01	.01	6.	1.01	16.55	203	.30	.30	.00	244.
1.01	5.00	60	.01	.01	.01	6.	1.01	17.00	204	.30	.30	.00	244.
1.01	5.05	61	.01	.01	.01	6.	1.01	17.05	205	.23	.23	.00	210.
1.01	5.10	62	.01	.01	.01	6.	1.01	17.10	206	.23	.23	.00	196.
1.01	5.15	63	.01	.01	.01	6.	1.01	17.15	207	.23	.23	.00	192.
1.01	5.20	64	.01	.01	.01	6.	1.01	17.20	208	.23	.23	.00	192.
1.01	5.25	65	.01	.01	.01	6.	1.01	17.25	209	.23	.23	.00	191.
1.01	5.30	66	.01	.01	.01	7.	1.01	17.30	210	.23	.23	.00	191.
1.01	5.35	67	.01	.01	.01	7.	1.01	17.35	211	.23	.23	.00	191.
1.01	5.40	68	.01	.01	.01	7.	1.01	17.40	212	.23	.23	.00	191.
1.01	5.45	69	.01	.01	.01	7.	1.01	17.45	213	.23	.23	.00	191.
1.01	5.50	70	.01	.01	.01	7.	1.01	17.50	214	.23	.23	.00	191.
1.01	5.55	71	.01	.01	.01	7.	1.01	17.55	215	.23	.23	.00	191.
1.01	6.00	72	.01	.01	.01	7.	1.01	18.00	216	.23	.23	.00	191.
1.01	6.05	73	.06	.04	.02	23.	1.01	18.05	217	.02	.02	.00	172.
1.01	6.10	74	.06	.04	.02	31.	1.01	18.10	218	.02	.02	.00	161.
1.01	6.15	75	.06	.04	.02	33.	1.01	18.15	219	.02	.02	.00	150.
1.01	6.20	76	.06	.04	.02	35.	1.01	18.20	220	.02	.02	.00	140.
1.01	6.25	77	.06	.04	.02	36.	1.01	18.25	221	.02	.02	.00	130.
1.01	6.30	78	.06	.04	.02	36.	1.01	18.30	222	.02	.02	.00	122.
1.01	6.35	79	.06	.05	.02	37.	1.01	18.35	223	.02	.02	.00	114.
1.01	6.40	80	.06	.05	.02	38.	1.01	18.40	224	.02	.02	.00	106.
1.01	6.45	81	.06	.05	.02	39.	1.01	18.45	225	.02	.02	.00	99.
1.01	6.50	82	.06	.05	.01	39.	1.01	18.50	226	.02	.02	.00	92.
1.01	6.55	83	.06	.05	.01	40.	1.01	18.55	227	.02	.02	.00	86.
1.01	7.00	84	.06	.05	.01	40.	1.01	19.00	228	.02	.02	.00	80.
1.01	7.05	85	.06	.05	.01	41.	1.01	19.05	229	.02	.02	.00	75.
1.01	7.10	86	.06	.05	.01	41.	1.01	19.10	230	.02	.02	.00	70.
1.01	7.15	87	.06	.05	.01	42.	1.01	19.15	231	.02	.02	.00	65.
1.01	7.20	88	.06	.05	.01	42.	1.01	19.20	232	.02	.02	.00	61.
1.01	7.25	89	.06	.05	.01	43.	1.01	19.25	233	.02	.02	.00	57.
1.01	7.30	90	.06	.05	.01	43.	1.01	19.30	234	.02	.02	.00	53.
1.01	7.35	91	.06	.05	.01	43.	1.01	19.35	235	.02	.02	.00	49.
1.01	7.40	92	.06	.05	.01	44.	1.01	19.40	236	.02	.02	.00	46.
1.01	7.45	93	.06	.05	.01	44.	1.01	19.45	237	.02	.02	.00	43.
1.01	7.50	94	.06	.05	.01	44.	1.01	19.50	238	.02	.02	.00	40.
1.01	7.55	95	.06	.05	.01	44.	1.01	19.55	239	.02	.02	.00	37.
1.01	8.00	96	.06	.05	.01	45.	1.01	20.00	240	.02	.02	.00	35.
1.01	8.05	97	.06	.05	.01	45.	1.01	20.05	241	.02	.02	.00	33.
1.01	8.10	98	.06	.06	.01	45.	1.01	20.10	242	.02	.02	.00	30.
1.01	8.15	99	.06	.06	.01	45.	1.01	20.15	243	.02	.02	.00	28.
1.01	8.20	100	.06	.06	.01	45.	1.01	20.20	244	.02	.02	.00	26.
1.01	8.25	101	.06	.06	.01	46.	1.01	20.25	245	.02	.02	.00	25.
1.01	8.30	102	.06	.06	.01	46.	1.01	20.30	246	.02	.02	.00	23.

END-OF-PERIOD FLOW (Cont'd)

1.01	8.35	103	.06	.06	.01	46.	1.01	20.35	247	.02	.02	.00	22.
1.01	8.40	104	.06	.06	.01	46.	1.01	20.40	248	.02	.02	.00	20.
1.01	8.45	105	.06	.06	.01	46.	1.01	20.45	249	.02	.02	.00	19.
1.01	8.50	106	.06	.06	.01	47.	1.01	20.50	250	.02	.02	.00	17.
1.01	8.55	107	.06	.06	.01	47.	1.01	20.55	251	.02	.02	.00	17.
1.01	9.00	108	.06	.06	.01	47.	1.01	21.00	252	.02	.02	.00	17.
1.01	9.05	109	.06	.06	.01	47.	1.01	21.05	253	.02	.02	.00	17.
1.01	9.10	110	.06	.06	.01	47.	1.01	21.10	254	.02	.02	.00	17.
1.01	9.15	111	.06	.06	.00	47.	1.01	21.15	255	.02	.02	.00	17.
1.01	9.20	112	.06	.06	.00	47.	1.01	21.20	256	.02	.02	.00	17.
1.01	9.25	113	.06	.06	.00	47.	1.01	21.25	257	.02	.02	.00	17.
1.01	9.30	114	.06	.06	.00	47.	1.01	21.30	258	.02	.02	.00	17.
1.01	9.35	115	.06	.06	.00	48.	1.01	21.35	259	.02	.02	.00	17.
1.01	9.40	116	.06	.06	.00	48.	1.01	21.40	260	.02	.02	.00	17.
1.01	9.45	117	.06	.06	.00	48.	1.01	21.45	261	.02	.02	.00	17.
1.01	9.50	118	.06	.06	.00	48.	1.01	21.50	262	.02	.02	.00	17.
1.01	9.55	119	.06	.06	.00	48.	1.01	21.55	263	.02	.02	.00	17.
1.01	10.00	120	.06	.06	.00	48.	1.01	22.00	264	.02	.02	.00	17.
1.01	10.05	121	.06	.06	.00	48.	1.01	22.05	265	.02	.02	.00	17.
1.01	10.10	122	.06	.06	.00	48.	1.01	22.10	266	.02	.02	.00	17.
1.01	10.15	123	.06	.06	.00	48.	1.01	22.15	267	.02	.02	.00	17.
1.01	10.20	124	.06	.06	.00	48.	1.01	22.20	268	.02	.02	.00	17.
1.01	10.25	125	.06	.06	.00	48.	1.01	22.25	269	.02	.02	.00	17.
1.01	10.30	126	.06	.06	.00	48.	1.01	22.30	270	.02	.02	.00	17.
1.01	10.35	127	.06	.06	.00	49.	1.01	22.35	271	.02	.02	.00	17.
1.01	10.40	128	.06	.06	.00	49.	1.01	22.40	272	.02	.02	.00	17.
1.01	10.45	129	.06	.06	.00	49.	1.01	22.45	273	.02	.02	.00	17.
1.01	10.50	130	.06	.06	.00	49.	1.01	22.50	274	.02	.02	.00	17.
1.01	10.55	131	.06	.06	.00	49.	1.01	22.55	275	.02	.02	.00	17.
1.01	11.00	132	.06	.06	.00	49.	1.01	23.00	276	.02	.02	.00	17.
1.01	11.05	133	.06	.06	.00	49.	1.01	23.05	277	.02	.02	.00	17.
1.01	11.10	134	.06	.06	.00	49.	1.01	23.10	278	.02	.02	.00	17.
1.01	11.15	135	.06	.06	.00	49.	1.01	23.15	279	.02	.02	.00	17.
1.01	11.20	136	.06	.06	.00	49.	1.01	23.20	280	.02	.02	.00	17.
1.01	11.25	137	.06	.06	.00	49.	1.01	23.25	281	.02	.02	.00	17.
1.01	11.30	138	.06	.06	.00	49.	1.01	23.30	282	.02	.02	.00	17.
1.01	11.35	139	.06	.06	.00	49.	1.01	23.35	283	.02	.02	.00	17.
1.01	11.40	140	.06	.06	.00	49.	1.01	23.40	284	.02	.02	.00	17.
1.01	11.45	141	.06	.06	.00	49.	1.01	23.45	285	.02	.02	.00	17.
1.01	11.50	142	.06	.06	.00	49.	1.01	23.50	286	.02	.02	.00	17.
1.01	11.55	143	.06	.06	.00	49.	1.01	23.55	287	.02	.02	.00	17.
1.01	12.00	144	.06	.06	.00	49.	1.02	0.00	288	.02	.02	.00	17.

SUM	32.50	31.06	1.44	27138.
	(825.)(	789.)(	37.)(	768.46)

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	1834.	298.	94.	94.	27133.
CMS	52.	8.	3.	3.	768.
INCHES		25.29	33.07	33.07	33.07
MM		642.34	840.02	840.02	840.02
AC-FT		143.	187.	187.	187.
THOUS CU M		176.	230.	230.	230.

SURFACE AREA=	0.	10.	14.	18.	23.
CAPACITY=	0.	117.	230.	397.	594.
ELEVATION=	665.	700.	710.	720.	730.

SUMMARY OF DAM SAFETY ANALYSIS

PMF

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	700.00	700.00	702.30
STORAGE	112.	112.	135.
OUTFLOW	0.	0.	144.

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
.20	702.29	0.00	135.	147.	0.00	15.83	0.00
.29	702.34	.04	136.	172.	.25	15.80	0.00
.50	702.94	.64	142.	402.	1.17	15.75	0.00
1.00	703.59	1.29	149.	1412.	5.17	15.67	0.00

SUMMARY OF DAM SAFETY ANALYSIS

100-YR. FLOOD

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	700.00	700.00	702.30
STORAGE	112.	112.	135.
OUTFLOW	0.	0.	164.

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	701.43	0.00	126.	35.	0.00	13.17	0.00