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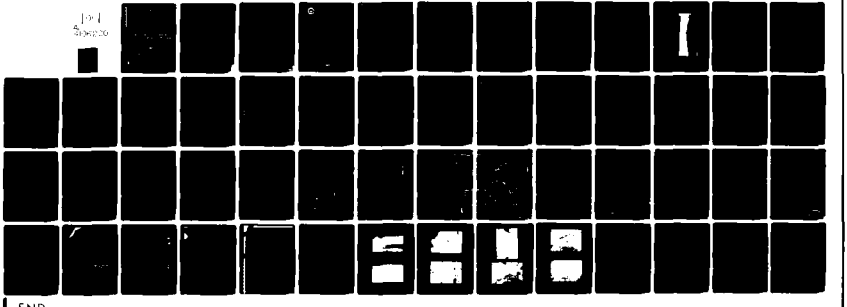

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MISSISSIPPI - KASKASKIA - ST. LOUIS BASIN

LAKE ARROWHEAD DAM
FRANKLIN COUNTY, MISSOURI
MO 30572

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

DACW 43-78-C-0143

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

FOR: STATE OF MISSOURI

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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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DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 NORTH 12TH STREET
ST. LOUIS, MISSOURI 63101

IN REPLY REFER TO

SUBJECT: Lake Arrowhead Dam

This report presents the results of a field inspection and an evaluation of the Lake Arrowhead Dam.

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

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

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

SUBMITTED BY: SIGNED
Chief, Engineering Division

8 MAR 1979
Date

APPROVED BY: SIGNED
Colonel, CE, District Engineer

8 MAR 1979
Date

LAKE ARROWHEAD DAM
FRANKLIN COUNTY, MISSOURI

MISSOURI INVENTORY NO. 30572

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

DECEMBER 1978

HS-7848-10

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam:	Lake Arrowhead Dam
State Located:	Missouri
County Located:	Franklin
Stream:	Johnson Branch Meramec River
Date of Inspection:	24 August 1978

The Lake Arrowhead Dam was visually inspected by engineering personnel of the office of Horner & Shifrin, Inc., Consulting Engineers, St. Louis, Missouri. The purpose of the 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 inspection and the results of certain hydrologic/hydraulic investigations performed under the direction of the inspection team.

Based on a visual inspection, the following deficiencies were noted during the inspection and are considered to have an adverse effect on the overall safety and future operation of the dam and spillway:

1. At the time of the inspection, the grass growing on the crest, and the upstream and downstream faces of the dam was on the order of 24 inches high. The grass should not be allowed to grow to a height that provides cover for burrowing animals or hinders inspection of the dam.

2. Several areas of dense brush that may conceal animal burrows and trees exist on the crest and upstream and downstream faces of the dam. Tree roots may, in time, provide pathways for lake seepage which could develop into a piping condition and subsequent failure of the dam.

3. Several holes that appear to be animal burrows were observed in the upstream face, downstream face, and crest of the dam. These holes provide voids through which seepage of water through the dam may occur and if left unattended can develop into a piping condition.

4. The upstream face of the dam is grass covered throughout. A considerable amount of erosion of the upstream slope of the dam at the waterline has occurred. A grass covered slope is not considered adequate to protect the slope against erosion by wave action. Erosion of the slope will reduce the cross section of the dam which may result in instability and/or overtopping of the dam.

5. The concrete retaining wall located on the downstream side of the dam near the left abutment that serves to support the embankment at this location is cracked in several locations. In addition, a section of the wall is leaning in an outward direction and appears unstable. Loss of the wall could result in failure of the embankment and overtopping of the dam. (The reason for the construction of the wall to support the embankment is unclear.)

6. The concrete slope paving located on the right bank of the principal spillway outlet channel at a point approximately 100 feet downstream of the spillway crest is undercut and the pavement subgrade and embankment extensively eroded. Erosion of the subgrade will reduce the embankment and may result in instability of the section.

7. Seepage, as evidenced by a small stream, was observed originating from the downstream toe of slope at a point about midway between the retaining wall and the right (looking downstream) side of the principal spillway. Seepage can develop into a piping condition that may result in failure of the dam.

8. The crest of the emergency spillway is located within an embankment section and is protected from erosion by grass. Erosion was observed in the area immediately downstream of the crest. A grass covered

surface is not considered adequate protection to prevent erosion of a fill section subjected to spillway flow. Erosion of the earth fill at this location could result in loss of the embankment and indiscriminate flooding of the area below the dam.

The conditions described above are not considered to be serious at this time to warrant immediate remedial action.

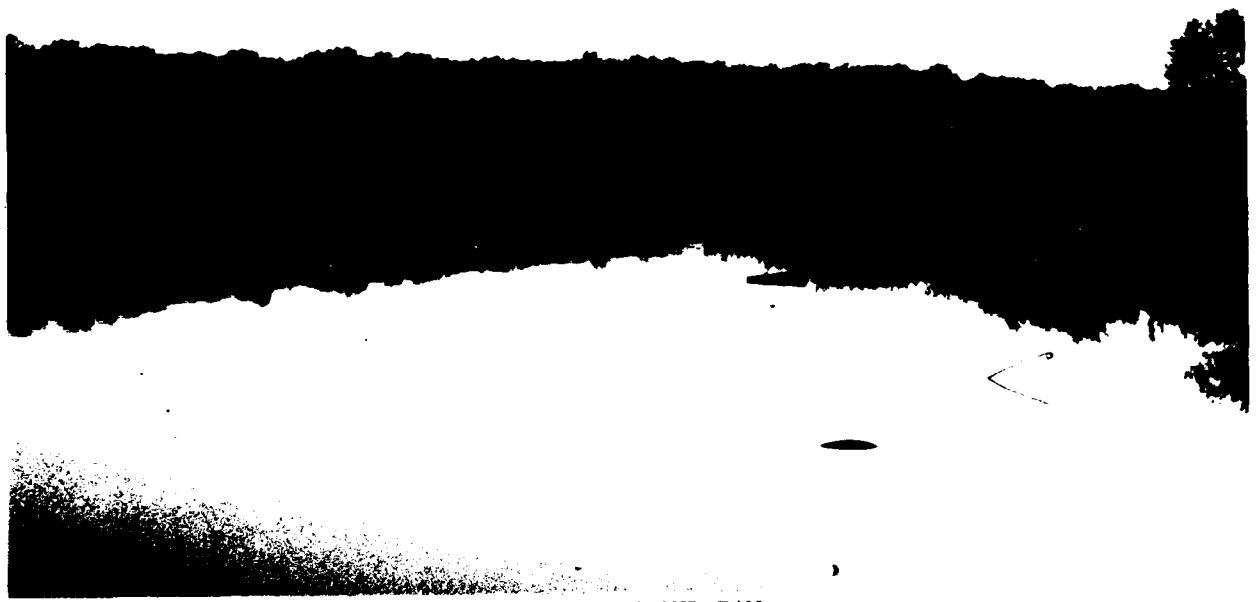
The crest of the dam was found to be approximately 2 feet lower at a point near the center of the dam than in the area adjacent to the principal spillway. (The low point of the dam is approximately 5 feet higher than the spillway crest.) As a result, the capacity of the spillway to discharge lake outflow without overtopping the dam is reduced. Based on the criteria set forth in the recommended guidelines (see text) and since there are eight homes within the estimated flood zone, the spillway design flood for this dam, which is classified as small in size and of high hazard potential, is considered to be Probable Maximum Flood (PMF). 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 existing spillways (principal plus emergency) are inadequate to pass lake outflow resulting from a storm of PMF magnitude without overtopping the dam. They are also inadequate to pass the lake outflow resulting from the 1 percent chance (100-year frequency) flood without overtopping the dam. The spillways are capable of passing lake outflow corresponding to approximately 11 percent of the PMF without overtopping the dam. The length of the downstream damage zone, should failure of the dam occur, is estimated to be one-half mile. There are eight homes and one subdivision street within the possible flood damage zone.

A review of available data did not disclose that seepage and 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 in the near future to correct or control the deficiencies and safety defects reported herein.

Albert B. Becker, Jr.

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



OVERVIEW OF LAKE AND DAM

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
LAKE ARROWHEAD DAM - ID NO. 30572

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

LAKE ARROWHEAD DAM - ID NO. 30572

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. National Dam Inspection Act, Public Law 92-367, dated 8 August 1972.

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 of the Chief of Engineers on the National Program of Dams," dated May 1975.

1.2. DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances. The Lake Arrowhead Dam is a earthfill embankment rising approximately 24 feet above the original stream bed. The dam has a length of 800 feet, a crest width of 20 feet, and in general embankment slopes of 1v on 1.3h upstream above the waterline and about 1v on 2.5h downstream. The dam has both a principal and an emergency spillway. Both spillways are overflow type sections with the principal spillway cut into rock at the left abutment and the emergency spillway in an embankment near the right abutment. A concrete retaining wall approximately 15 feet high provides support for the embankment on the downstream side of the dam near the principal spillway. (The reason for retaining the embankment with a wall in lieu of allowing the fill to be self supporting similar to rest of the dam is unclear.)

The downstream slope between the retaining wall and the embankment that forms the right (looking downstream) side of the principal spillway is about 1v on 1.7h and is covered with stone riprap.

The main section of the dam crosses the valley in a north-south direction. The dam alignment follows an "S" configuration at the north end of the structure. Beginning at a point approximately 125 feet south of the hillside that becomes the north abutment, the dam curves sharply (deflection angle about 90 degrees) forming the left (looking downstream) side of the approach channel for the emergency spillway. At a point approximately 350 feet west of the main section of the dam, the dam alignment again curves, this time to the north and joins the hillside that forms the north (right) abutment. A 20-foot wide depression in the top of the east-west section of the dam forms the emergency spillway crest. The crest of the emergency spillway is located in the embankment about 300 feet west of the main section of the dam. A general plan of the dam is shown on Plate 3.

The principal spillway is cut into rock at the left abutment. The spillway channel is U-shaped with a bottom approximately 30 feet wide. A series of rock waterfalls approximately 70 feet in length exist in the spillway outlet channel beginning at a point about 100 feet downstream of the spillway crest. The spillway outlet channel joins the downstream channel, Johnson Branch, immediately below the falls.

The emergency spillway as indicated above is located in an embankment near the right abutment. The crest elevation of the emergency spillway is approximately 1 foot higher than the crest elevation of the principal spillway. The approach channel to the emergency spillway is a U-shaped section cut in the right abutment. The approach channel has a bottom width of about 70 feet. The spillway crest is a V-shaped depression in the embankment at the left side of the approach channel. The emergency spillway outlet channel and the point where the outlet joins the downstream channel are not readily discernible. The spillway outlet appears to, in general, follow a southernly course until it reaches the downstream channel, Johnson Branch.

At normal pool elevation, the lake occupies approximately 23 acres. There are no drawdown facilities for dewatering the lake. A plan of the Lake Arrowhead Subdivision showing the lake, dam, roads and other improvements is shown on Plate 2.

b. Location. The dam and lake are located on Johnson Branch, a tributary of the Meramec River, and within the Lake Arrowhead Subdivision. The entrance to the subdivision is located on the west side of State Route N about 2 miles north of Lonedell, Missouri, in Franklin County, as shown on the Regional Vicinity Map, Plate 1. The dam is located in the northeast quarter of Section 31, Township 42 North, Range 2 East.

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 Lake Arrowhead Dam, according to the St. Louis District, Corps of Engineers, has a high hazard potential, meaning that the dam is located such that failure may cause loss of life, serious damage to homes, extensive agricultrual, industrial and commercial facilities, important public utilities, main highways, or railroads. The estimated flood damage zone, should failure of the dam occur, has been determined by the St. Louis District to extend one-half mile downstream of the dam. There are eight homes and one subdivision street within the possible flood damage zone.

e. Ownership. The lake and dam are owned by Lake Arrowhead Inc., a subdivision association. The address of the corporation is Post Office Box 7070, Lonedell, Missouri 63060. Mr. Neal Manicmann is the current president of the corporation.

f. Purpose of the Dam. The dam impounds water for recreational use by the property owners of Lake Arrowhead Subdivision and their guests.

g. Design and Construction History. According to a representative of the Owner, the dam was constructed at least 40 years ago by the original property owner using a horse-drawn scraper. The original owner of the property was reported to be an individual by the name of Shuster. Reportedly, Mr. Shuster is deceased. The manner by which Lake Arrowhead Inc. obtained ownership of the property is unknown.

According to a representative of the Owner, no data relating to the design or construction of the dam are available.

h. Normal Operational Procedure. The lake level is unregulated.

1.3 PERTINENT DATA

a. Drainage Area. The area tributary to the lake, with the exception of the immediate area surrounding the lake which is in various stages of residential development, is for the most part undeveloped and in a natural state covered with timber. The watershed above the dam amounts to approximately 2,100 acres. The watershed area is outlined on Plate 1.

b. Discharge at Damsite.

(1) Estimated maximum known flood at damsite ... 260 cfs[1]

(2) Spillway capacity (principal plus emergency) ... 2,280 cfs

c. Elevation. The crest of the principal spillway was assumed to be elevation 529 (feet above MSL); the basis for this assumption being the contours shown on the 1969 Lonedell, Missouri, Quadrangle Map, 7.5 minute series. The following elevations were determined using this elevation (529.0) as a benchmark.

(1) Top of dam ... 533.9 (min.)

(2) Normal pool (principal spillway crest) ... 529.0

(3) Emergency spillway crest ... 530.0

[1] Based on a high water mark elevation as indicated by a representative of the Owner.

(4) Streambed at centerline of dam ... 510+

(5) Maximum tailwater (Johnson Branch) ... Unknown

(6) Pool at date of inspection ... 529.0

d. Reservoir.

(1) Length of normal pool (elevation 529.0) ... 2,000 ft.

(2) Length of maximum pool (elevation 533.9) ... 2,600 ft.

e. Storage.

(1) Normal pool ... 140 ac.ft.

(2) Top of dam (incremental) ... 130 ac.ft.

f. Reservoir Surface.

(1) Top of dam ... 27 acres

(2) Normal pool ... 23 acres

g. Dam.

(1) Type ... Earthfill

(2) Length ... 800 ft.

(3) Height ... 24 ft.

(4) Top width ... 20 ft.

(5) Side slopes

a. Upstream ... 1v on 1.3h above waterline

b. Downstream ... 1v on 2.5h (est.), 1v on 1.7h[1]

(6) Cutoff ... Unknown

(7) Slope protection

a. Upstream ... Grass

b. Downstream ... Grass

h. Principal Spillway ... Rock cut, broad-crested U-section, 30 foot bottom width.

(1) Crest ... Elevation 529.0

(2) Approach ... Lake

[1] Slope of 1v on 1.7h occurs between retaining wall and principal spillway.

i. Emergency Spillway ... Excavated earth, broad-crested V-section.

(1) Crest ... Elevation 530.0

(2) Approach Channel

(a) Width ... 70 ft.

(b) Length ... 300 ft.

(c) Slope ... 0.0033 ft. per ft.

j. Outlet for Lake Drawdown ... No drawdown facilities exist.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

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

2.2 CONSTRUCTION

To our knowledge no formal records were kept during the construction of the dam. A representative of the Owner reported that the dam was supposedly constructed using a horse-drawn scraper.

2.3 OPERATION

The lake level is normally governed by the principal spillway, consisting of an uncontrolled, excavated rock section.

A letter dated 8 April 1978 to a property owner at Lake Arrowhead Subdivision from Mr. James H. Williams, Chief Engineering Geologist with the Missouri Geological Survey (MGS), reference Charts 2-1 and 2-2, regarding the general condition of the dam and the adequacy of the spillways is presented herein. Mr. Williams stated in his letter some of the problems that existed at this dam at the time of his inspection along with recommendations for remedial measures.

A letter dated 16 May 1975, from Mr. Thomas J. Dean, Geologist, also with the MGS, to a property owner at Lake Arrowhead Subdivision, reference Charts 2-3 and 2-4, indicated that the dam may be overtopped before lake outflow passes the emergency spillway. Mr. Dean, when contacted by Horner & Shifrin personnel, stated that his conclusion concerning the overtopping of the dam prior to operation of the emergency spillway was based upon a rough hand level survey made at the time of his visit to Lake Arrowhead. Results of the dam inspection by Horner and Shifrin, indicated that the emergency spillway crest elevation is approximately 4 feet lower than the low point of the dam. Mr. Dean

also stated in his letter that it was obvious the emergency spillway had not been completed at the time of his inspection.

2.4. EVALUATION

a. Availability. Engineering data for assessing the design of the earthfill 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 dam and spillway was made by Horner & Shifrin engineering personnel (R.E. Sauthoff, Civil Engineer and Hydrologist; D.L. Heideman, Civil and Soils Engineer) on 24 August 1978. Also inspected at this time were the area downstream from the dam and the homes between the dam and a point about one-half mile downstream of the dam. Photographs of the dam and spillways taken at the time of the inspection are included on Page A-1 through A-4 of the Appendix.

b. Dam. The visible portions of the upstream and downstream faces of the dam (see Photos 1 and 2) appeared to be in sound condition. The entire embankment, including the top of the dam, was covered with brush and grass that was approximately 24 inches high at the time of the inspection. Two bike paths, one near the left and one near the right abutment, exist on the downstream slope. Small-to-large trees are present on the downstream slope of the dam. The trees are primarily located near the center of the dam and at the left abutment. Several large tree trunks (see Photo 3) and a few holes, assumed to be animal burrows (see Photo 4), were noticed in the upstream slope of the dam near the waterline. Dense brush and small trees cover the crest and slopes of the embankment that defines the left side of the emergency spillway approach channel. A considerable amount of erosion of the upstream face of the dam that appeared to be due to wave action exists at the waterline. In eroded areas, the exposed soil appeared to be a redish-brown clay containing gravel and small stones.

The top of the dam was found to be about 2 feet lower at a point near the center of the dam than in the area adjacent to the principal spillway. The low point of the dam is approximately 5 feet higher than the principal spillway crest and 4 feet higher than the emergency spillway crest. A profile of the top of the dam extending through the crests of the principal and emergency spillways and based on survey data obtained during the inspection is shown on Plate 3.

An L-shaped concrete retaining wall, approximately 15 feet high (see Photo 5), which supports the embankment, is located on the downstream side of the dam approximately 120 feet from the left abutment. Large trees are growing in the embankment in back of the wall and in the foundation material in front of the wall. Several cracks, that approach 1/4-inch in width, were noticed in the visible portions of the wall. A section of the wall that parallels the dam was leaning in an outward (away from the dam) direction by about 2 inches at the top of the wall. A dense cover of brush and trees prevented a detailed examination of the entire wall.

Seepage, as evidenced by a small stream estimated to be flowing at about 5 gpm, was observed originating from the downstream toe of slope at a point about midway between the retaining wall and the embankment that forms the right side of the principal spillway. The stream, with pools about 6 inches deep and 2 feet wide, joins the downstream channel about 100 feet below the dam. Seepage was not noticed elsewhere at the time of the inspection.

c. Spillways. The principal spillway, a U-shaped broad-crested section having a 30-foot bottom width, is cut into rock at the left abutment. A series of rock waterfalls approximately 70 feet in length exist in the spillway outlet channel beginning approximately 100 feet downstream of the spillway crest. A profile of the principal spillway channel is shown on Plate 3. A section of concrete slope paving, placed to protect the right bank of the spillway outlet channel, has been undercut (see Photo 7) beginning at a point immediately adjacent to the rock waterfalls. Large concrete slabs and miscellaneous debris are present and vegetation is growing in the outlet channel. The outlet channel joins the original stream course, Johnson Branch, immediately below the falls. A profile of the spillway through the control section is shown on Plate 3.

The emergency spillway, a V-shaped broad-crested section having a width of about 20 feet, has been constructed at the end of the embankment that forms the left side of the spillway channel. The spillway crest is located approxi-

mately 300 feet downstream of the main section of the dam. The invert of the spillway crest is approximately 1 foot higher than normal pool level. The spillway crest has a grass cover to protect it against erosion. Erosion to a depth of about 2 feet has occurred in the area immediately downstream of the crest. Brush, small trees, and miscellaneous debris (see Photo 8) were present in the spillway approach channel. The exact route by which flow passing the spillway crest reaches the downstream channel was not apparent at the time of the inspection.

d. Downstream Channel. The downstream channel, Johnson Branch, is unimproved. A gravel surfaced road fords the stream about 300 feet below the dam. The stream joins the Meramec River approximately 2 miles below the dam.

e. Reservoir. The area contiguous to the lake was found to be in satisfactory condition with the lake banks covered with grass and trees. No appreciable amount of sediment was observed in the lake.

3.2 EVALUATION

The deficiencies observed during this inspection are not considered of major consequence to warrant immediate remedial action. The trees should be removed from the downstream slope and from around the retaining wall near the left abutment and the slope and wall re-examined to determine their condition. The removal work should be performed in a manner which will not disturb the existing turf cover, or damage the wall. The wall should be examined in detail by a structural engineer.

A means of controlling the seepage that is occurring between the retaining wall and the embankment at the right side of the principal spillway should be provided.

Since the emergency spillway crest is located within an embankment, grass cover is not considered adequate protection to prevent erosion of the section by spillway flow of the magnitude under consideration.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

The principal and emergency spillway are uncontrolled. The water surface level is governed by rainfall runoff, evaporation, seepage, and the capacity of the uncontrolled spillway.

4.2 MAINTENANCE OF DAM AND SPILLWAY

Based on the dense cover of vegetation on the upstream and downstream slopes of the dam, and the numerous holes and tree trunks on the upstream slope of the dam, it is apparent that the dam receives only limited attention. According to a representative of the Owner, the grass on the downstream slope is seldom mowed.

4.3 MAINTENANCE OF OUTLET OPERATING FACILITIES

No outlet operating facilities exist at this dam.

4.4 DESCRIPTION OF ANY WARNING SYSTEMS IN EFFECT

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

4.5 EVALUATION

Poor maintenance is considered detrimental to the safety of the dam. It is recommended that maintenance on a regular basis of the dam and spillways be undertaken.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. Design data not available.

b. Experience Data. The drainage area and lake surface area were developed from the 1969, Lonedell, Missouri, Quadrangle Map. The proportions and dimensions of the spillways and dam were determined from surveys made during the inspection. With respect to overtopping, the top of the dam was considered to be the actual dam profile, varying between low and high points within reaches.

c. Visual Observations.

(1) The principal spillway and outlet channel are cut into rock at the left abutment of the dam. Spillway releases within the capacity of the spillway, could endanger the integrity of the dam since erosion has negated a part of the embankment slope protection.

(2) The emergency spillway is located near the right abutment. The crest of the emergency spillway is about one foot higher than the crest of the principal spillway and approximately four feet lower than the top of the dam. The crest and approach channel are mostly grass lined. The course of the outlet channel is not readily discernible. Spillway releases may endanger the integrity of the embankment by erosion resulting in indiscriminate flooding of the area below the dam.

(3) The top of the dam is approximately 2 feet lower near the center of the dam than the top of the dam adjacent to the principal spillway.

(4) There are no facilities to dewater the lake.

d. Overtopping Potential. The spillway section is inadequate to pass the probable maximum flood, the 1/2 probable maximum flood, or the lake outflow resulting from the 1 percent change (100-year frequency) flood without overtopping the dam. The results of a dam overtopping analysis are as follows:

Ratio of PMF	Q - Peak Outflow (cfs)	Max. Lake Water Surface Elev.	Max. Depth of Flow Over Dam (Elev. 533.9)	Duration of Overtopping of Dam (Hours)
0.11	2,280	533.9	0	0
0.5	11,570	536.3	2.4	5.7
1.0	23,180	537.7	3.8	6.9
100-Year Flood	6,830	535.5	1.6	1.5

The flow safely passing the spillways (principal and emergency) just prior to overtopping amounts to about 2,280 cfs, which is the lake outflow resulting from the inflow of a storm of 11 percent probable maximum flood magnitude. The flow safely passing the spillways is less than the lake outflow resulting from a storm of 1 percent chance (100-year frequency) magnitude.

Procedures and data for determining the probable maximum flood, the 100-year frequency flood, and the discharge rating curve for flow over the spillway and the dam crest are presented on Pages B-1 and B-2 of the Appendix. A listing of the HEC-1 (Dam Safety Version) input data is shown on Page B-3 and a copy of the computer output "Summary of the Dam Safety Analysis" is presented on Page B-4 of the Appendix.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

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

b. Design and Construction Data. No design or construction data relating to the structural stability of the dam are known to exist. Also, no data relating to the design or construction of the retaining wall located in the downstream slope of the dam was available.

c. Operating Records. No appurtenant structures or facilities requiring operation exist at this dam. According to a representative of the Owner, no records have been kept of lake level, spillway discharge, dam settlement, or seepage.

d. Post Construction Changes. The Owner's representative is not aware of any post construction changes made to the dam that could affect the structural stability of the dam.

e. Seismic Stability. Due to the relatively low profile of this dam, maximum height of approximately 24 feet, and since there are no reported geological faults in this immediate area, a detailed seismic analysis of this structure is not considered necessary. Also, since the dam is located within a Zone II seismic probability area, an earthquake of the magnitude predicted is not expected to produce a hazardous condition to the dam, provided that static stability conditions are satisfactory and conventional safety margins exist.

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 2,280 cfs without the level of the lake exceeding the low point in the top of the dam. A hydrologic analysis of the runoff from the lake watershed area, as discussed in Section 5, indicated that for a storm runoff of probable maximum flood magnitude, the lake outflow would be on the order of 23,180 cfs, which would result in a 3.8- foot maximum depth of flow over the top of the dam at its low point. For the 1 percent chance (100-year frequency) flood, the lake outflow would be about 6,830 cfs and would also overtop the dam.

Several items were noticed during the visual inspection that adversely affect the safety of the dam. These items, which exist on the entire embankment, are trees, brush, holes, large tree trunks and surface erosion. The extent of the effect of these items can be better assessed after the trees and brush are removed. The holes, believed to be animal burrows, observed in the crest and upstream face of the dam are also considered detrimental to the safety of the dam since they provide pathways for seepage. In addition, the retaining wall supporting the embankment on the downstream side of the dam was found to be in a distressed condition as evidenced by cracking and outward rotation of one section of the wall. Loss of the wall could result in failure of the dam.

Investigations made during the inspection did not disclose that stability and seepage analyses of the dam had been performed. Engineering data relating to the design of the retaining wall was also unavailable.

b. Adequacy of Information. Due to lack of engineering and construction data, the assessments reported herein were based on external conditions as determined during the visual inspection. Those recommendations with regard to

the hydrology of the lake and the 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 the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

c. Urgency. The safety defects noted in paragraph 7.1a and the remedial measures recommended in paragraph 7.2 should be accomplished in the near future.

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

e. Seismic Stability. As indicated in paragraph 6.1e, a detailed seismic analysis of this dam is not considered necessary. Also, since the dam is located within a Zone II seismic probability area, an earthquake of the magnitude predicted is not expected to produce a hazardous condition to the dam, provided that static stability conditions are satisfactory and conventional safety margins exist.

7.2 REMEDIAL MEASURES

a. Recommendations. The following actions are recommended:

(1) Based upon criteria set forth in the recommended guidelines, alterations to this design of the dam should be made in order to pass lake outflow resulting from a storm of probable maximum flood magnitude. In any event, it is recommended that the low area located near the center of the dam be raised such that it no longer restricts spillway capacities.

(2) Obtain the necessary soil data and perform stability and seepage analyses in order to determine the structural stability of the dam for all

operational conditions. Seepage and stability analyses should be performed by a professional engineer experienced in the design and construction of dams. Stability analyses should include a section at the location of the retaining wall in addition to other critical locations.

b. Operation & Maintenance (O & M) Procedures. The following O & M procedures are recommended:

(1) Remove the trees and brush from the crest, and the upstream and downstream slopes of the dam. Tree roots provide a passageway for seepage and can lead to a piping condition and subsequent failure of the dam. The existing turf cover should be restored if destroyed or missing. Maintain the turf cover on the slope at a height that will not hinder inspection of the slope. The removal of trees should be performed under the direction of an engineer experienced in the design and construction of earth dams.

(2) Provide some means of preventing piping due to seepage occurring in the area between the retaining wall and the principal spillway since a piping condition could result in failure of the dam.

(3) The retaining wall located on the downstream side of the embankment should be thoroughly examined by a structural engineer in order to determine its stability and structural capability. Based upon the recommendations of the structural engineer, the wall should be removed, replaced, and/or repaired as required.

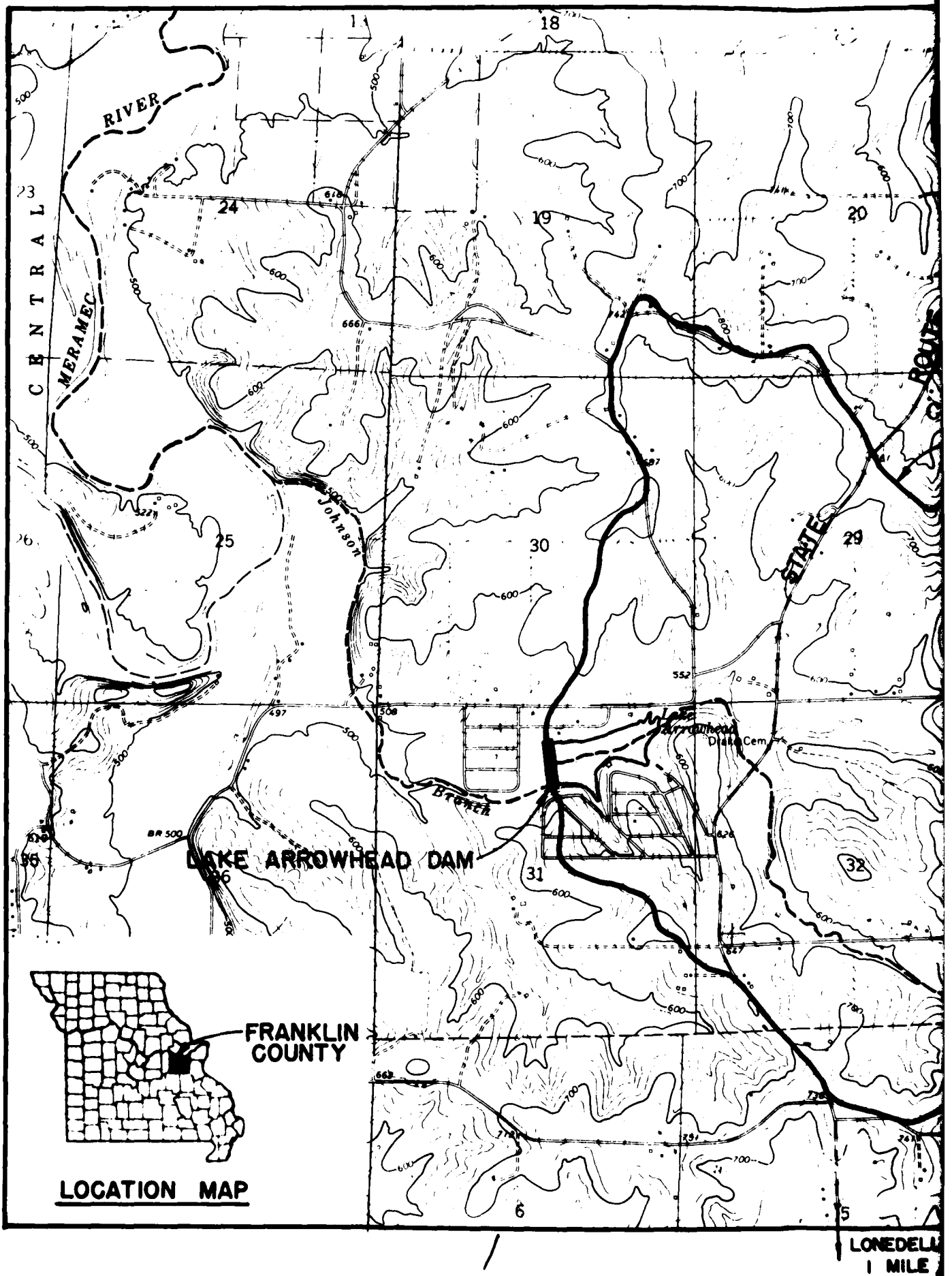
(4) Provide some form of protection at the crest and downstream slope of the emergency spillway in order to prevent erosion by spillway flow. Erosion of the embankment at this location could result in indiscriminate flooding of the area below the dam.

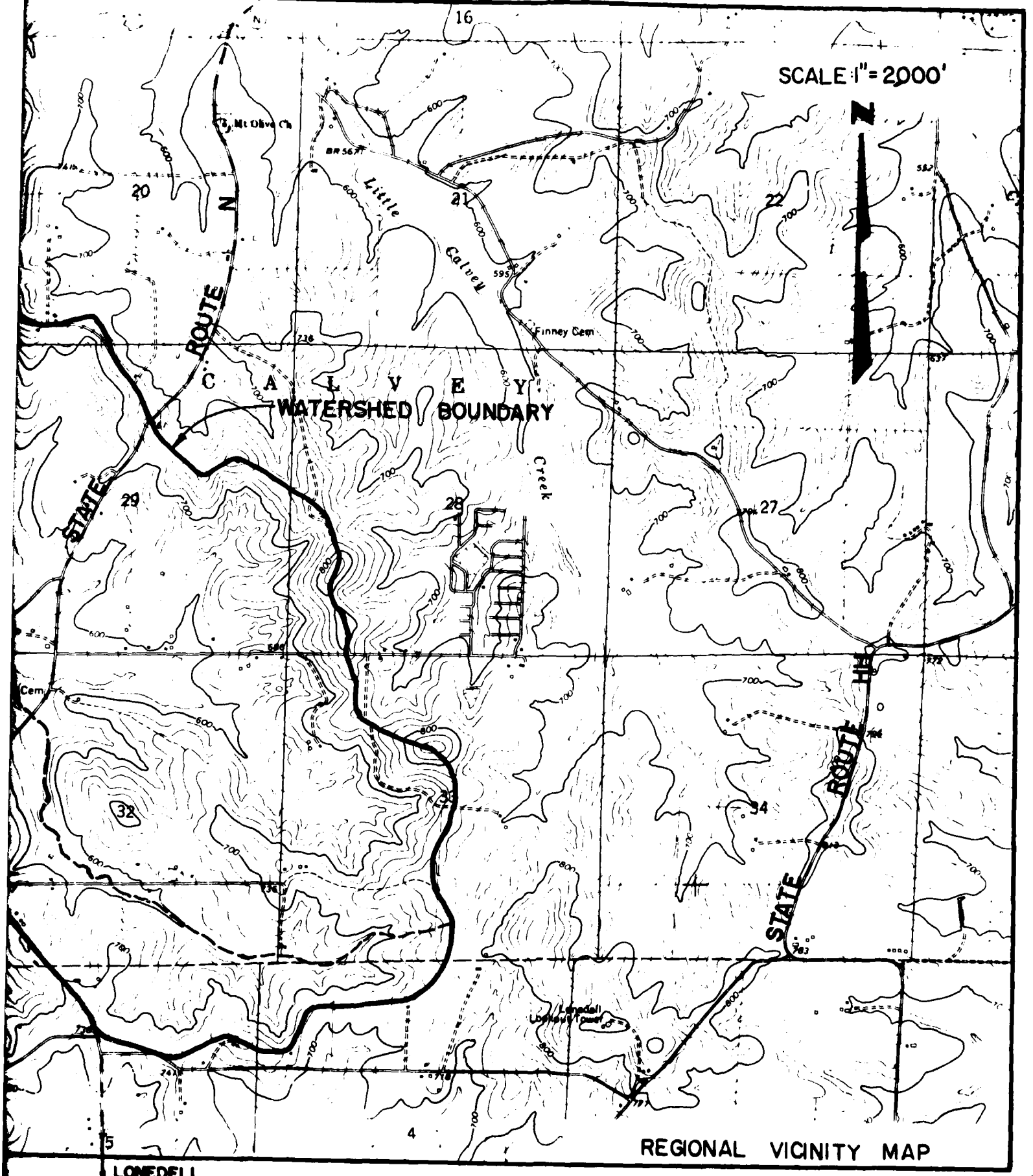
(5) Eliminate holes in dam, created by burrowing animals or by the removal of tree roots, in order to reduce the seepage potential and the possibility of a piping condition.

(6) Restore the subgrade and repair the concrete slope pavement at the right bank of the outlet channel for the principal spillway in order to prevent additional erosion at this location and sloughing of the bank.

(7) Restore the eroded upstream face of the dam and provide some form of slope protection to protect the slope against erosion by wave action.

(8) A detailed inspection of the dam should be institued 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.


CENTRAL
MERAMEC
RIVER
Johnson
Branch
STATE
Lake Arrowhead
Dam & Cem
LAKE ARROWHEAD DAM
FRANKLIN
COUNTY
LOCATION MAP
LONEDELL
1 MILE
18
19
20
23
24
25
26
29
30
31
32
35
36
6
5

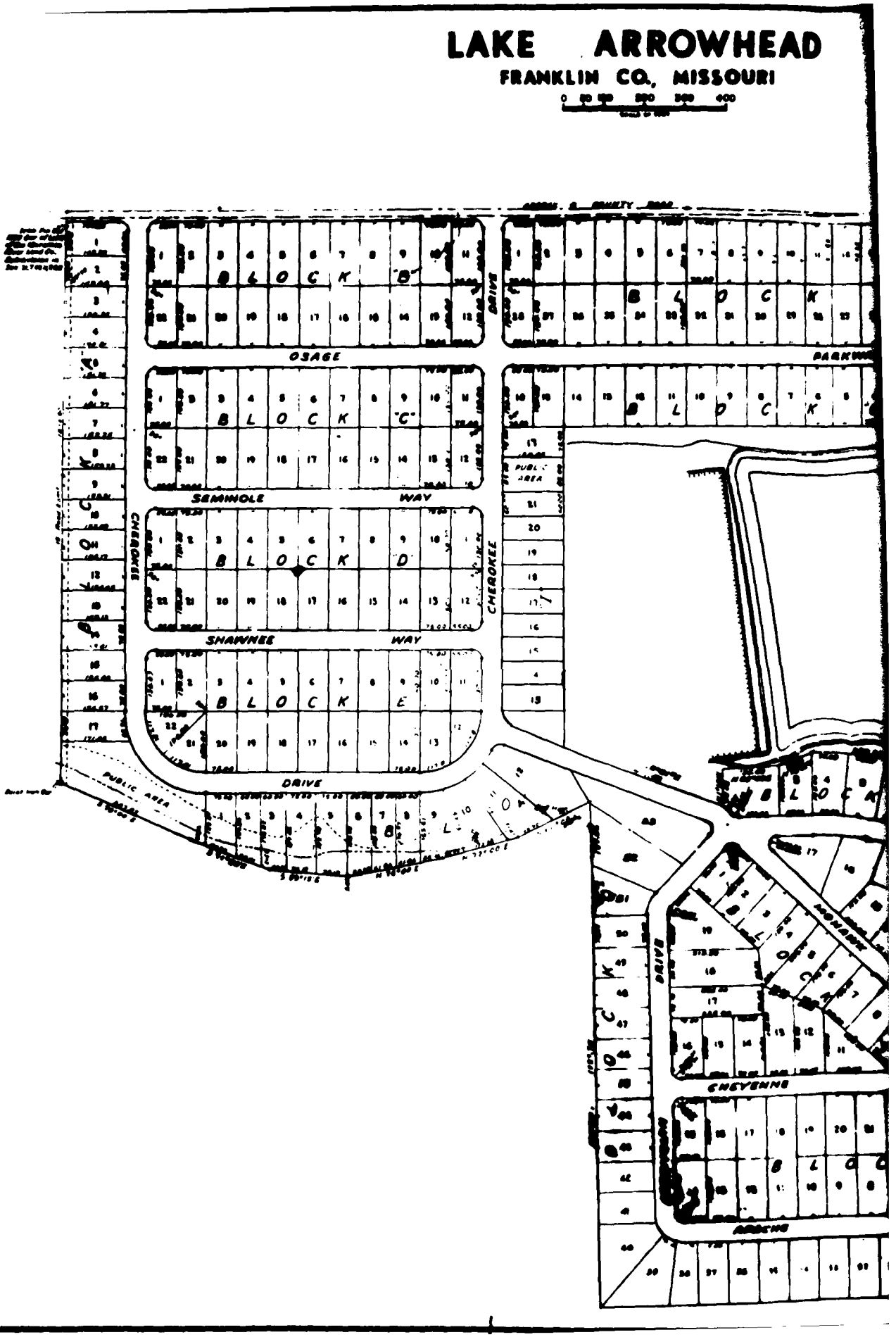


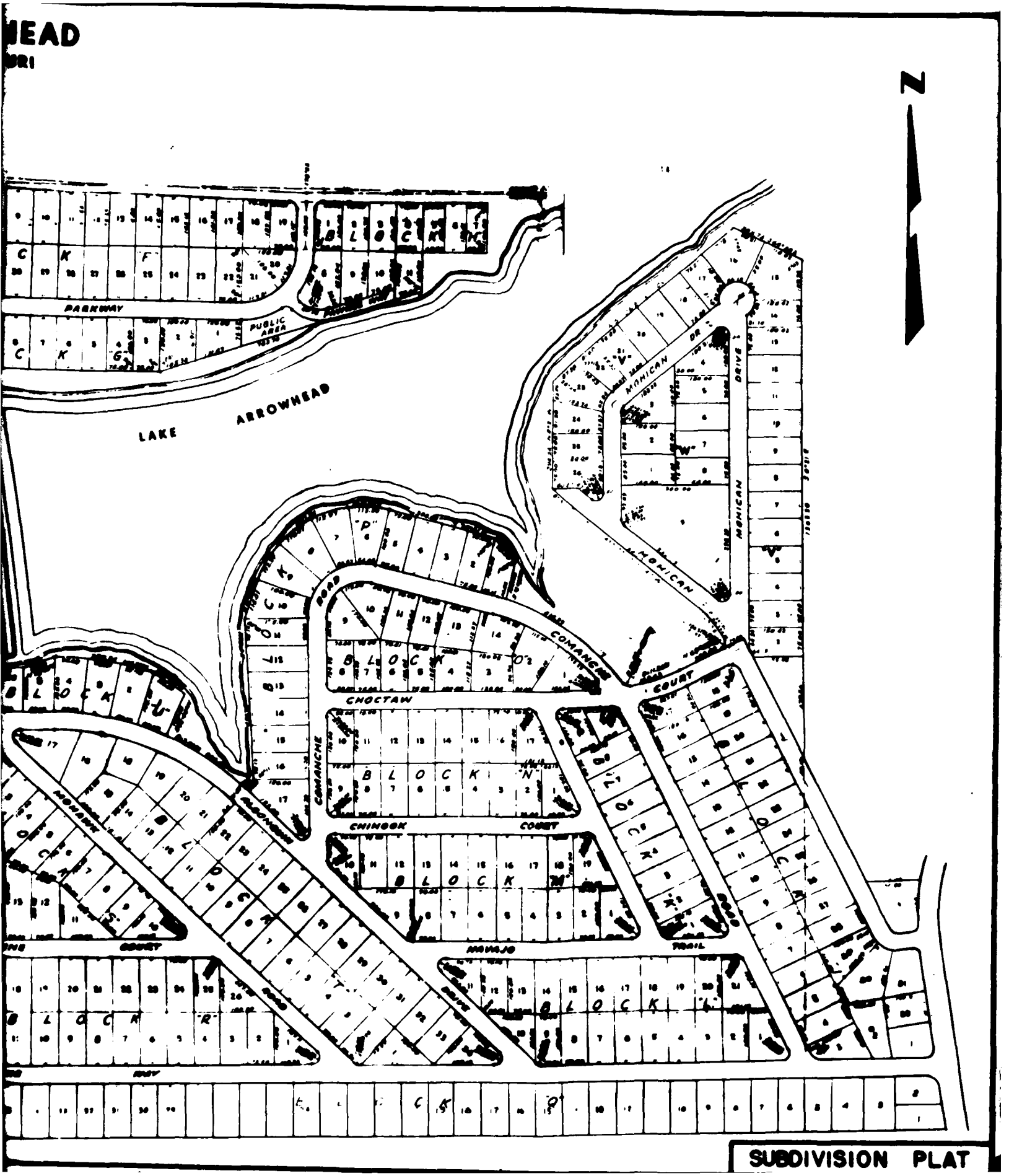
REGIONAL VICINITY MAP

PLATE 1

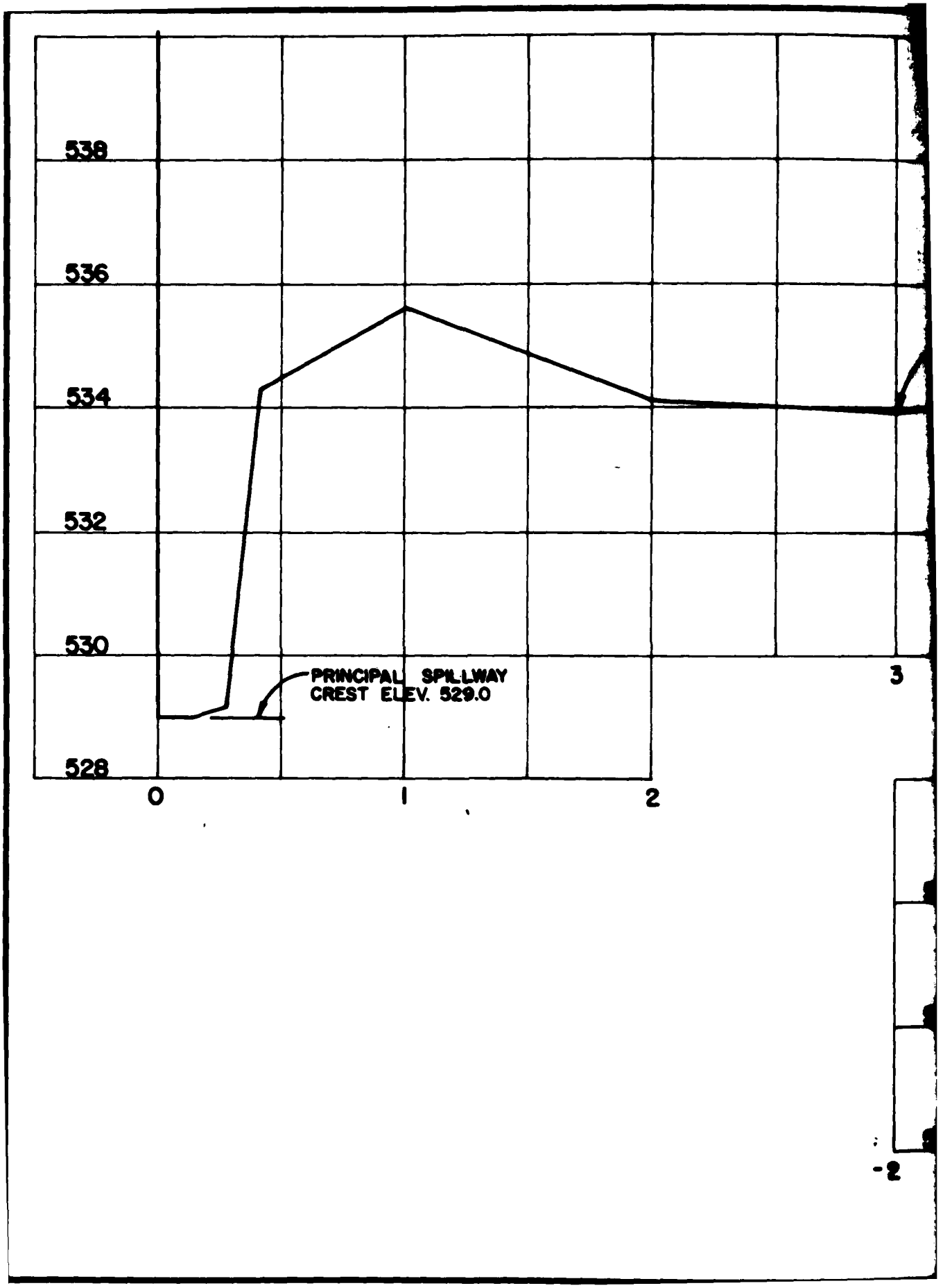
LAKE ARROWHEAD

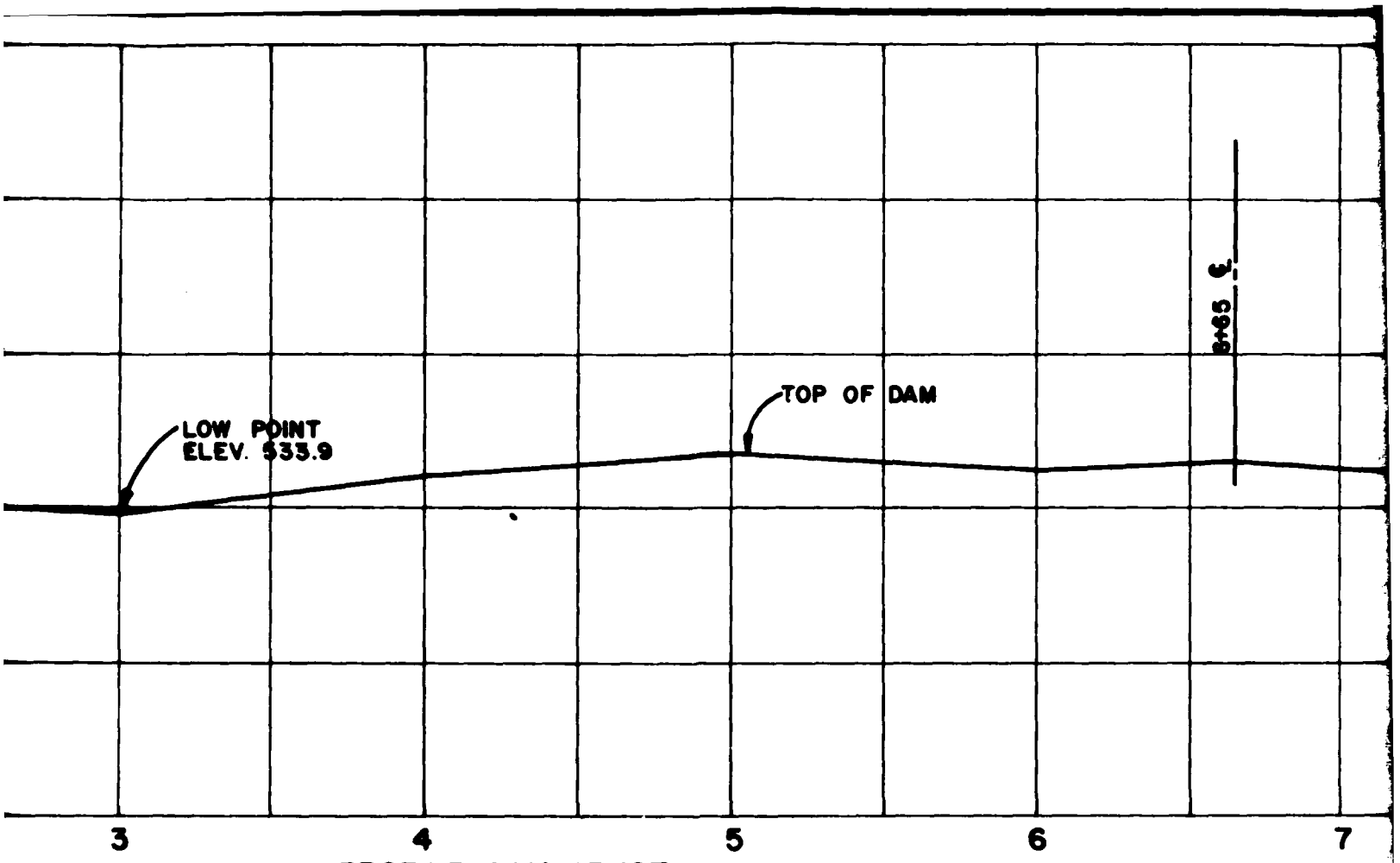
FRANKLIN CO., MISSOURI



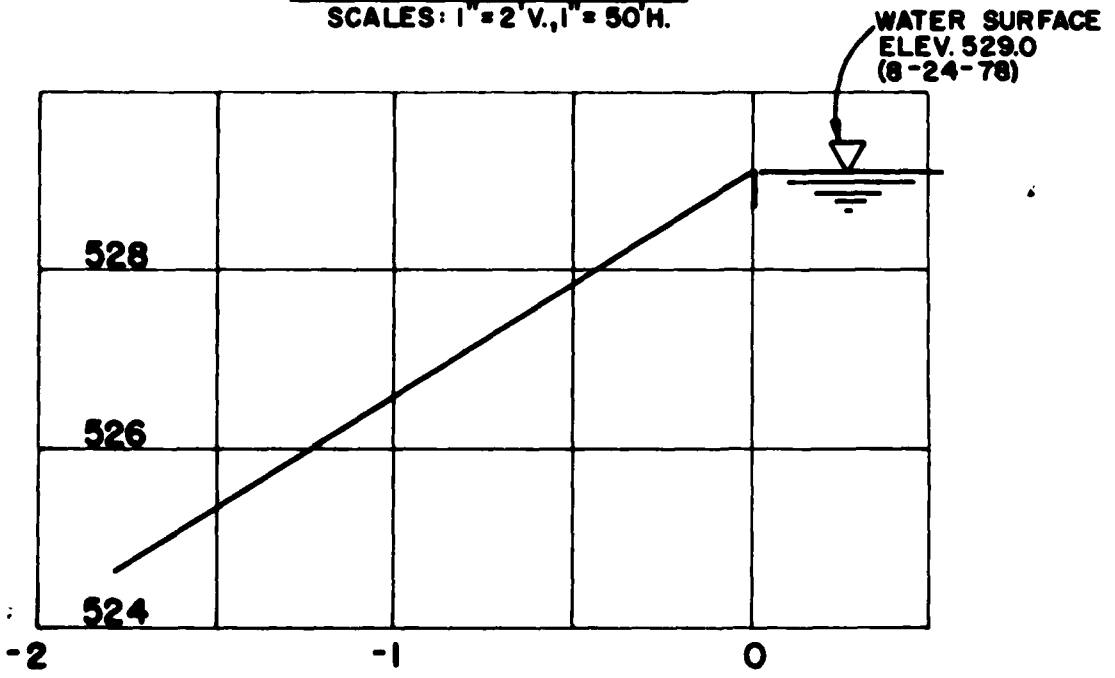


SUBDIVISION PLAT

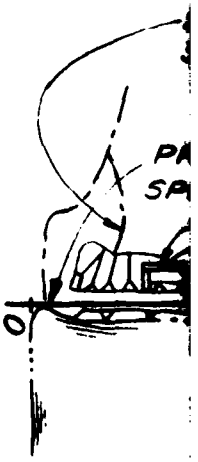

538
536
534
532
530
528
0
1
2
3
PRINCIPAL SPILLWAY
CREST ELEV. 529.0
-2

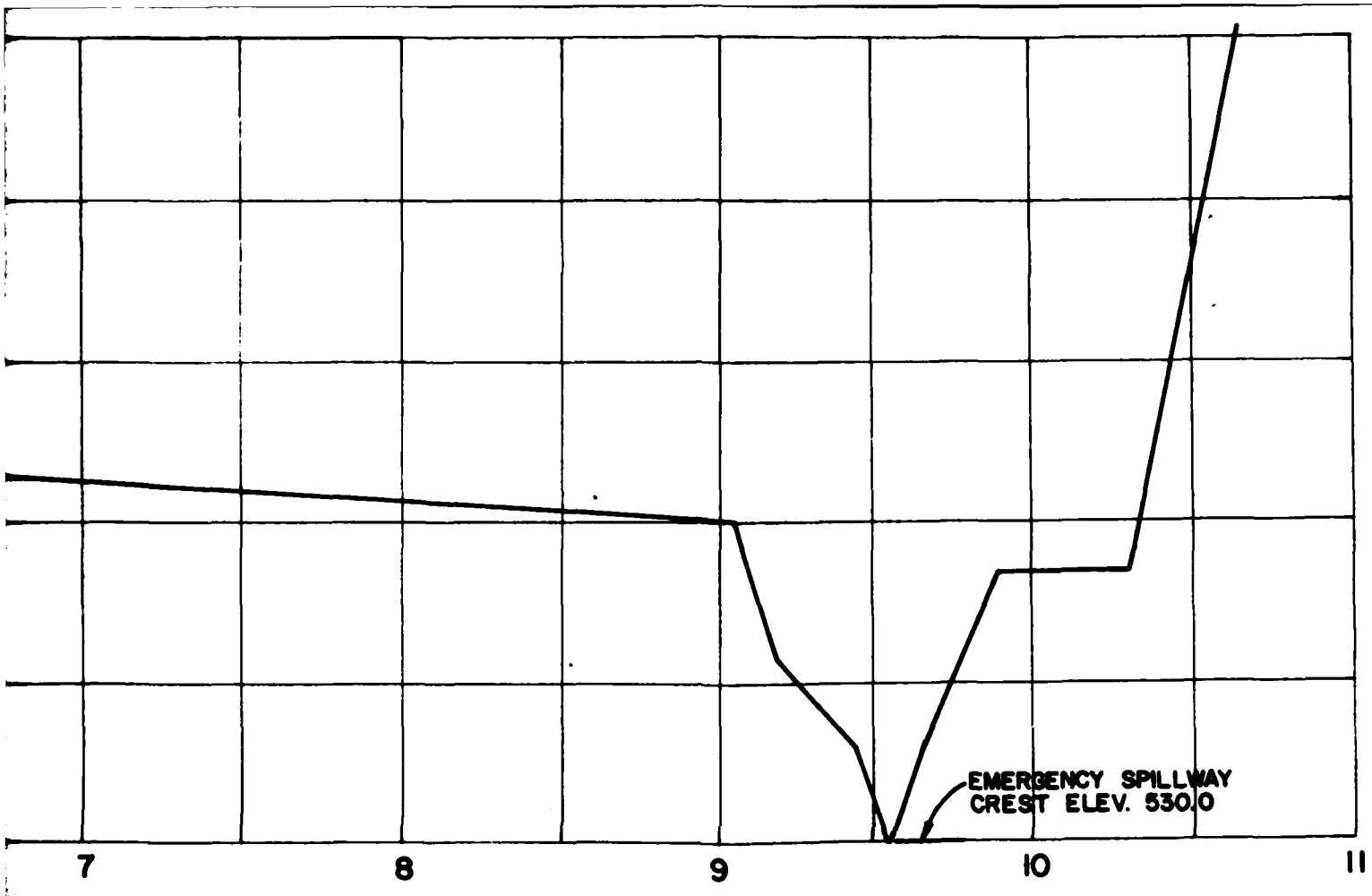


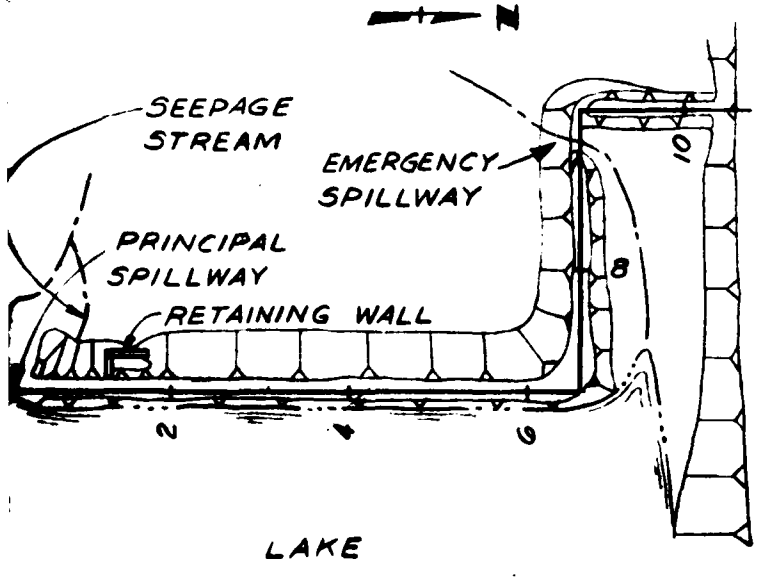
PROFILE DAM CREST
SCALES: 1"=2'V., 1"=50'H.



PROFILE PRINCIPAL SPILLWAY
SCALES: 1"=2'V., 1"=50'H.

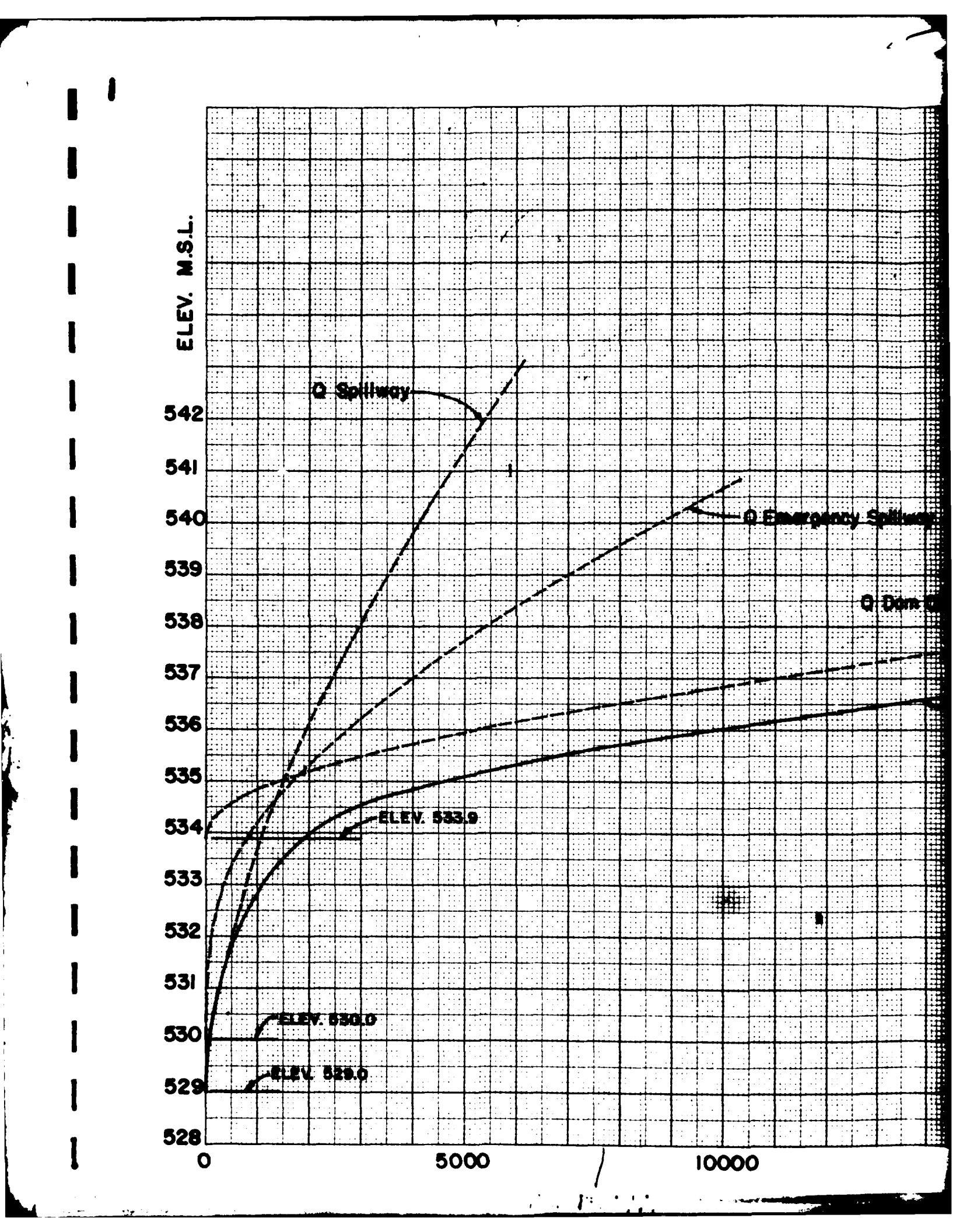


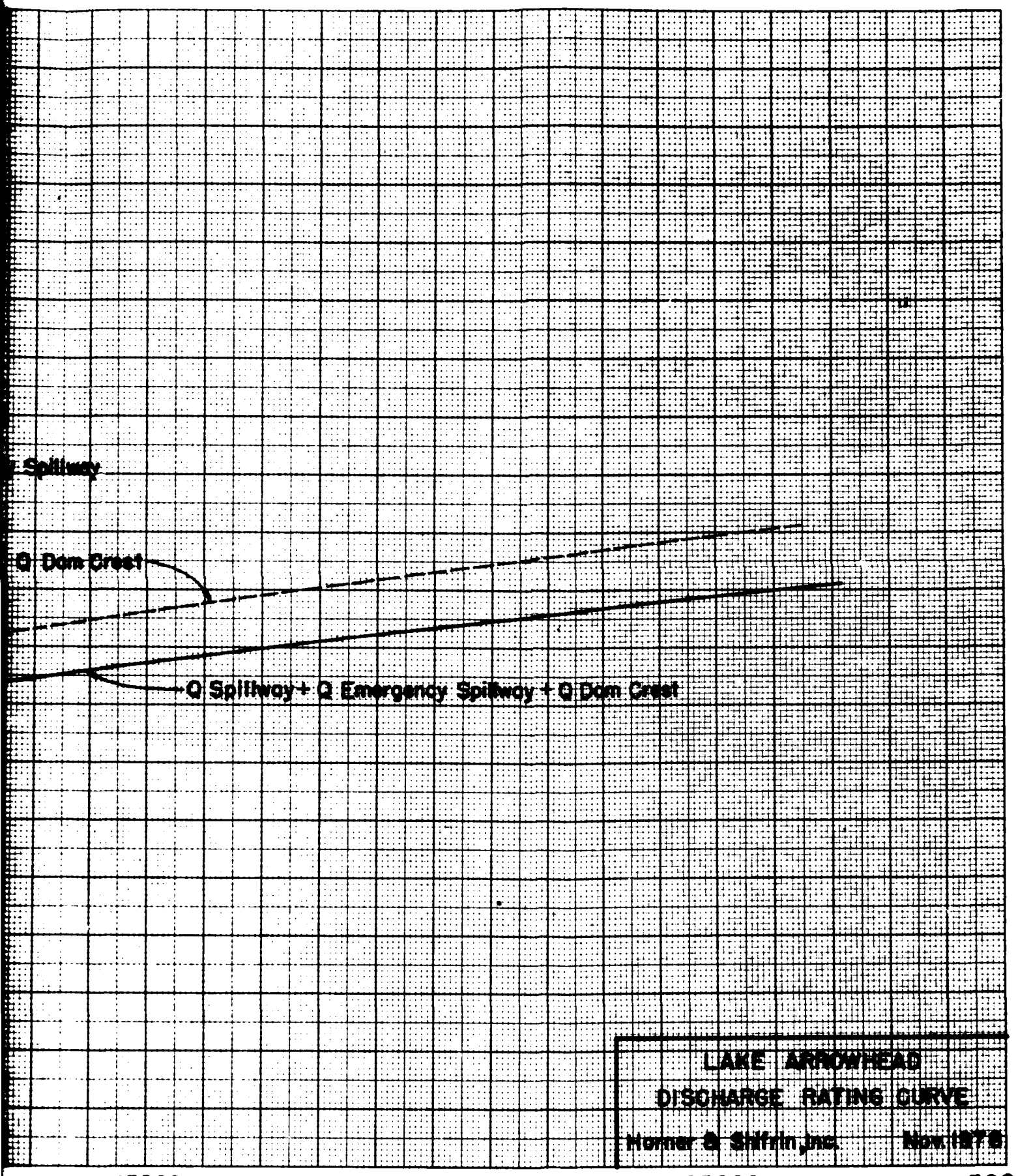




GENERAL PLAN

LAKE ARROWHEAD
DAM & SPILLWAY PROFILES
Horner & Shifrin, Inc. Nov. 1978


ELEV. M.S.L.
542
541
540
539
538
537
536
535
534
533
532
531
530
529
528
0
5000
10000
Q Spillway
Q Emergency Spillway
Q Dam
ELEV. 533.9
ELEV. 530.0
ELEV. 529.0



LAKE ARROWHEAD

DISCHARGE RATING CURVE

Horner & Shifrin, Inc. Nov. 1978

PLATE 4

LAKE ARROWHEAD
PMF INFLOW & OUTFLOW
HYDROGRAPHS

Horner & Shifrin, Inc. Nov. 1978

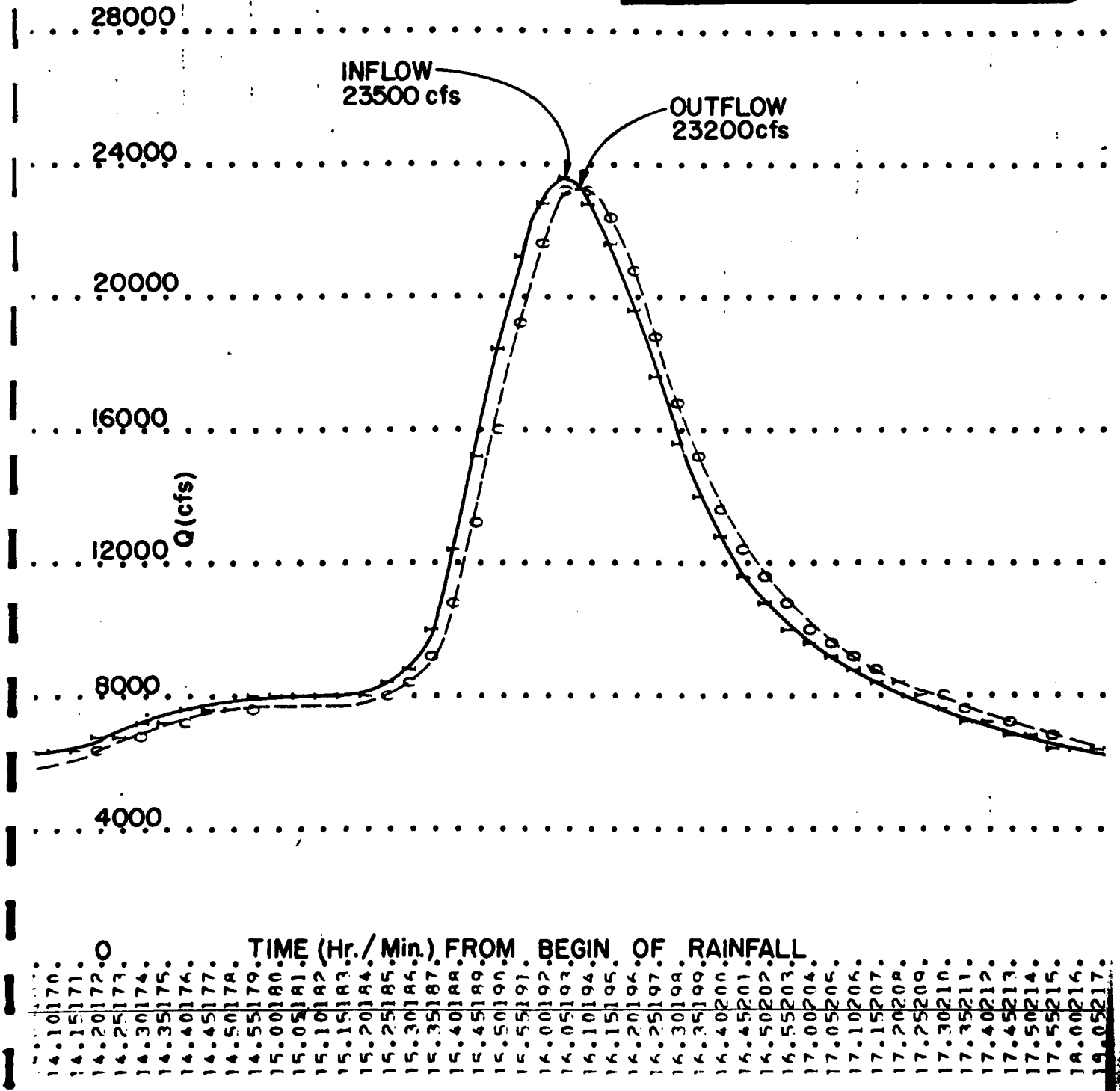


PLATE 5

Kiesewetter
Franklin Co

April 8, 1968

C. E. Menckel
1512 Surf Side Drive
St. Louis, Missouri 63130

Dear Mr. Menckel:

Lake Arrowhead is located in the NE¼ sec. 31, T.42 N., R.2 E. (St. Clair Quad.), Franklin County. It is situated on Johnson Creek and apparently is an enlargement of an old lake which was present here when the St. Clair Quadrangle, dated 1950, was completed. The lake is approximately 20 acres in size and it has a watershed of 2000 acres. These measurements are scaled from the St. Clair topographic map and therefore are only approximate. However, they are sufficiently accurate to note that the drainage to lake ratio is about 100 to 1. This is about 100 acres of watershed per 1 acre of lake.

Lake Arrowhead has not been listed as one of the potentially hazardous dams in Missouri, but it has many of the features which are typical of those lakes which have been included on the list. It is important to remember however, that it is not possible to categorically state that this lake will fail by overtopping or by any other manner of destruction such as earthen slides on the dam. However, because several of the obvious conditions which point to failure exist here all precautions necessary should be taken.

Mr. Ed Lutzen, Engineering Geologist in our section, has visited Lake Arrowhead and discussed the potential hazards with the owners. Many times we have found that lake owners were not fully aware of conditions at a dam and have been glad to make corrections when they are brought to their attention.

Some of the problems at Lake Arrowhead consist of a tree choked principal spillway and an emergency spillway that needs to be modified by grading. The owners plan to correct these as well as cut the trees that line the front of the dam. A tree lined dam can develop leakage leading to possible failure by piping. A crest width of the dam is too narrow. However, since this is a low dam, the narrow crest width is not as hazardous as if the dam were much higher.

With reference to the houses downstream of the dam, they no doubt would be affected if the dam should be overtopped during flooding. However, because of the relatively shallow water in the lake, that is 15 to perhaps 20 feet, it is doubtful that these houses would suffer a great deal more damage than they would

Chart 2-1

E. Menckel

during a major flood on this stream channel. Also because of the relatively low dam and shallow water, if the dam should develop very serious leaks, slides, etc. it would be more easily and economically repaired than a high dam with deep water.

The primary causes for dam failure throughout the world are inadequate spillways. With the correction made on the spillway at Lake Arrowhead, this will reduce this one main hazard.

Sincerely,

James H. Williams
Chief, Eng. Geol. Section

JHW:cj

Lake Arrowhead Franklin Co.

Address Reply To:
Post Office Box 250
Rolla, Missouri 65401

May 16, 1975

Mr. George Mann
Post Office Box 105
Londell, Missouri 63060

Dear Mr. Mann:

Mr. Jerry Phalen, Corps of Engineers, St. Louis office, relayed to this office your call concerning potential problems with inadequate spillways a. Lake Arrowhead in Franklin County. I visited the lake on the 14th of May and I'm sorry we could not make contact. I did not know I would be in the area that day and as such did not call prior to the visit.

Your neighbor to the west showed me the dam and the row of stakes that you had placed at the high water mark a few days prior to this visit. The height at which the stakes were placed indicates that the dam might be overtopped before the emergency spillway would be in operation. The emergency spillway obviously has not been completed as the outlet area for the spillway is higher than the inlet area. While the dam has from 5 to 7 feet of freeboard in selected areas, there are low spots in the dam considerably lower than that.

Aerial photography in 1941 shows that the lake was constructed prior to that time with the principal and emergency spillway respectively in their same positions. I do not know the age of the dam, but considering its longivity, it appears to be in very good shape with no obvious landslieds or earth cracks opened up.

The drainage area incompassing the lake is approximately 2,050 acres with the surface area of the lake scaled at between 20 and 25 surface acres. The lake is reported to be about 55 acres in size, but I believe 25 acres would be more accurate. This leaves a rather high lake size to drainage area ratio. I am not a registered engineer, and as such do not feel confident to calculate the needed design spillway for this lake and its corresponding watershed. I do feel that it would be in your best interest to have this done by engineering people experienced in lake design. The present condition of the spillways would lend one to assume that they are inadequate for 25 and 50 year frequency rainfalls. Given the right rainfall intensity overtopping probably would occur. Again, to repeat, I would recommend that an engineer experienced in lake design be consulted for proper sizing and design of the spillway capacity of the lake.

If you do not know any civil engineers in your area, contact Mr. Paul N. Doll, P.E., Executive Director, Missouri Society of Professional Engineers, 210 Monroe Street, Post Office Box 365, Jefferson City, Missouri 65101, for a list of professional engineers and/or recommendations on who is available in your area for such design work.

If we can be of further assistance, do not hesitate to call or write.

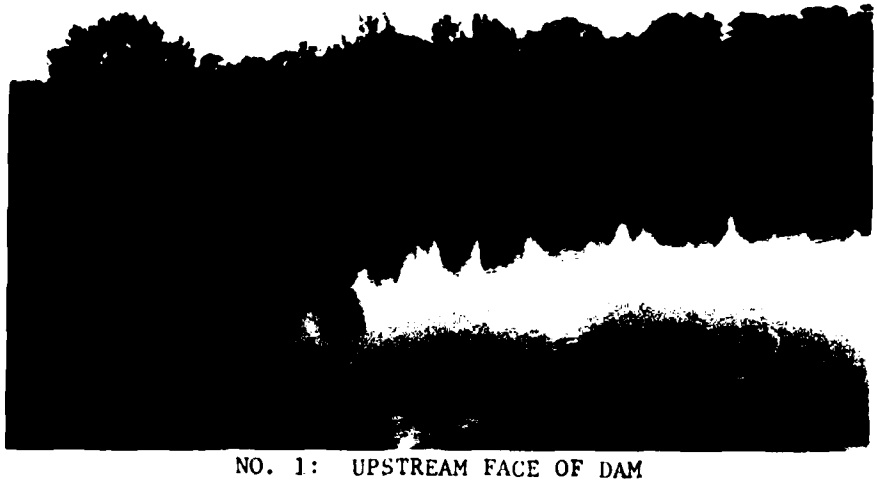
Yours truly,

Thomas J. Dean, Geologist
Applied Engineering & Urban Geology
Missouri Geological Survey

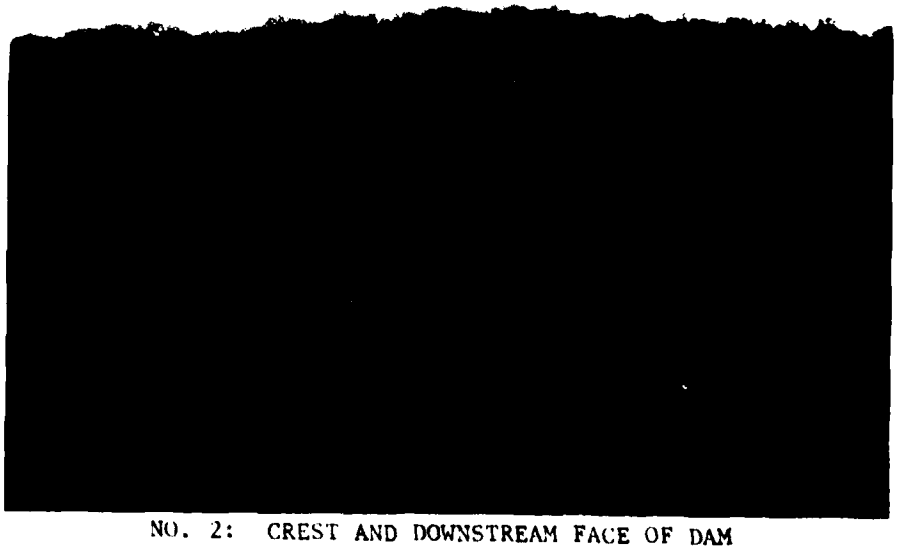
TJD:dh

cc: Jerry Phalen

APPENDIX

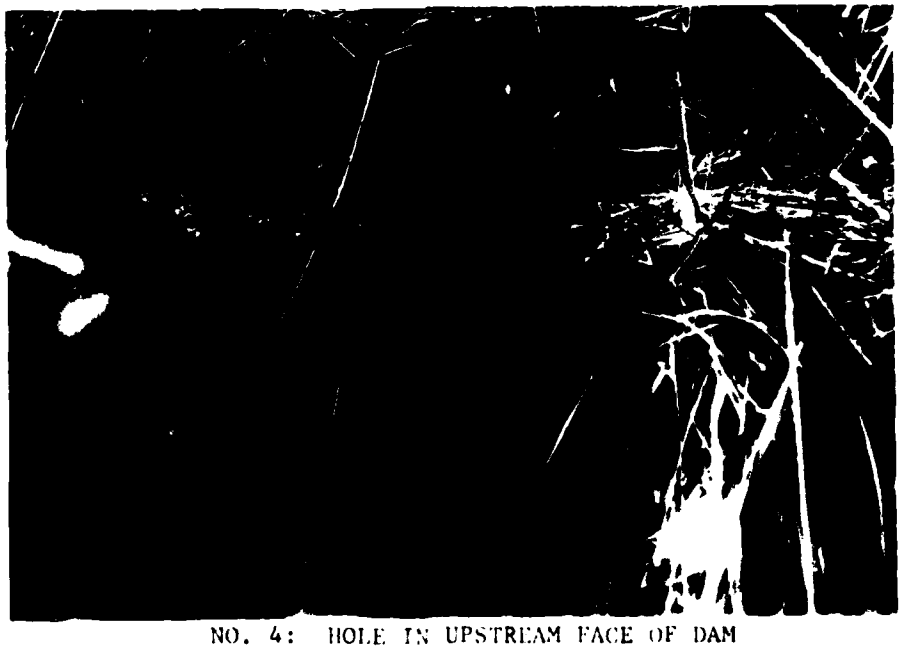


NO. 1: UPSTREAM FACE OF DAM



NO. 2: CREST AND DOWNSTREAM FACE OF DAM

NO. 3: TREE TRUNK IN UPSTREAM FACE OF DAM

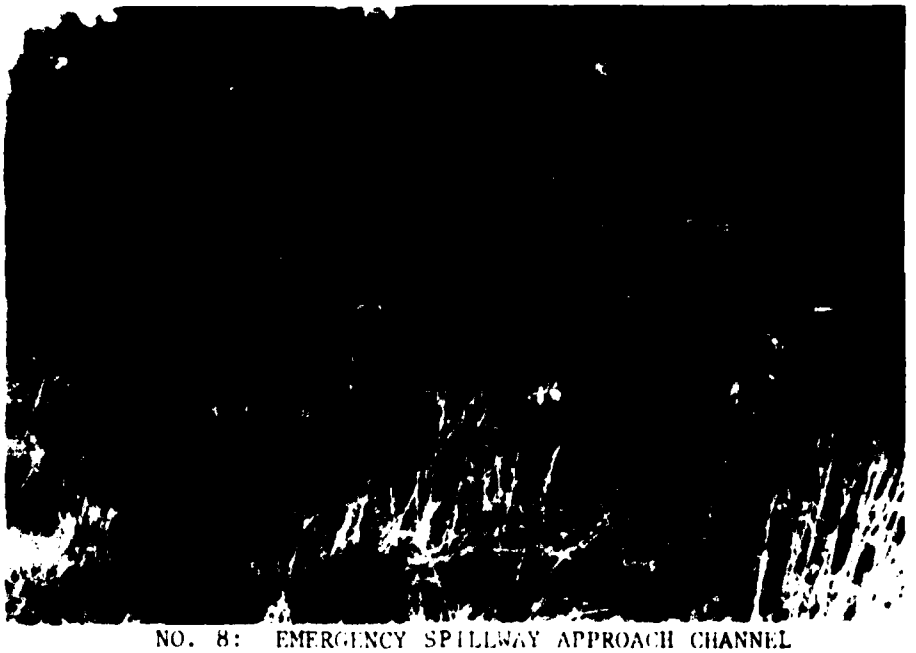


NO. 4: HOLE IN UPSTREAM FACE OF DAM

NO. 5: CONCRETE RETAINING WALL

NO. 6: PRINCIPAL SPILLWAY OUTLET CHANNEL

NO. 7: UNDERCUT CONCRETE PAVING AT SPILLWAY BANK



NO. 8: EMERGENCY SPILLWAY APPROACH CHANNEL

HYDROLOGIC COMPUTATIONS

1. The HEC-1 Dam Safety Version (July 1978) 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 25.5 inches) from Hydrometerological Report No. 33. One hundred year frequency (one square mile precipitation, 24-hour value equals 7.21 inches) from U.S. Weather Bureau Technical Paper No. 40.

b. Drainage area = 3.28 square miles
= 2,100 acres

c. SCS parameters:

Lag time = 0.53 hours
Soil type CN = 91 (Soil type C, AMC III)

2. The spillway sections consist of a broad-crested, approximately U-shaped rock section and a V-shaped broad-crested excavated earth section for which conventional weir formulas do not apply.

Spillway release rates were determined as follows:

(1) Spillway crest section properties (area, a and top width, t) were computed for various depths, d.

(2) It was assumed that flow leaving the spillway crest would occur at critical depth. Flow at critical depth (Q_c) was computed as $Q_c = \left(\frac{a}{t} g\right)^{0.5}$ for the various depth, d.

Corresponding velocities (v_c) and velocity heads (H_{vc}) were determined using conventional formulas.

(3) Static lake levels corresponding to the various Q_c values passing over the spillway were computed as critical depths plus critical velocity head ($d_c + H_{vc}$), 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.

3. The profiles of the dam crest is irregular and flow over the dam crest cannot be determined by conventional weir formulae. Flow quantities overtopping the dam crest were computed as described in the preceeding paragraphs and corresponding flow over the dam and spillway for given elevations for the dam were added to obtain the combined outflow rating curve for the dam and spillway. These rating curves are shown on Plate 4. Inflow and outflow hydrographs for the PMF for each dam are presented on Plate 5.

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**********
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  3 AUG 78
**********
    1                 A1       ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
    2                 A2       HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF LAKE ARROWHEAD DAM
    3                 A3       RATIOS OF PMF ROUTED THROUGH RESERVOIR
    4                 R    288        0        5       -0       -0       -0       -0       -0       -0       -0
    5                 R1     5
    6                 J      1        3        1
    7                 J1  0.12     0.50     1.00
    8                 K      0   INFLOW                                    3        1
    9                 K1       INFLOW HYDROGRAPH
   10                 M      1        2     3.28                       1.0                         1
   11                 P      0     25.5      102      120      130
   12                 T                                                          -1      -91
   13                 W2            0.53
   14                 X   -1.0     -.10      2.0
   15                 K      1      DAM                        2        3        1
   16                 K1       RESERVOIR ROUTING BY MODIFIED PULS
   17                 Y                                    1        1
   18                 Y1     1                                                142.5       -1
   19                 Y4   529      530      531      532      533    533.9      534    534.5      535    535.5
   20                 Y4   536      537      538      539      540
   21                 Y5     0       80      260      590     1090     1870     1980     2820     4530     6870
   22                 Y5  9780    17060    25950    36050    47480
   23                 $A     0     22.5     46.8    155.2
   24                 $E   510      529      540      560
   25                 $$   529
   26                 $D 533.9
   27                 K     99
```

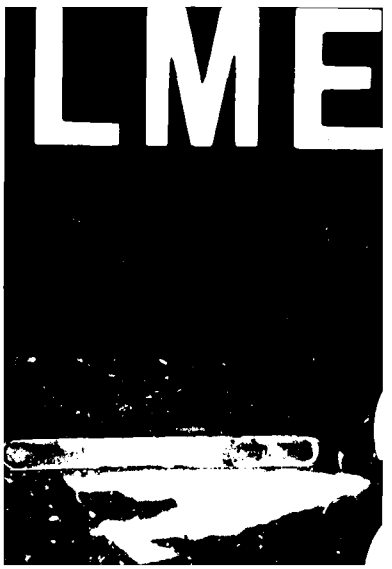
SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	529.00	529.00	533.90
STORAGE	142.	142.	276.
OUTFLOW	0.	0.	1870.

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*	534.18	.28	285.	2287.	.58	16.33	0.00
.50	536.25	2.35	358.	11568.	5.67	16.17	0.00
1.00	537.69	3.79	414.	23179.	6.92	16.17	0.00

* Adjusted to 11 percent for depth over dam equal to zero.


LME