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NATIONAL DAM SAFETY PROGRAM. LAKE ARROWHEAD DAM (MO 11016), MIS--ETC(U)
MAY 79 C L METZLER, E R BURTON, H L CALLAHAN DACW43-79-C-0040
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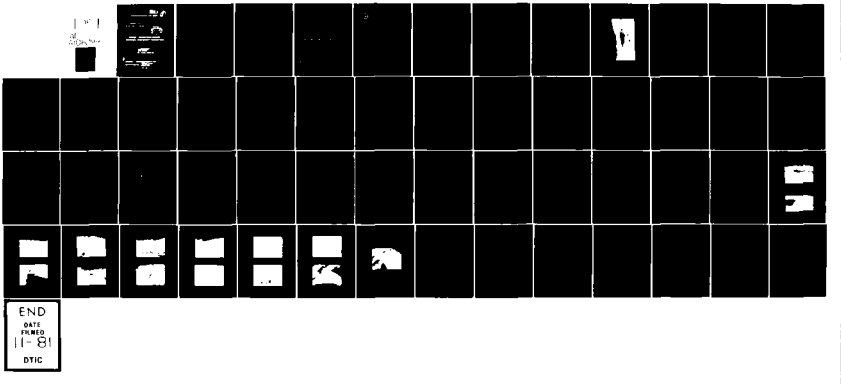

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MISSOURI-KANSAS CITY BASIN

LAKE ARROWHEAD DAM

CLINTON COUNTY, MISSOURI

MO 11016

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY INSPECTION

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

MAY 1979

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, Missouri
ID No. 11016
Phase I Inspection Report

This report presents the results of field inspection and evaluation of the Lake Arrowhead Dam. It was prepared under the National Program of Inspection of Non-Federal Dams.

SUBMITTED BY: SIGNED
Chief, Engineering Division
20 SEP 1979
Date

APPROVED BY: SIGNED
Colonel, CE, District Engineer
20 SEP 1979
Date

LAKE ARROWHEAD DAM

CLINTON COUNTY, MISSOURI

MISSOURI INVENTORY NO. 11016

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

PREPARED BY:

BLACK & VEATCH
CONSULTING ENGINEERS
KANSAS CITY, MISSOURI

UNDER DIRECTION OF

ST. LOUIS DISTRICT CORPS OF ENGINEERS

FOR

GOVERNOR OF MISSOURI

MAY 1979

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam	Lake Arrowhead Dam
State Located	Missouri
County Located	Clinton County
Stream	Muddy Fork
Date of Inspection	31 May 1979

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

The guidelines used in the assessment were furnished by the Department of the Army, Office of the Chief of Engineers and developed with the help of several Federal and state agencies, professional engineering organizations, and private engineers. Based on these guidelines, this dam is classified as an intermediate size dam with a high downstream hazard potential. According to the St. Louis District, Corps of Engineers, failure would threaten the life and property of approximately 21 homes downstream of the dam within the estimated damage zone which extends approximately seven miles downstream of the dam.

Our inspection and evaluation indicates the spillway does not meet the criteria set forth in the guidelines for a dam having the above size and hazard potential. The spillway will not pass the probable maximum flood without overtopping the dam, but will pass 50 percent of the probable maximum flood and the 100-year flood with no overtopping. The spillway design flood recommended by the guidelines is 100 percent of the probable maximum flood. The probable maximum flood is defined as the flood discharge which may be expected from the most severe combination of critical meteorologic and hydrologic conditions which are reasonably possible in the region.

Deficiencies visually observed by the inspection team were erosion of the upstream and downstream embankment material, erosion and sloughing of material in the berm at the right of the spillway channel, apparent blockage of drainage blanket outlets, presence of animal burrows on the embankment, and seepage near the right abutment and within the spillway channel. Seepage and stability analyses required by the guidelines were not available.

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

C. L. Metzler

C. L. Metzler, PE
Missouri E-3642

Edwin R Burton

Edwin R. Burton, PE
Missouri E-10137

Harry L Callahan

Harry L. Callahan, Partner
Black & Veatch

OVERVIEW OF DAM

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
LAKE ARROWHEAD DAM

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APPENDIX

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

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

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

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

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances.

(1) The Lake Arrowhead Dam is a recently constructed earthen structure located in southeastern Clinton County, Missouri on Muddy Fork. This structure was designed by the late Robert J. Spiegel, P.E., for the National Development Company of Dallas, Texas. The principal purpose for this dam is as a recreational facility. The dam is 60 feet wide at the crest and 890 feet long. The upstream face of the dam is riprapped with large boulders and limestone slabs. The downstream face is laden with 3 to 4 feet high weeds. A gravel road traverses the crest of the dam and is a primary access to the development on the east side of the lake.

(2) The spillway consists of a channel excavated in shale and limestone at the left abutment varying in width of approximately 100 to 250 feet. A concrete slab is located at the upstream portion of the spillway which serves as the spillway crest and low water crossing for the extension of the gravel road across the crest of the dam. The spillway discharges to a broken limestone and shale channel immediately downstream of the embankment toe.

(3) Available plans for the dam indicate the presence of a toe drainage system consisting of an 8-inch perforated pipe embedded within

a drainage blanket parallel to the longitudinal axis of the dam near the downstream embankment toe with two 8-inch CMP discharge pipes. The inspection team could not locate the discharge pipes.

(a) Pertinent physical data are given in paragraph 2.

b. Location. The dam is located in southeastern Clinton County, Missouri, as indicated on Plate 1. The dam may be located on the United States Geological Survey 7.5 minute series quadrangle map for Holt, Missouri in Section 19 of T54N, R30W. Only a portion of Lake Arrowhead and its drainage basin are shown on the Holt quadrangle map. The total basin can be located on the USGS 15 minute series quadrangle map for Plattsburg, Missouri.

c. Size Classification. Criteria for determining the size classification of dams and impoundments are presented in the guidelines referenced in paragraph 1.1c above. Based on these criteria, the dam and impoundment are in the intermediate size category.

d. Hazard Classification. The hazard classification assigned by the Corps of Engineers for this dam is as follows: The Lake Arrowhead Dam has a high hazard potential, meaning that the dam is located where failure may cause loss of life, and serious damage to homes, agricultural, industrial and commercial facilities, and to important public utilities, main highways, or railroads. For the Lake Arrowhead Dam the estimated damage zone extends downstream for approximately seven miles. Within the damage zone are 21 dwellings.

e. Ownership. The dam is owned by National Development Company, P.O. Box 91, Lathrop, Missouri, 64465.

f. Purpose of Dam. The dam forms a 114-acre recreational lake.

g. Design and Construction History. Limited data relating to the design and construction was made available in the form of design drawings and boring logs by the National Development Company. The owner reported that the dam was completed in the Fall, 1975. Subsequent to surveys made by the inspection team, it is thought that the design height of dam was decreased with no alteration to the embankment design up to the existing crest.

h. Normal Operating Procedure. Normal rainfall, runoff, transpiration, evaporation, and the capacity of the spillway all combine to maintain a relatively stable water surface elevation.

PERTINENT DATA

a. Drainage Area - [illegible] acres

b. Discharge at Damsite

(1) Normal discharge at the damsite is through an uncontrolled spillway.

(2) Estimated experienced maximum flood at damsite - No information was available on the maximum flood at the damsite, however, a world record rainfall of 12 inches fell within 42 minutes in June, 1947 at Holt, Missouri approximately two miles downstream of the dam.

(3) Estimated ungated spillway capacity at maximum pool elevation 13,200 cfs (top of Dam El 940.8±).

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

(1) Top of dam - 940.8 ± (see Plate 3)

(2) Spillway crest - 927.4

(3) Streambed at toe of dam - 890 ±

(4) Maximum tailwater - Unknown.

d. Reservoir.

(1) Length of maximum pool - 11,000 feet ±

(2) Length of normal pool - 7,000 feet ±

e. Storage (Acre-feet).

(1) Top of dam - 3,209

(2) Spillway crest - 1,120

(3) Design surcharge - Unknown.

f. Reservoir Surface (Acres).

(1) Top of dam - 217

(2) Spillway crest - 114

g. Dam

(1) Type - Earth embankment

(2) Length - 890 feet

(3) Height - 50 feet +

(4) Top width - 60 feet +

(5) Side slopes - upstream face 1.0 V on 2.3 H, downstream face 1.0 V on 3.8 H (see Plate 4, surveyed section)

(6) Zoning - According to design drawings, consists of random fill, drainage blanket, and impervious fill (see Plate 4).

(7) Impervious core - Design drawings indicate the presence of impervious fill in what would normally be considered as the dam's core and extending to the upstream face. Design material is unknown (see Plate 4).

(8) Cutoff - Design drawings indicate cutoff trench extending approximately 1.0 feet into shale with side slopes of 1.0 V on 1.0 H and extending up the abutment walls.

(9) Grout curtain - None.

h. Diversion and Regulating Tunnel - None.

i. Spillway.

(1) Type - Open channel consisting of concrete, shale, and limestone.

(2) Width of channel - Varies from 100 to 250 feet.

(3) Crest elevation - 927.4 feet m.s.l.

(4) Gates - None.

(5) Upstream channel - Not applicable.

(6) Downstream channel - Open channel comprised of broken limestone and shale located near the toe of the downstream embankment slope.

j. Regulating Outlets - None.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

Limited design data consisting of design drawings and boring logs were made available by the owner.

2.2 CONSTRUCTION

Construction records were not available, however, the owner reported the dam was completed in the Fall, 1975 by the National Development Company.

2.3 OPERATION

Procedural criteria for operation of this dam were not available. Documentation of past experiences of a serious nature were also not available.

2.4 GEOLOGY

The dam is constructed across a shallow valley containing Muddy Fork. The soil of the dam and reservoir areas consists of the Marshall silt loam soil series (Geology and Soils Manual, Missouri State Highway Commission, 1962) which is derived from loess and consists of sand, silt, and clay. For engineering purposes the soils are classified as clayey silt (ML) and silty clay (CL). The bedrock of the area consists of limestone and shale of the Kansas City and Lansing Groups of the Pennsylvanian System.

Plate 6 shows subsurface interpretations of boring data taken along the centerline of the dam prior to its construction (from design drawings). These interpretations indicate the soil varies in thickness from a few feet on the slopes to 15 feet in the valley. The soil on the slopes and the hill crests consists of clay, and the soil in the valley consists of topsoil over clay over sand. Bedrock consists of interbedded limestone and shale units of the Kansas City and Lansing Groups. The contact between the Lansing and Kansas City Groups occurs at Elevation 945±.

The core trench foundation of the dam is shown to be in a shale unit of the Wyandotte Formation of the Kansas City Group. All soil material for the core trench foundation is shown on the design drawings to be removed during construction and replaced with impervious fill. Actual conditions are unknown. The abutments of the dam are shown to be in a thin limestone unit of the Wyandotte Formation and the Bonner Springs Shale Formation of the Kansas City Group.

The spillway of the dam is located at the left abutment between the embankment and a steep hill slope. The hill slope consists of interbedded limestones and shales of the Lansing and Kansas City Group as shown on Plate 6 and Photo 5. The spillway is unlined and constructed in the Bonner Springs Shale. A limestone unit (approximately 2 feet thick) of the Bonner Springs Shale is exposed at the downstream end of the spillway discharge channel. This unit contains two sets of vertical joints normal to each other which have been exposed by erosion. This unit is present in the abutments although the condition of the joints is unknown. A limestone unit (approximately 7 feet thick) of the Wyandotte Formation is exposed further down the discharge channel. It also contains two sets of vertical joints and is present in the abutments. The condition of the joints is unknown. A mantle of loess over residual soil overlies the bedrock along the discharge channel.

2.5 EVALUATION

a. Availability. Only limited engineering data in the form of design drawings and boring logs were obtained from the National Development Company.

b. Adequacy. Limited engineering data were available from which to make an assessment of the design, construction, and operation. Engineering data for making a detailed assessment were not 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 and made a matter of record.

c. Validity. The validity of the design, construction, and operation could not be determined due to the unavailability of design and construction data in addition to insufficient data to coordinate the exact location of the boring holes corresponding with available boring logs. The boring plan from the design drawings did not correspond to available boring logs.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. A visual inspection of Lake Arrowhead Dam was made on 31 May 1979. The inspection team included professional engineers with experience in dam design and construction, hydrology - hydraulic engineering, and geotechnical engineering. Specific observations are discussed below. No observations were made of the condition of the upstream face of the dam below the pool elevation at the time of the inspection.

b. Dam. The inspection team observed the following items at the dam. Riprap on the upstream face consists of large, randomly placed boulders and limestone slabs. Erosion of embankment material beneath the riprap has occurred in the large void areas of the riprap protection. The downstream embankment face was covered with 3- to 4-feet high weeds which hampered a thorough visual inspection. Several erosion gullies were observed on the downstream face of the dam which appeared to be the results of surface runoff. These gullies extended from the crest of the dam, down the slope, across the berm, and down the berm slope to the spillway channel. The larger gullies were about 3 feet wide and 2 to 3 feet deep. (Photos 10, 11, and 12).

Minor seepage was observed dripping from joints in the limestone of the right abutment. The magnitude of flow was extremely minute.

A flow of clear water approximately 5 to 6 gpm was observed between the limestone and shale formations exposed in the spillway channel upstream of the first falls. The seepage area was observed at an elevation higher than the adjacent spillway flow. The flow appeared to be that of seepage rather than part of the discharge over the spillway crest. Inspection of the spillway channel upstream of the seepage area revealed no source of entry where water could flow to beneath the spillway channel. The source of the seepage flow is thought to be from the lake.

The inspection team sought to locate the outlets for the drainage blanket shown on the design drawings. The outlets could not be located; thus, it is speculated that the embankment drainage blanket, if constructed, is ineffective in dispensing seepage through the embankment.

Animal burrows were observed at various locations along the embankment. The crest of the dam was uniform, wide, and in good condition. No sinkholes, settlement, sliding, or cracking of the embankment were observed at the time of inspection.

c. Appurtenant Structures. The inspection team observed the following items pertaining to appurtenant structures. The only discharge

outlet for the reservoir is a spillway constructed at the left abutment of the structure. The spillway was constructed by excavating a channel in existing limestone, shale, clay, and loessial deposits. The spillway crest consists of a concrete low water crossing. The remainder of the spillway channel downstream of the crest is unlined and eroding along the channel bottom and adjacent side slopes. A berm is located at the right bank of the spillway channel adjacent to the embankment which was constructed to direct spillway discharges away from the downstream embankment toe. This berm is sloughing and eroding due to inadequate provision for slope protection. The spillway channel has two falls which allow discharges to proceed through the remainder of the excavation to the original stream channel. Erosion of the berm and excavation slopes is extensive in the areas of these falls. A flow of approximately 5 to 6 gpm was observed in the limestone joints of the spillway excavation.

d. Reservoir Area. No slides or excessive erosion due to wave action were observed along the shore of the reservoir.

e. Downstream Channel. An open channel comprised of broken limestone and shale is located near the toe of the downstream embankment slope.

f. Geology. A visual inspection of the dam and the immediate area was conducted to verify the geology in which the dam was constructed. The embankment consists of silty clay and was observed to be severely eroding at the water line beneath the large boulders and limestone slabs placed on the upstream face. One outcrop of limestone, 3-feet thick, thin-bedded with widely spaced vertical joints and horizontal bedding, was observed where the right abutment joins the downstream face of the embankment. Minor seepage was observed from the limestone unit. Shale covered with loess (silt) was observed in the left abutment downstream of the centerline of the dam. The spillway is formed in shale to the left of the dam and is cut through the edge of a hill between the hill and the embankment. The discharge channel of the spillway consists of shale and limestone and contains two benches formed along the limestone units. A flow of approximately 5 to 6 gpm was observed from the limestone formations.

3.2 EVALUATION

The inspection team observed deficiencies which warrant attention. None of these deficiencies should be considered to be in an emergency category, although, in order to maintain this dam in good condition, they should be rectified.

(1) Lack of adequate slope protection along the berm constructed at the right of the spillway has resulted in sloughing and erosion of material adjacent to areas of potentially high spillway discharge flow.

Should this berm continue to erode, severe damage to the embankment could result.

(2) The inadequacy of proper vegetal cover on the downstream face has contributed to formation of erosion gullies. Establishment and maintenance of proper vegetal cover on the downstream face and repair of erosion damage are needed to preclude more serious embankment damage. Proper cleaning, backfilling, and compaction of eroded areas should also be accomplished.

(3) The improper placement and extremely random size of riprap on the upstream embankment face has proved conducive to erosion of embankment material beneath the riprap. Reconstruction or extensive repair of the riprap protection and repair of eroded areas of the upstream face may preclude development of more severe erosion.

(4) The potential for uncontrolled seepage through an embankment is lessened with the installation of a drainage blanket near the downstream toe. Although the design drawings indicate the presence of a drainage blanket and outlets, the inspection team was unable to locate the outlets. It is felt that these outlets must be located and maintained free of debris to function as intended.

(5) Animal burrows were located on the upstream and downstream embankment slopes as well as the berm to the right of the spillway. These burrows may ultimately jeopardize the safety of an earthen structure. A program designed to control burrowing animals should be implemented to include proper cleaning, backfilling, and compaction of these areas.

(6) Seepage near the right abutment and beneath the spillway channel should be monitored regularly with documentation of observed changes in the quality and/or quantity of the discharge.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

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

4.2 MAINTENANCE OF DAM

Maintenance performed was unknown.

4.3 MAINTENANCE OF OPERATING FACILITIES

No operating facilities are known to exist.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

There is no existing warning system or preplanned scheme for warning occupants of the hazard zone for this dam.

4.5 EVALUATION

The apparent lack of maintenance of this structure has resulted in development of severe erosion on the upstream and downstream faces. As mentioned in Section 3, the absence of adequate slope protection and/or vegetal cover has contributed to the deteriorating condition of the embankment and spillway berm. Subsequent to the introduction of proper riprap and vegetal cover, and removal of burrowing animal holes, a periodic inspection and maintenance of these items should be initiated.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. Limited design data pertaining to hydrology and hydraulics were available. Independent calculations were performed for this report in accordance with the referenced guidelines.

b. Experience Data. The drainage area and lake surface area are developed from USGS Plattsburg Quadrangle Map. The spillway and dam layouts are from surveys made during the inspection and available design documents.

c. Visual Observations.

(1) The spillway is in fair condition. The discharge channel of the spillway and adjacent berm need better side slope protection.

(2) No facilities are available which could serve to draw down the pool.

(3) A spillway and exit channel are located at the left abutment. Spillway discharges may endanger the integrity of the dam due to the fact that overflow from the spillway has caused erosion of the spillway berm which protects the embankment.

d. Overtopping Potential. The spillway will not pass the probable maximum flood without overtopping the dam. The probable maximum flood is defined as the flood discharge which may be expected from the most severe combination of critical meteorologic and hydrologic conditions which are reasonably possible in the region. The spillway will pass 50 percent of the probable maximum flood and the 100-year flood without overtopping the dam. According to the recommended guidelines from the Department of the Army, Office of the Chief of Engineers, a high hazard dam of intermediate size should pass 100 percent of the probable maximum flood. The portion of the estimated peak discharge of the probable maximum flood overtopping the dam would be 13,000 cfs of the total discharge from the reservoir of 29,000 cfs. The estimated duration of overtopping is 3.7 hours with a maximum height of 2.8 feet above the top of dam. There is evidence that the silty soils characteristic of the embankment tend to erode. Although the inspection team found no evidence of overtopping of the embankment, prolonged overtopping of the embankment may cause erosion which could lead to failure. Failure of upstream water impoundments shown on the USGS map would not have a significant impact on the hydrologic or hydraulic analysis.

According to the St. Louis District, Corps of Engineers, the effect from rupture of the dam is estimated to extend approximately seven miles downstream of the dam. There are 21 dwellings downstream of the dam which could be severely damaged and lives could be lost should failure of the dam occur.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

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

b. Design and Construction Data. Design data relating to the structural stability of the dam were not available. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were unavailable, which is considered a deficiency. Detailed seepage and stability analysis should be performed as required by the guidelines.

c. Operating Records. No operational records were available.

d. Post Construction Changes. No known post construction changes.

e. Seismic Stability. The dam is located in Seismic Zone 1 which is a zone of minor seismic risk. A properly designed and constructed earth dam using sound engineering principles and conservatism should pose no serious stability problems during earthquakes in this zone.

Adequate descriptions of embankment design parameters, foundation and abutment conditions, or static stability analyses to assess the seismic stability of this embankment were not available and therefore no inferences will be made regarding the seismic stability. An assessment of the seismic stability should be included as part of the stability analysis required by the guidelines.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. Several items noted during the visual inspection by the inspection team which should be monitored or controlled are erosion of the embankment at the downstream face, erosion of the embankment material in voids of the large riprap on the upstream face, erosion of berm material at the right of the spillway, and the presence of animal burrows. The drainage blanket discharge outlets should be located and maintained free of debris. Seepage near the right abutment and beneath the spillway floor should be monitored for changes in the quality and/or quantity of discharge.

b. Adequacy of Information. The conclusions in this report were based only on performance history, visual conditions, and the available engineering design data. The inspection team considers that these data are sufficient to support the conclusions herein. However, seepage and stability analyses comparable to the requirements of the guidelines were not available, which is considered a deficiency.

c. Urgency. It is the opinion of the inspection team that a program should be developed to implement remedial measures recommended in paragraph 7.2b. If the safety deficiencies listed in paragraph 7.1a are not corrected, they will continue to deteriorate and lead to potential failure.

d. Necessity for Phase II. The Phase I investigation does not raise any serious questions relating to the safety of the dam or identify any serious dangers which would require a Phase II investigation.

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

7.2 REMEDIAL MEASURES

a. Alternatives. The existing spillway has the capacity to pass 50 percent of the probable maximum flood without overtopping the dam. In order to pass 100 percent of the probable maximum flood as required by the Recommended Guidelines, the spillway size and/or height of dam will need to be increased.

b. Operation and Maintenance Procedures. The following operation and maintenance procedures are recommended:

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

(2) The side slopes of the spillway discharge channel should be protected from erosion especially near the dam embankment to prevent additional erosion.

(3) Measures should be implemented to monitor and maintain control of burrowing animals. Existing burrows should be repaired through proper cleaning, backfilling, and compaction.

(4) The erosion of the downstream face due to inadequate and improper vegetal cover and the upstream face due to the large voids in the riprap should be repaired. Introduction of proper vegetal or riprap cover should be implemented to improve the slope protection in both instances.

(5) Eroded areas of the embankment and appurtenances should be properly cleaned, backfilled, and compacted.

(6) The drainage blanket outlets should be located, cleaned, and maintained free of debris.

(7) Seepage through the embankment or abutments and beneath the spillway floor should be carefully monitored periodically with documentation of observed conditions relating to the quantity and quality of seepage discharges. Should the quality decrease and/or the quantity increase of the seepage flow, a professional engineer experienced in earthen embankment design and construction should be retained to evaluate the seepage.

(8) A detailed inspection of the dam should be made periodically by an engineer experienced in design and construction of dams. More frequent inspections may be required if additional deficiencies are observed or the severity of the reported deficiencies increases.

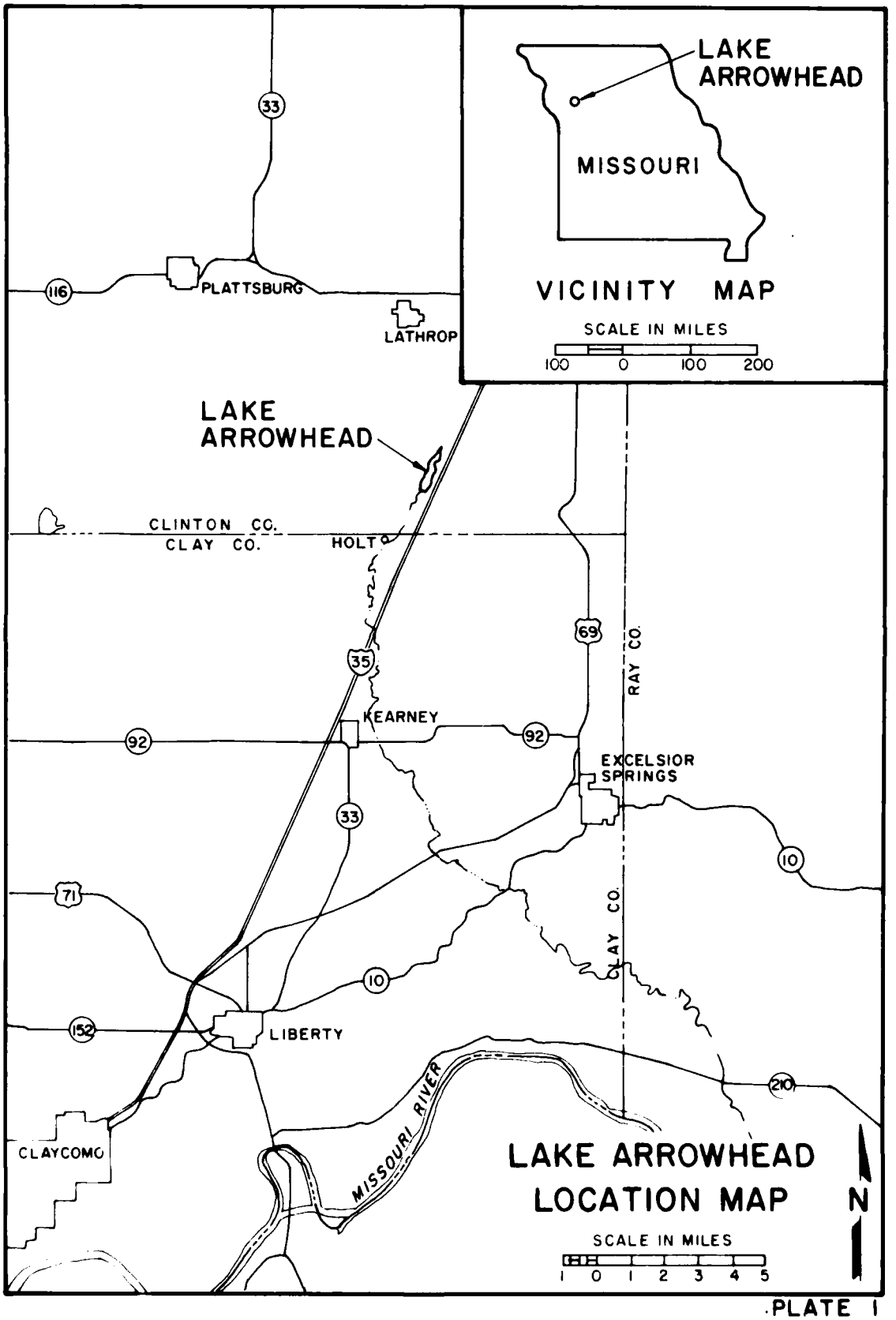

LAKE ARROWHEAD
MISSOURI
VICINITY MAP
SCALE IN MILES
100 0 100 200
33
116
PLATTSBURG
LATHROP
LAKE ARROWHEAD
CLINTON CO.
CLAY CO.
HOLT
69
RAY CO.
35
KEARNEY
92
92
EXCELSIOR SPRINGS
33
10
71
CLAY CO.
10
152
LIBERTY
210
CLAYCOMO
MISSOURI RIVER
LAKE ARROWHEAD LOCATION MAP
N
SCALE IN MILES
1 0 1 2 3 4 5

PLATE 1

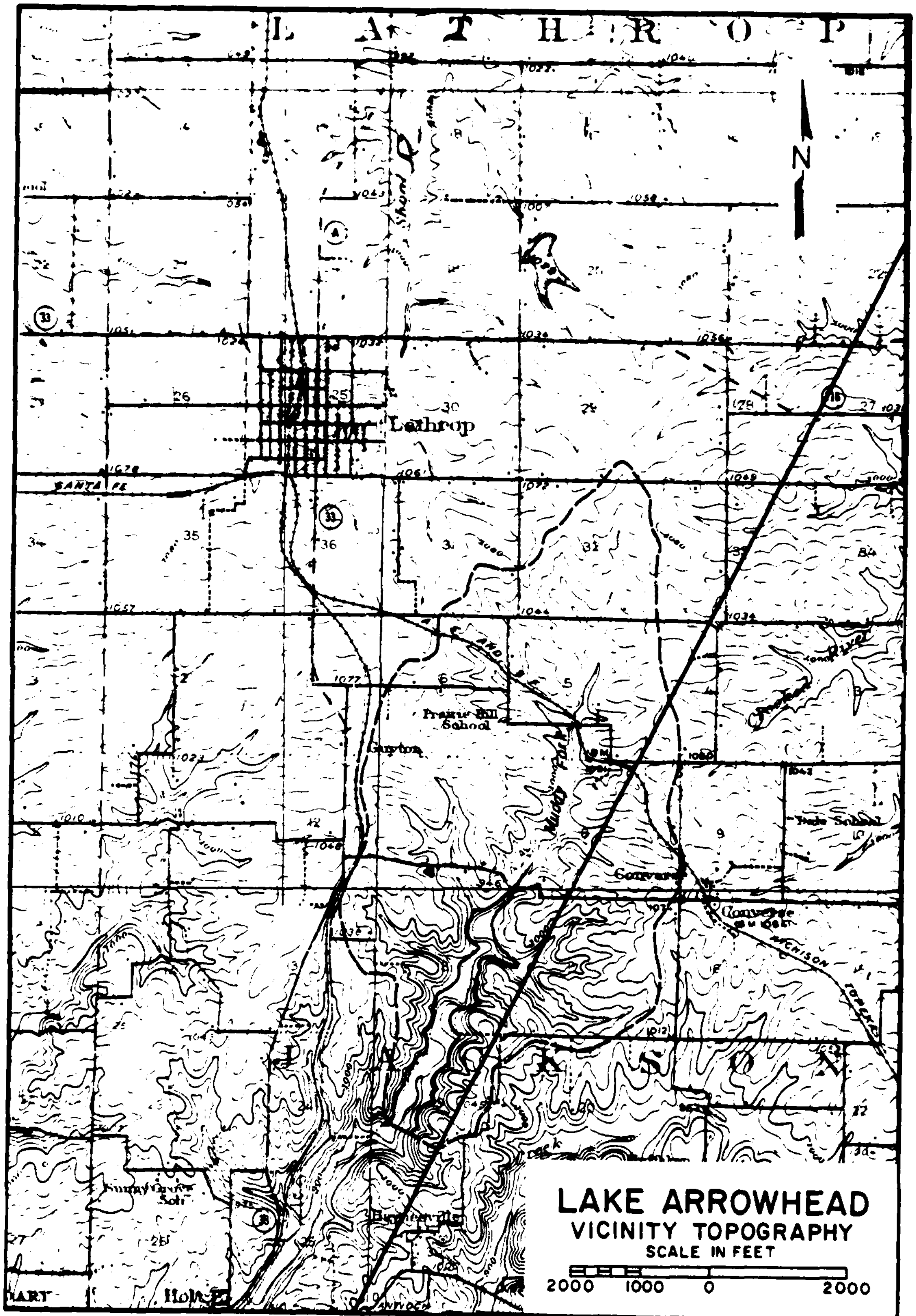
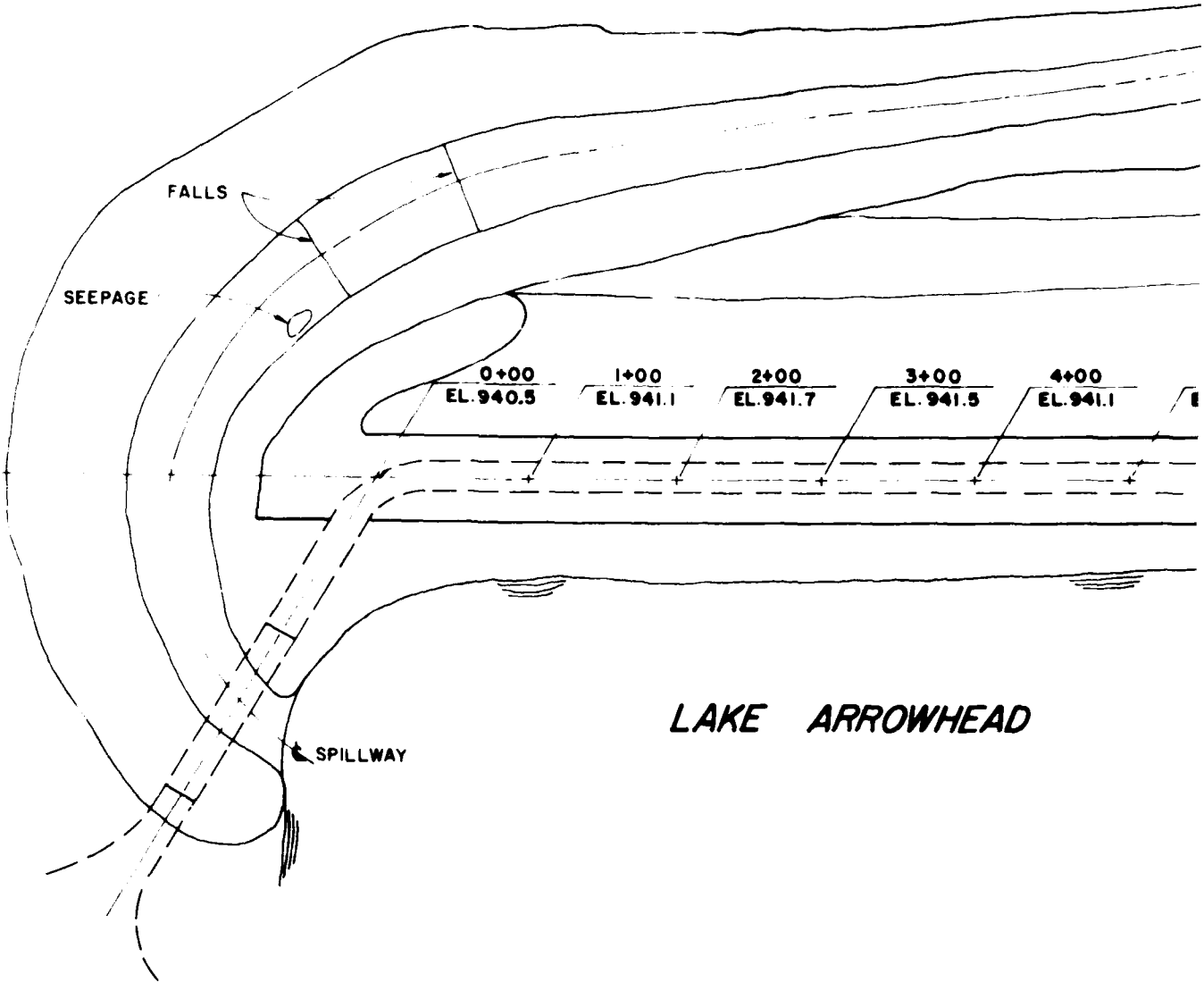
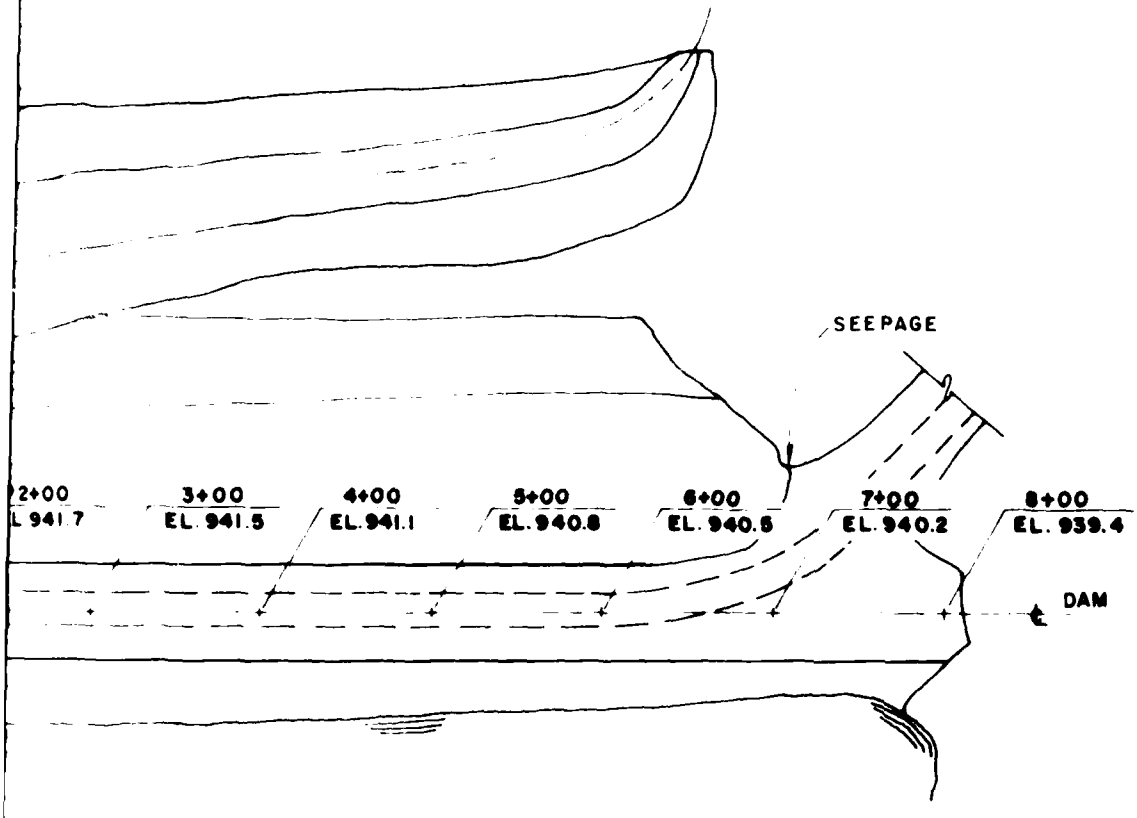

L A T H R O P
N
Lathrop
SANTA FE
Prairie Hill School
Gayton
Converse
J A C K S O N
LAKE ARROWHEAD
VICINITY TOPOGRAPHY
SCALE IN FEET
2000 1000 0 2000

PLATE 2


FALLS
SEEPAGE
0+00
EL. 940.5
1+00
EL. 941.1
2+00
EL. 941.7
3+00
EL. 941.5
4+00
EL. 941.1
SPILLWAY
LAKE ARROWHEAD

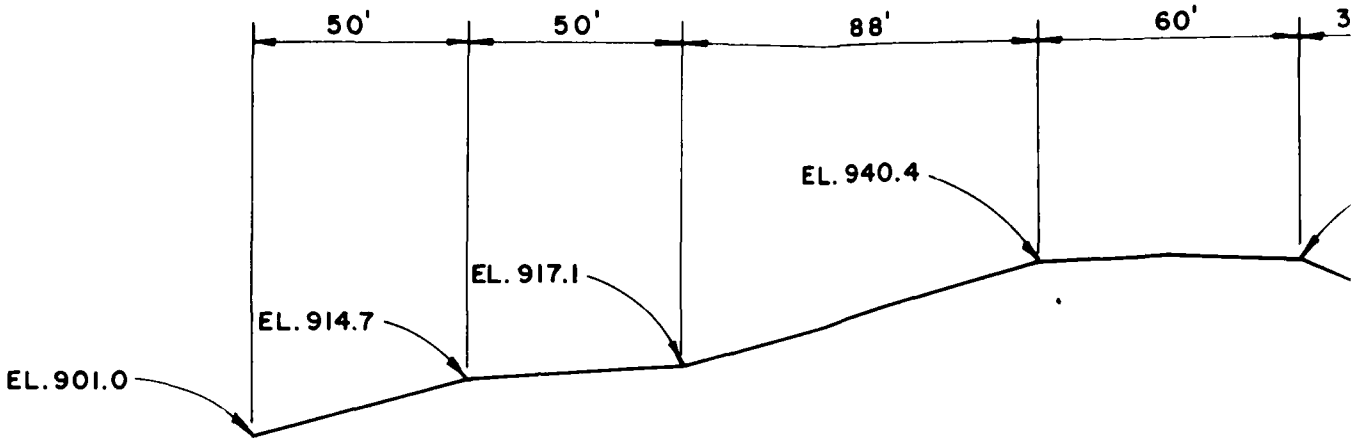


E ARROWHEAD

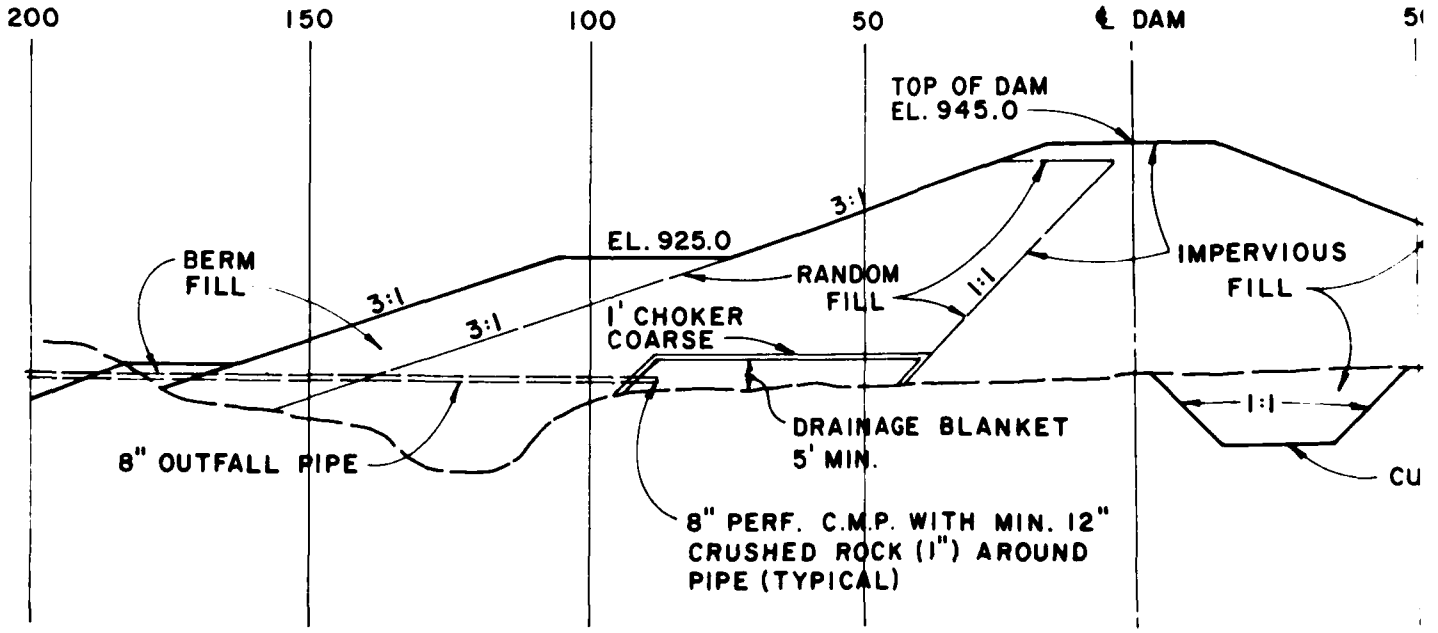
N

LAKE ARROWHEAD
PLAN

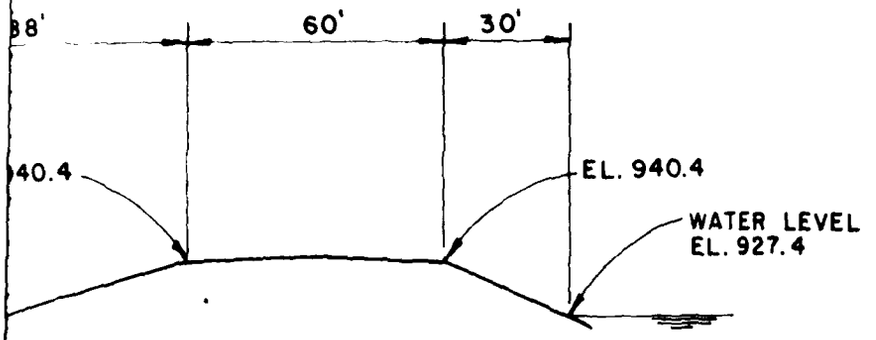
PLATE 3



SURVEYED SECTION TAKEN AT APPROX. STATION 4+2



SECTION FROM DESIGN DRAWING AT STATION 7+00
(PROVIDED BY OWNER)



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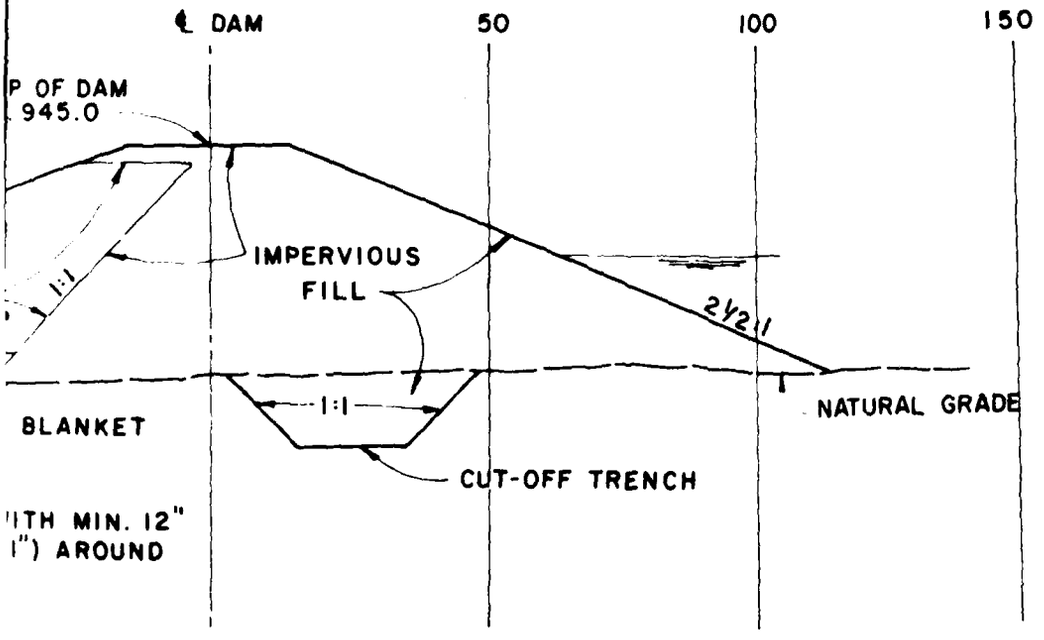
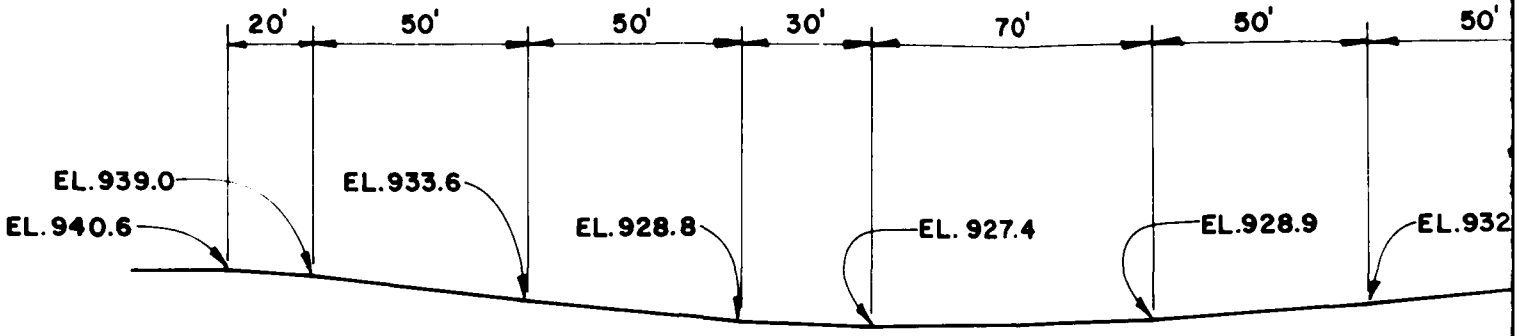


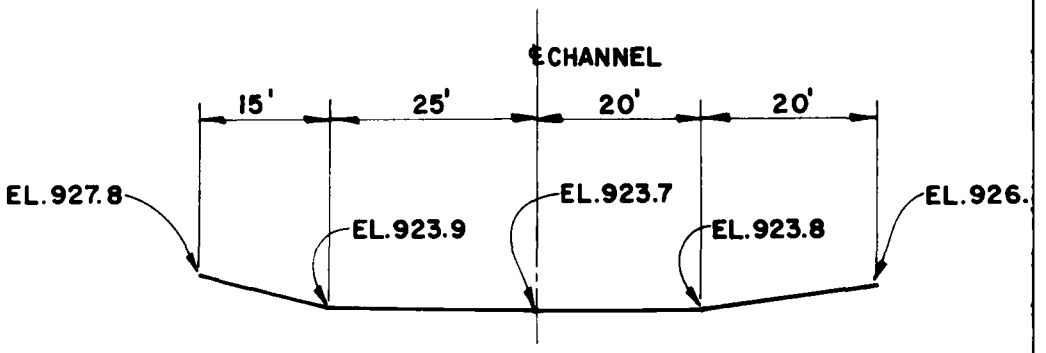
GN DRAWING AT STATION 7+00
IER)

LAKE ARROWHEAD
TYPICAL SECTION

PLATE 4

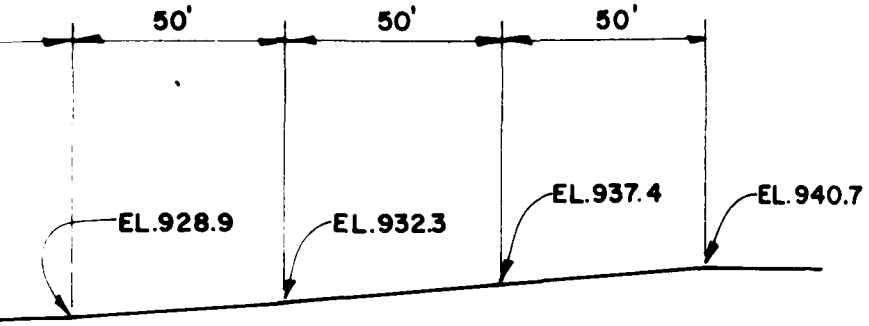


SPILLWAY CREST SECTION



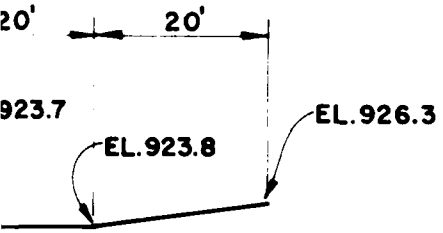
CHANNEL SECTION

(400 FEET DOWNSTREAM OF SPILLWAY CREST)



T SECTION

INEL

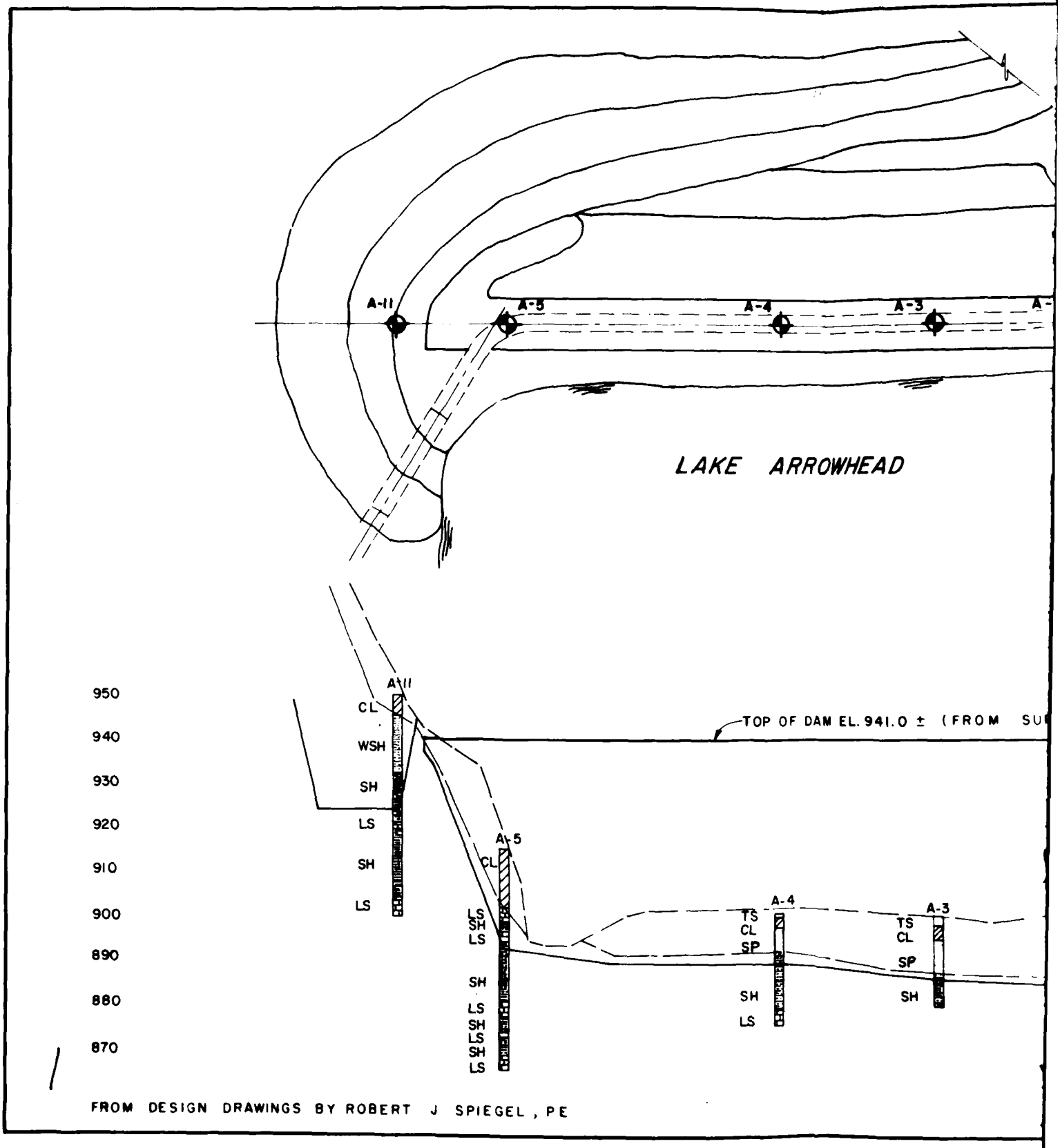


ECTION

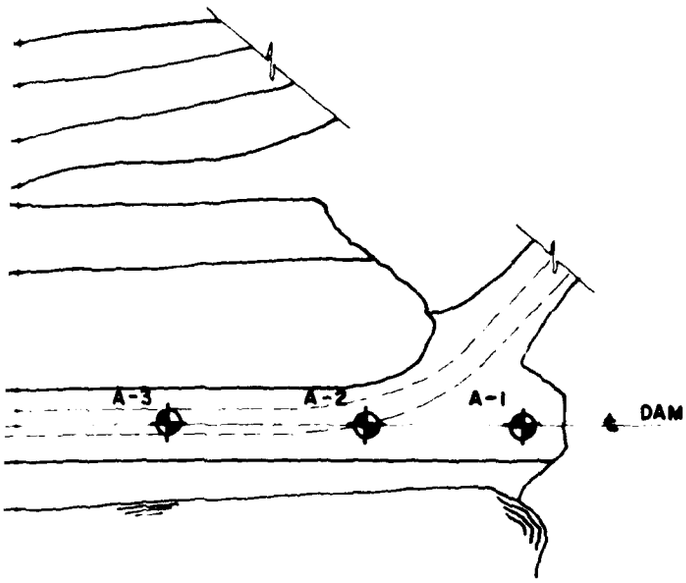
I OF SPILLWAY CREST)

LAKE ARROWHEAD
SECTIONS

PLATE 5

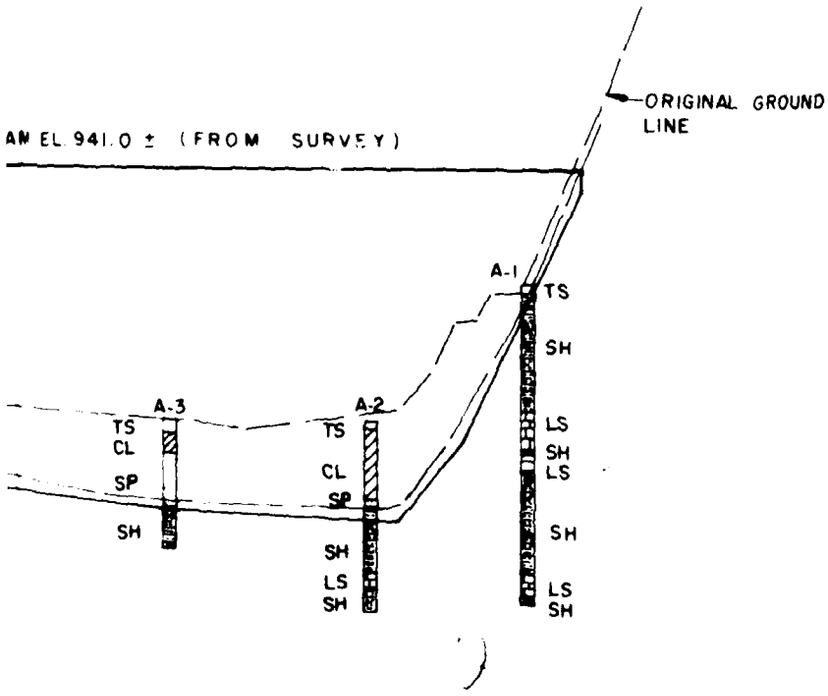


FROM DESIGN DRAWINGS BY ROBERT J SPIEGEL, PE



'OWHEAD

N

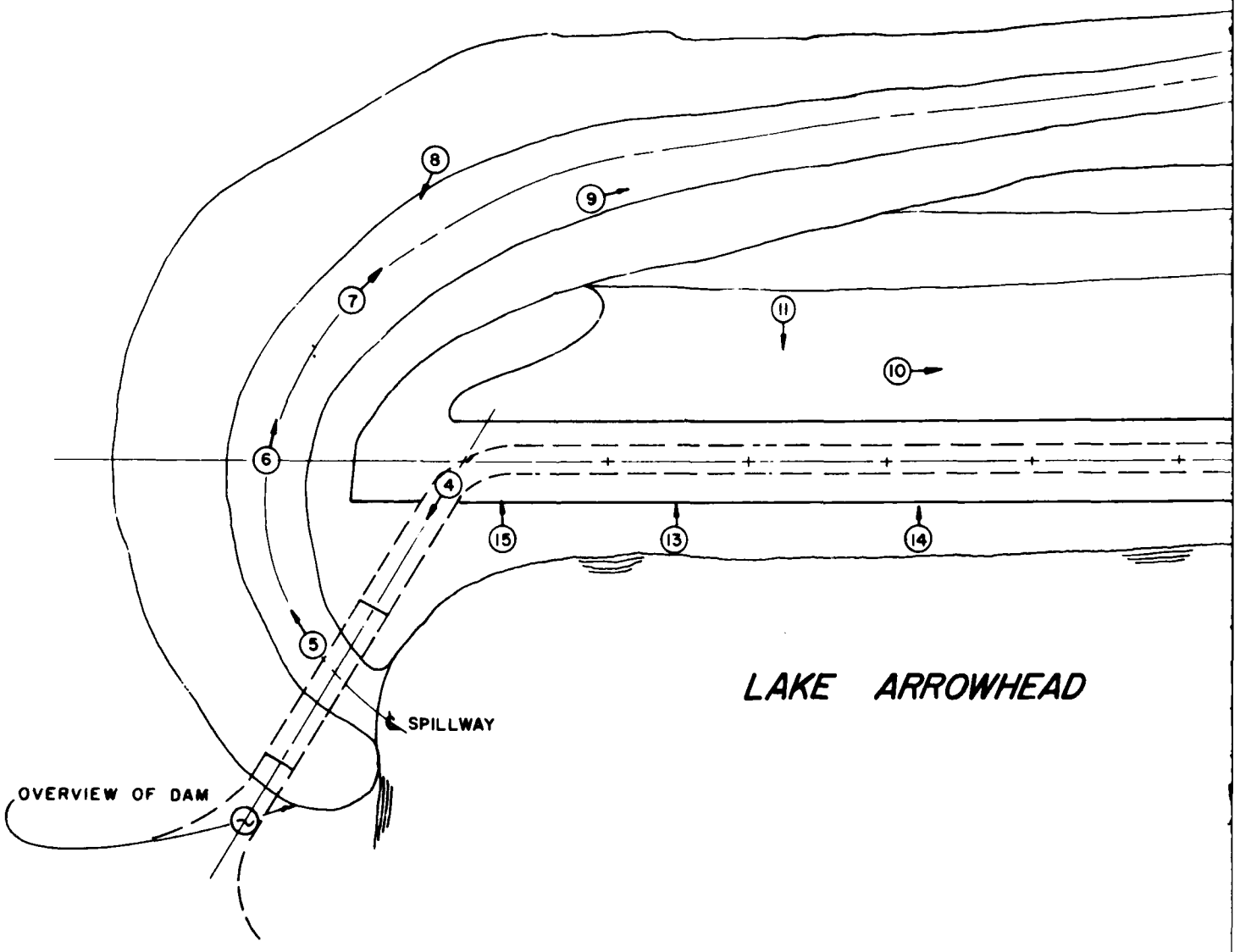


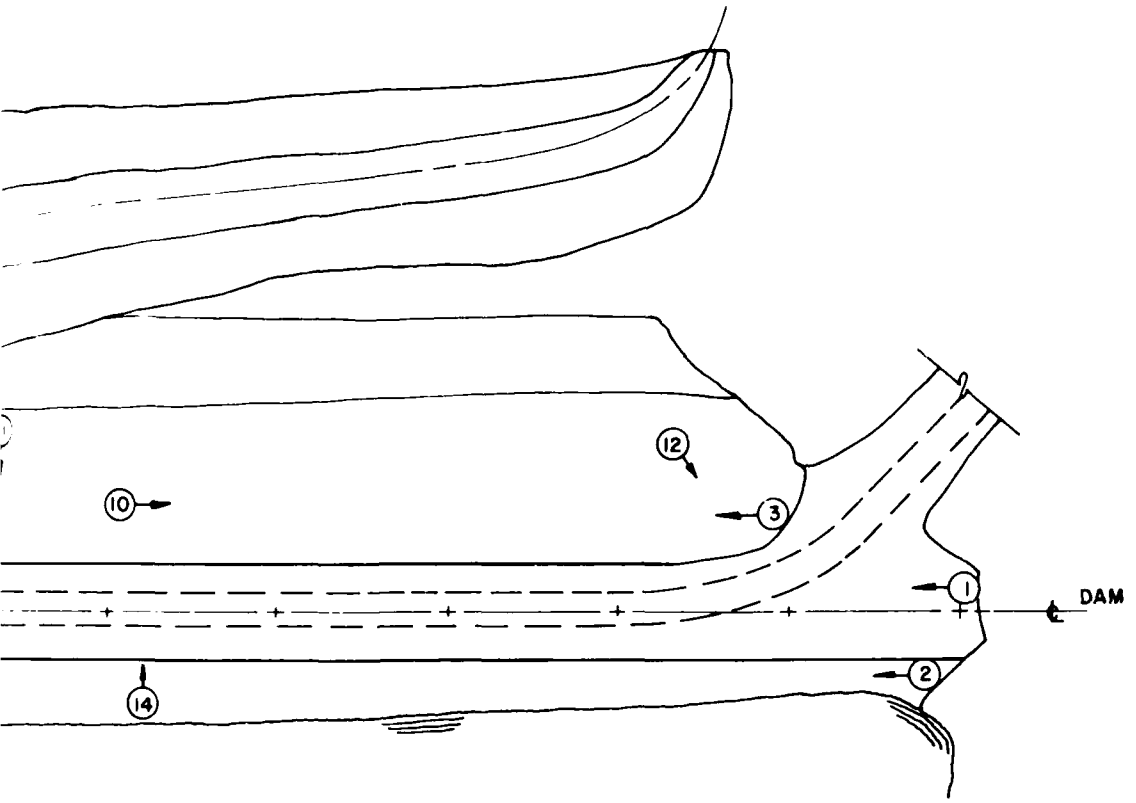
LEGEND

⊕	BORING HOLE LOCATION
CL	CLAY
WSH	WEATHERED SHALE
SH	SHALE
LS	LIMESTONE
SP	SAND
TS	TOPSOIL

LAKE ARROWHEAD BORING PLAN

PLATE 6


8
9
7
11
10
6
4
15
13
14
5
SPILLWAY
OVERVIEW OF DAM
LAKE ARROWHEAD



KE ARROWHEAD

N

LAKE ARROWHEAD
PHOTO INDEX

PLATE 7

PHOTO 1: CREST OF DAM (FROM RIGHT ABUTMENT)

PHOTO 2: UPSTREAM FACE (FROM RIGHT ABUTMENT)

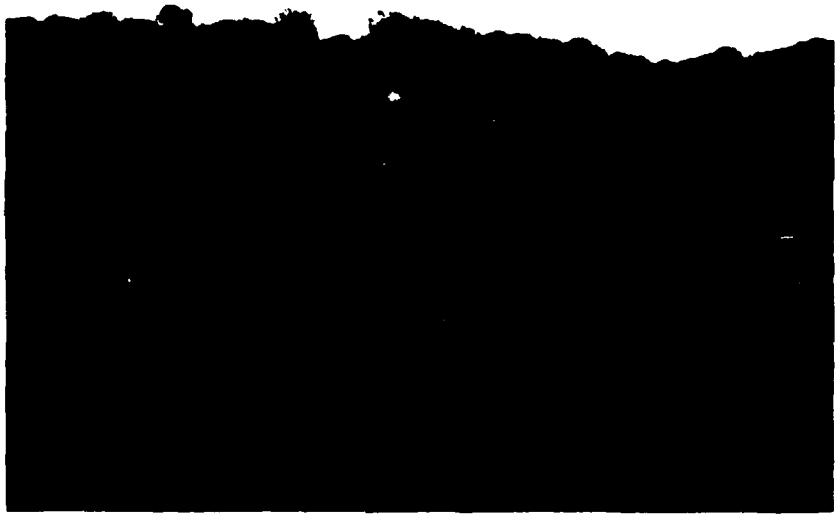


PHOTO 3: DOWNSTREAM FACE (FROM RIGHT ABUTMENT)

PHOTO 4: SPILLWAY (FROM CREST OF DAM)

PHOTO 5: SPILLWAY DISCHARGE CHANNEL (FROM SPILLWAY CREST LOOKING DOWNSTREAM)

PHOTO 6: SPILLWAY DISCHARGE CHANNEL (200 FEET DOWNSTREAM OF SPILLWAY CREST)

PHOTO 7: SPILLWAY DISCHARGE CHANNEL (400 FEET DOWNSTREAM OF SPILLWAY CREST AT BRINK OF LIMESTONE)

PHOTO 8: LIMESTONE AND SHALE FALLS (LOOKING UPSTREAM IN SPILLWAY CHANNEL)

PHOTO 9: DOWNSTREAM DISCHARGE CHANNEL

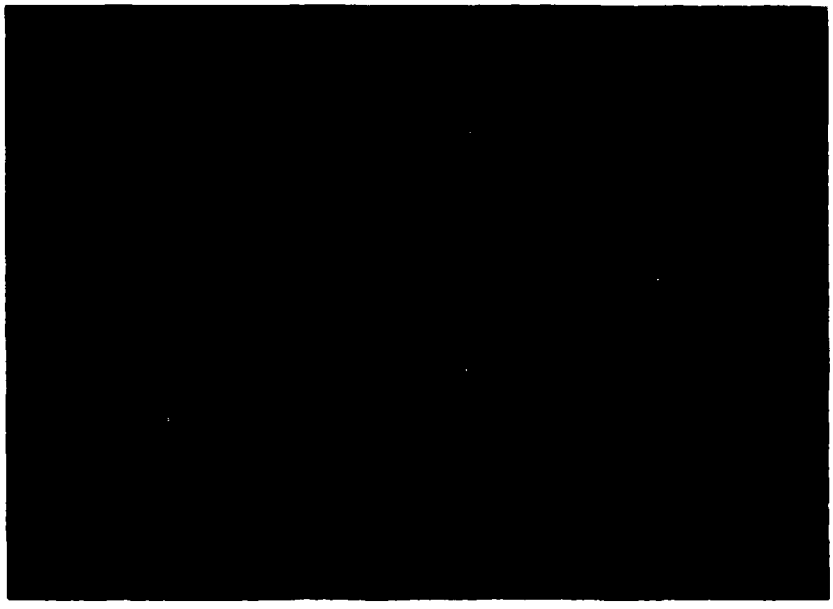


PHOTO 10: DOWNSTREAM EMBANKMENT EROSION, TYPICAL COVER

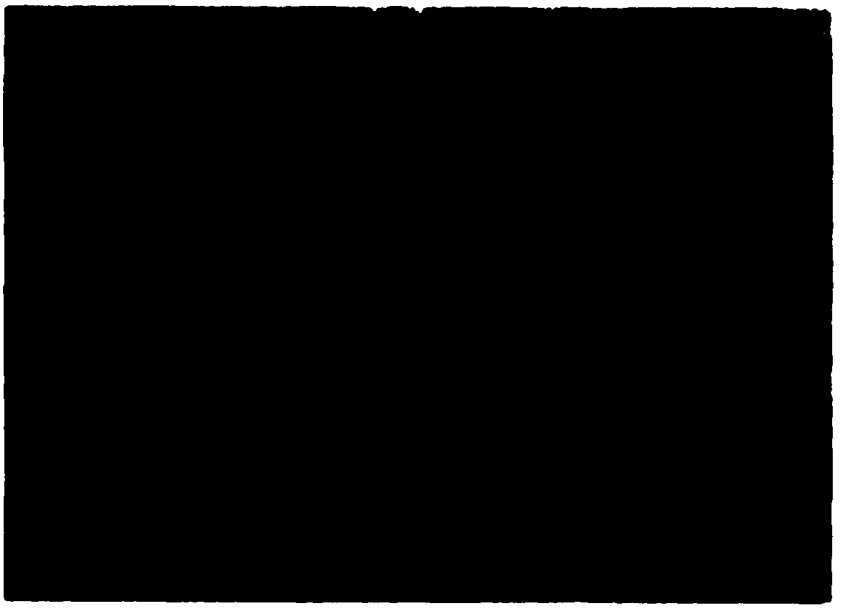


PHOTO 11: EROSION GULLY ON DOWNSTREAM FACE

PHOTO 12: EROSION GULLY ON DOWNSTREAM FACE NEAR RIGHT ABUTMENT

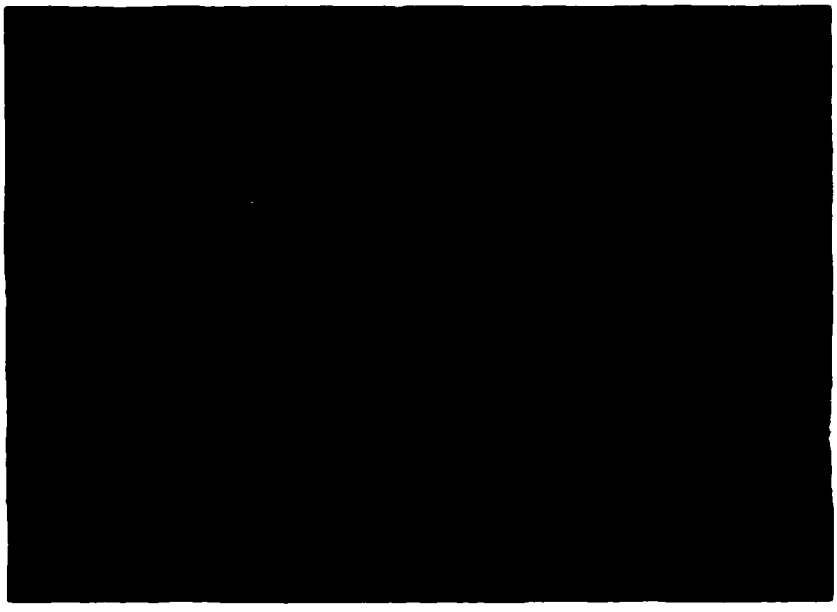


PHOTO 13: EROSION OF EMBANKMENT MATERIAL BENEATH RIPRAP ON UPSTREAM FACE

PHOTO 14: EROSION OF EMBANKMENT MATERIAL BENEATH RIPRAP ON UPSTREAM FACE

PHOTO 15: ANIMAL BURROW ON UPSTREAM FACE

APPENDIX A

HYDROLOGIC COMPUTATIONS

HYDROLOGIC COMPUTATIONS

1. The Soil Conservation Service (SCS) dimensionless unit hydrograph and HEC-1 (1) were used to develop the inflow hydrographs, and hydrologic inputs are as follows:

a. Forty-eight hour, probable maximum precipitation determined from U.S. Weather Bureau Hydrometeorological Report No. 33.

200 square mile, 24 hour rainfall inches	- 24.5
10 square mile, 6 hour percent of 24 hour 200 square mile rainfall	- 101%
10 square mile, 12 hour percent of 24 hour 200 square mile rainfall	- 120%
10 square mile, 24 hour percent of 24 hour 200 square mile rainfall	- 130%
10 square mile, 48 hour percent of 24 hour 200 square mile rainfall	- 140%

b. Drainage area = 5,030 acres.

c. Time of concentration:

$$Lag = C_T(LL_{CA})^{0.3}$$

Lag = time from midpoint of rainfall to peak discharge in hours.

L = length of watershed in miles.

L_{CA} = Length along main channel to a point opposite the watershed centroid in miles.

C_T = Coefficient of watershed characteristics = 2.0.

Lag = 1.4 hours (2).

T_c = 2.3 hours (3).

d. Losses were determined in accordance with SCS methods for determining runoff using a curve number of 86 and antecedent moisture condition III. The hydrologic soil groups in the basin were types B, C, and D.

e. Listed below is the most current information regarding the major soils found in the Lake Arrowhead drainage area. These soil names were obtained from Mr. Martin W. Burch, District Conservationist, from an advance field sheet prepared by the Soil Conservation Service and were noted as being subject to change.

Soil Name		Est. % of Area	Hydrologic Group
Grundy	14B	5	C
Sharpsburg	7B	5	B
Lagonda	11C	5	C
Lamoni	42C	8	D
Armstrong	33C & D	10	D
Ladoga	16B & C	2	B
Gara	37D & E	5	C
Nodaway	61	15	B
Armster	31D	2	C
*Gossport	29D	2	D
*Gossport	229D	32	D
Wyota	222	3	B
*Gossport	5C	3	D
Nevin	24	3	C

*These soils are being proposed as a new series. They are similar to the presently named Gossport series.

2. Spillway release rates are based on backwater calculation within the spillway discharge channel with the critical depth occurring at or near the brink of the limestone and shale falls.

Discharge rates over the top of the dam are based on the weir equation:

$$Q = CLH^{1.5}$$ (C = 3.1, L = 890 feet, H = head on the dam in feet).

3. The elevation-storage relationship above normal pool elevation was constructed by planimetering the area enclosed within each contour above normal pool. The storage between two elevations was computed utilizing the conic method for computation of reservoir volume provided in HEC-1(1). The summation of these increments below a given elevation is the storage below that level.

4. Floods are routed through the spillway using HEC-1, modified Puls to determine the capability of the spillway.

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

(2) Ven Te Chow, Editor-in-Chief, Handbook of Applied Hydrology, McGraw-Hill, 1964.

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

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**********
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  26 FEB 79
**********
     1              AIMISSOURI DAM INSPECTION PROGRAM
     2              A2ST. LOUIS DISTRICT US ARMY CORPS OF ENGR
     3              A3LAKE ARROWHEAD  MO ID NO 11016
     4              B    144       0      20       0       0       0       0       0       0       0
     5              B1     5
     6              J      1       3       1
     7              J1   .45     .50     1.0
     8              K      0  INFLOW                                       3
     9              K1    48 HR PMF INFLOW TO LAKE ARROWHEAD
    10              M      1       2    7.86                               1
    11              P             24.4     101     120     130     140
    12              T                                                    -1     -86
    13              W2           1.4
    14              X                      T
    15              K      1     DAM                                       1
    16              K1    ROUTE THROUGH SPILLWAY OF LAKE ARROWHEAD DAM
    17              Y                                      T       T
    18              Y1     1                                            -927.4      -1
    19              Y4927.4 928.28  928.57  928.82  929.2   930.06  930.86  931.59  932.24  932.85
    20              Y4933.42933.96  934.47  934.97  935.92  936.81  937.65  938.44  939.19  942.58
    21              Y50.    100.    200.    300.    500.    1000.   1500.   2000.   2500.   3000.
    22              Y53500. 4000.   4500.   5000.   6000.   7000.   8000.   9000.   10000.  15000.
    23              $A     5     58.    208.    436.
    24              $E   900.    920.    940.    960.
    25              $$927.4
    26              $$940.8 3.1     1.5     890.
    27              K      99
```

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS		
				RATIO 1 .45	RATIO 2 .50	RATIO 3 1.00
HYDROGRAPH AT	INFLOW	7.86	1	13949.	15499.	30997.
		(20.36)		(394.98)(	438.87)(	877.74)(
ROUTED TO	DAM	7.86	1	10019.	11227.	29423.
		(20.36)		(283.72)(	317.92)(	833.16)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	927.40	927.40	940.80
STORAGE	1120.	1120.	3209.
OUTFLOW	0.	0.	12375.

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
.45	939.20	0.00	2876.	10019.	0.00	42.00	0.00
.50	940.02	0.00	3044.	11227.	0.00	42.00	0.00
1.00	943.60	2.80	3850.	29423.	3.67	41.33	0.00

END

DATE
FILMED

11-81

DTIC