

AD-A105 985

WOODWARD-CLYDE CONSULTANTS CHICAGO IL
NATIONAL DAM SAFETY PROGRAM, LAKE AGGRAVATION DAM (MO 30557). M--ETC(U)
SEP 80

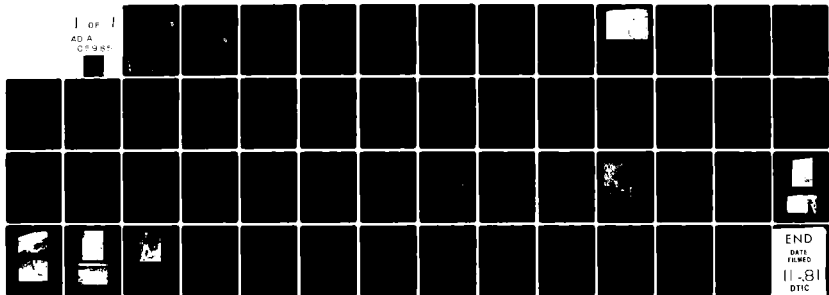
F/G 13/13

DACW43-80-C-0066

NL

UNCLASSIFIED

1 of 1
AD A
CROSS*



END
DATE
FILMED
11-81
DTC

LEVEL II

(1)

MISSISSIPPI-KASKASKIA-ST. LOUIS BASIN

AD A105985

LAKE AGGRAVATION DAM
FRANKLIN COUNTY, MISSOURI
MO. 30557

DTIC
COLLECTED
OCT 22 1981
D
H

**PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY INSPECTION**



**United States Army
Corps of Engineers**

... Serving the Army
... Serving the Nation

St. Louis District

*Original contains color
plates: All DTIC reproductions
will be in black and
white*

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

FOR: STATE OF MISSOURI

SEPTEMBER 1980

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

81 10 21

ENC. PHOTOCOPY

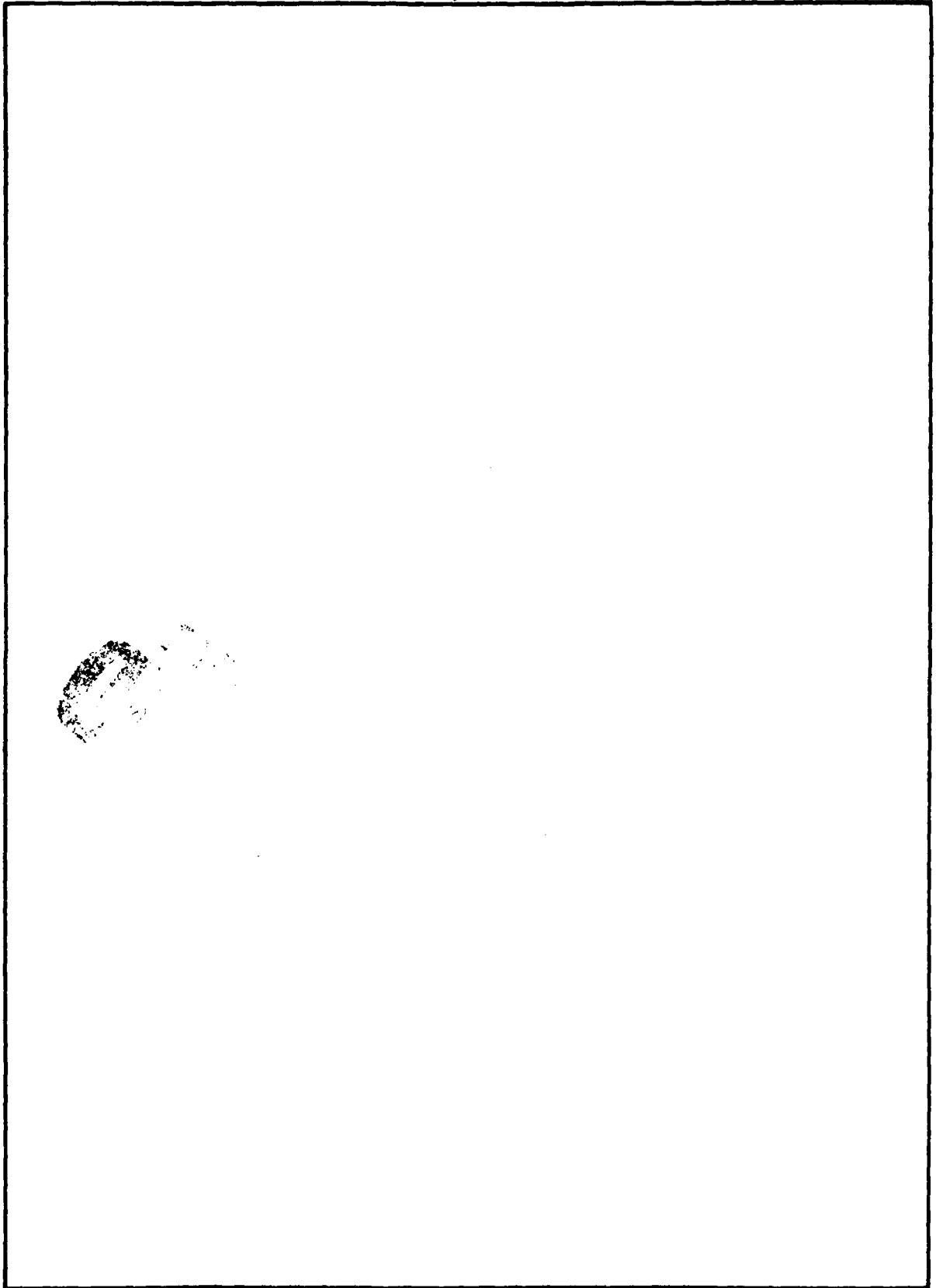
UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A105985	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Phase I Dam Inspection Report National Dam Safety Program Lake Aggravation Dam (MO 30557) Franklin County, Missouri	5. TYPE OF REPORT & PERIOD COVERED Final Report	
	6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s) Woodward-Clyde Consultants	8. CONTRACT OR GRANT NUMBER(s) DACW43-80-C-0066	
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Engineer District, St. Louis Dam Inventory and Inspection Section, LMSED-PD 210 Tucker Blvd., North, St. Louis, Mo. 63101	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer District, St. Louis Dam Inventory and Inspection Section, LMSED-PD 210 Tucker Blvd., North, St. Louis, Mo. 63101	12. REPORT DATE September 1980	
	13. NUMBER OF PAGES Approximately 50 SECURITY CLASS. (of this report)	
14. MONITORING & National Dam Safety Program. Lake Aggravation Dam (MO 30557). Mississippi- Kaskaskia-St. Louis Basin, Franklin County, Missouri. Phase I Inspection Report.	UNCLASSIFIED DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION Approved for release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
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.		

DTIC
 SELECTED
 OCT 22 1981
 H

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)



SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)



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

REPLY TO
 ATTENTION OF

SUBJECT: Lake Aggravation Dam Phase I Inspection Report

This report presents the results of field inspection and evaluation of Lake Aggravation Dam (MO 30557).

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

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

- a. Spillway will not pass 50 percent of the Probable Maximum Flood without overtopping the dam.
- b. Overtopping of the dam could result in failure of the dam.
- c. Dam failure significantly increases the hazard to loss of life downstream.

SIGNED

SUBMITTED BY:

Chief, Engineering Division

Signed

25 SEP 1980

Date

APPROVED BY:

Colonel, CE, District Engineer

25 SEP 1980

Date

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
A	

DISTRIBUTION STATEMENT A
 Approved for public release;
 Distribution Unlimited

LAKE AGGRAVATION DAM
Franklin County, Missouri
Missouri Inventory No. 30557

Phase I Inspection Report
National Dam Safety Program

Prepared by

Woodward-Clyde Consultants
Chicago, Illinois

Under Direction of
St Louis District, Corps of Engineers

for
Governor of Missouri
September 1980

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams for Phase I Investigations. Copies of these guidelines may be obtained from the Office of the Chief of Engineers, Washington, D. C., 20314. The purpose of a Phase I investigation is not to provide a complete evaluation of the safety of the structure nor to provide a guarantee on its future integrity. Rather the purpose of the program is to identify potentially hazardous conditions to the extent they can be identified by a visual examination. The assessment of the general condition of the dam is based upon available data (if any) and visual inspections. Detailed investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify the need for more detailed studies. In view of the limited nature of the Phase I studies no assurance can be given that all deficiencies have been identified.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with any data which may be available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action removes the normal load on the structure, as well as the reservoir head along with seepage pressures, and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through frequent inspections can unsafe conditions be detected, so that corrective action can be taken. Likewise continued care and maintenance are necessary to minimize the possibility of development of unsafe conditions.

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam	Lake Aggravation Dam
State Located	Missouri
County Located	Franklin
Stream	Tyrey Creek
Date of Inspection	2 June, 1980

Lake Aggravation Dam, Missouri Inventory Number 30557, was inspected by Richard Berggreen (engineering geologist), David Hendron (geotechnical engineer), and Sean Tseng (hydrologist).

The dam inspection was made following the guidelines presented in the "Recommended Guidelines for Safety Inspections of Dams". These guidelines were developed by the Chief of Engineers, US Army, Washington, D.C., with the help of federal and state agencies, professional engineering organizations, and private engineers. The resulting guidelines represent a consensus of the engineering profession. They are intended to provide an expeditious identification, based on available data and a visual inspection of those dams which may pose hazards to human life or property. In view of the limited nature of the study, no assurance can be given that all deficiencies have been identified.

The St Louis District, Corps of Engineers, has classified this dam as a high hazard; we concur with this classification. The estimated damage zone extends approximately 4 mi downstream of the dam. Two dams and lakes surrounded by vacation homes and permanent residences are located immediately downstream from Lake Aggravation Dam. Loss of life and property could be large in the event of overtopping and failure of this dam.

Lake Aggravation Dam is in the small size classification based on its maximum height of 33 feet and on its storage capacity of 163 ac-ft.

Our inspection and evaluation indicate the dam is in an unsatisfactory condition. Several small slumps were noted on the face of the embankment, and seepage near the spillway appeared to be carrying fine sand. Hydrologic analysis indicates the spillway will pass only 35 percent of the Probable Maximum Flood (PMF). The spillway discharge

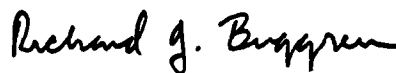
capacity is calculated at $1971 \text{ ft}^3/\text{sec}$. The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. A flood with 1 percent probability-of-occurrence will be contained within the reservoir with a maximum spillway discharge of $844 \text{ ft}^3/\text{sec}$.

It is recommended that the following studies be made and the following actions be taken, under the guidance of an engineer experienced in the design and construction of dams:

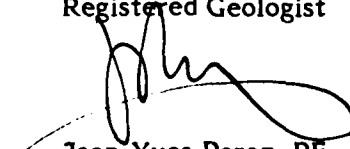
1. Increase spillway size and/or dam height to pass the appropriate design flood. In either case, the spillway should be protected to prevent erosion.
2. Make seepage and stability analyses of the dam and spillway, comparable to those required in the recommended guidelines. These analyses should be made for appropriate loading conditions, including earthquake loads.
3. Undertake a program of periodic inspections to detect increases in slope slumping, seepage rate, turbidity of seepage water, and spillway erosion.
4. Implement a maintenance program as needed. In particular, immediate maintenance work should be undertaken to repair cracked and leaking concrete weir, fill and patch holes in the discharge channel lining, and remove the tree growing in this channel.

It is suggested the owner takes action on those recommendations in the near future to avoid further deterioration of this structure which could lead to the development of unsafe emergency conditions.

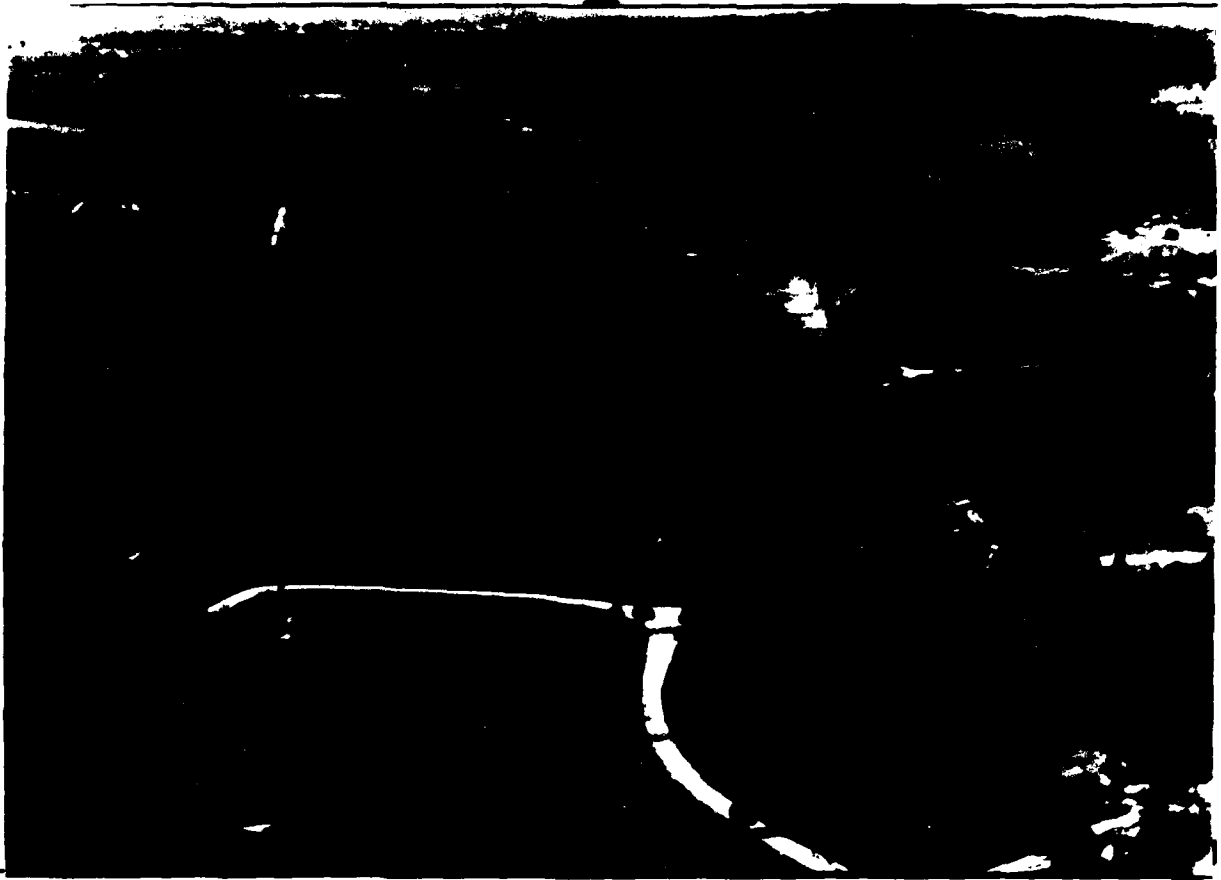
WOODWARD-CLYDE CONSULTANTS



Richard G. Berggreen
Registered Geologist



Jean-Yves Perez, PE
Project Manager



OVERVIEW

LAKE AGGRAVATION DAM

MISSOURI INVENTORY NUMBER 30557

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
LAKE AGGRAVATION DAM - INVENTORY NO. 30557

TABLE OF CONTENTS

<u>Paragraph No.</u>	<u>Title</u>	<u>Page No.</u>
SECTION 1 - PROJECT INFORMATION		
1.1	General	1
1.2	Description of Project	2
1.3	Pertinent Data	3
SECTION 2 - ENGINEERING DATA		
2.1	Design	6
2.2	Construction	6
2.3	Operation	6
2.4	Evaluation	6
2.5	Project Geology	7
SECTION 3 - VISUAL INSPECTION		
3.1	Findings	9
3.2	Evaluation	11
SECTION 4 - OPERATIONAL PROCEDURES		
4.1	Procedures	12
4.2	Maintenance of Dam	12
4.3	Maintenance of Operating Facilities	12
4.4	Description of Any Warning System in Effect	12
4.5	Evaluation	12
SECTION 5 - HYDRAULIC/HYDROLOGIC		
5.1	Evaluation of Features	14

<u>Paragraph No.</u>	<u>Title</u>	<u>Page No.</u>
----------------------	--------------	-----------------

SECTION 6 - STRUCTURAL STABILITY

6.1	Evaluation of Structural Stability	16
-----	------------------------------------	----

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1	Dam Assessment	18
7.2	Remedial Measures	19

REFERENCES		21
------------	--	----

FIGURES

1. Site Location Map
2. Drainage Basin and Site Topography
3. Dam and Spillway Cross-sections and Plan
4. Regional Geologic Map

APPENDICES

A Figure A-1: Photo Location Sketch

Photographs

1. Downstream hazards below Lake Aggravation Dam looking south.
2. Erosion below riprap at spillway looking west.
3. Crack and leakage at spillway weir. Looking upstream, south.
4. Hole eroded through concrete lining of discharge channel.
5. Seepage from base of rock pile adjacent to spillway.
6. Discolored water in lake below dam, possibly seepage exiting underwater.
7. 2 ft wave-cut erosion on upstream edge of Lake Aggravation Dam looking west.

B Hydraulic/Hydrologic Data and Analyses

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
LAKE AGGRAVATION DAM, INVENTORY NO. 30557

SECTION I
PROJECT INFORMATION

1.1 General

- a. Authority. The National Dam Inspection Act, Public Law 92-367, provides for a national Inventory and inspection of dams throughout the United States. Pursuant to the above, an inspection was conducted of the Lake Aggravation Dam, Missouri Inventory number 30557.

- b. Purpose of inspection. "The primary purpose of the Phase I investigation program is to identify expeditiously those dams which may pose hazards to human life or property... The Phase I investigation will develop an assessment of the general condition with respect to safety of the project based upon available data and a visual inspection, determine any need for emergency measures and conclude if additional studies, investigations and analyses are necessary and warranted." (Chapter 3, Recommended Guidelines for Safety Inspection of Dams).

- c. Evaluation criteria. The criteria used to evaluate the dam were established in the "Recommended Guidelines for Safety Inspection of Dams"; "Engineering Regulation No. 1110-2-106 and Engineering Circular No. 1110-2-188", Engineering and Design National Program for Inspection of Non-Federal Dams, prepared by the Office of Chief of Engineers, Department of the Army, and "Hydrologic/Hydraulic Standards, Phase I Safety Inspection of Non-Federal Dams" prepared by the St Louis District, Corps of Engineers (SLD). 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.** Lake Aggravation Dam is an earth dam (Photo 1). The spillway, located at the right abutment as the observer faces downstream, consists of a trapezoidal concrete lined weir (Photo 2). The spillway is approximately 67 ft wide at the top of the embankment. The crest of the spillway is approximately 4.4 ft below the low point surveyed on the crest of the embankment. No low level outlet was found. No control structures were found for regulating spillway flows.
- b. **Location.** The dam is located on Tyrey Creek, approximately 3.2 mi north of the town of Richwoods in Franklin County Missouri, Section 16, T40N, R2E; (Figure 1). The dam location is on the USGS 7.5 minute Richwoods NE, quadrangle sheet.
- c. **Size.** The dam is classified small due to its 33 ft height and its reservoir volume of 163 ac-ft.
- d. **Hazard classification.** SLD has classified this dam as high hazard dam; we concur with this classification. The estimated damage zone extends approximately 4 mi. downstream of the dam. Within this damage zone are two earth dams, MO 30555, MO 30554 and a number of vacation and permanent residences that line the shore of the lakes downstream from this dam. An access road to some homes crosses the spillway and downstream face of this dam. Loss of life and property could be large in the event of overtopping and failure of this dam.
- e. **Ownership.** We understand the dam is owned by Lonedell Lakes Residents Association, PO Box 100, Lonedell, Missouri, 63063. Correspondence should be addressed to the attention of Mr Floyd Montgomery.
- f. **Purpose of dam.** The reservoir is used for recreation purposes.
- g. **Design and construction history.** No design or construction reports were found for Lake Aggravation Dam.

Lake Aggravation Dam was constructed 18 to 20 years ago according to Mr A. Wilson, local resident, and Ms J. Allen, secretary to Residents Association. The owner of the property when the dam was built, Mr Jack Patrick, is now deceased.

Mr Wilson worked on the construction of the dam for Lake Aggravation, and indicated the dam foundation was excavated to bedrock. He also indicated no sand or gravel drains were installed during construction.

No other records or accounts of the dam construction could be found.

- h. Normal operating procedures. No operating records were found. Flood flows pass over the uncontrolled spillway at the right abutment.

1.3 Pertinent Data

- a. Drainage area. approximately 1.22 mi² (including 0.28 mi² from upstream Lonedell Lake Dam, MO 31395)

- b. Discharge at damsite.

Maximum known flood at damsite	Unknown
Warm water outlet at pool elevation	N/A
Diversion tunnel low pool outlet at pool elevation	N/A
Diversion tunnel outlet at pool elevation	N/A
Gated spillway capacity at pool elevation	N/A
Gated spillway capacity at maximum pool elevation	N/A
Ungated spillway capacity at maximum pool elevation	1971 ft ³ /sec
Total spillway capacity at maximum pool elevation	1971 ft ³ /sec

- c. Elevation (ft above MSL).

Top of dam	772.3
Maximum pool-design surcharge	N/A
Full flood control pool	N/A

Recreation pool	767.6
Spillway crest (gated)	N/A
Upstream portal invert diversion tunnel	N/A
Downstream portal invert diversion tunnel	N/A
Streambed at centerline of dam	Unknown
Maximum tailwater	N/A
Toe of dam at maximum section	739.2

d. Reservoir.

Length of maximum pool	approximately 1800 ft
Length of recreation pool	approximately 1750 ft
Length of flood control pool	N/A

e. Storage (acre-feet).

Recreation pool	approximately 163
Flood control pool	N/A
Design surcharge	N/A
Top of dam	approximately 259

f. Reservoir surface (acres).

Top of dam	approximately 24.5
Maximum pool	approximately 24.5
Flood control pool	N/A
Recreation pool	N/A
Spillway crest	approximately 17.6

g. Dam.

Type	Rolled earth fill
Length	approximately 643 ft
Height	33 ft (maximum section)
Crest width	18 ft (typical)

Side slopes	Downstream 1.9H to 1V (upper portion) 3.1H to 1V (lower portion) 11 ft wide roadway bench at mid down- stream slope Upstream; Unknown
Zoning	Unknown
Impervious core	Unknown (probably homogeneous section)
Cutoff	Unknown (probably to bedrock at shallow depth)
Grout curtain	Unknown (probably none)

h. Diversion and regulating tunnel.

Type	None
Length	N/A
Closure	N/A
Access	N/A
Regulating facilities	N/A

i. Spillway.

Type	Trapezoidal concrete weir at right abutment.
Length of weir	65 ft at bottom; 67 ft at top
Crest elevation	767.6 ft MSL
Gates	None
Upstream channel	None
Downstream channel	Concrete lined and exposed bedrock

j. Regulating outlets.

None

SECTION 2 ENGINEERING DATA

2.1 Design

No design plans or reports were found for this dam. The property owner at the time of construction, Mr Jack Patrick, is now deceased.

2.2 Construction

According to local residents, the dam was constructed 18 to 20 years ago (Mr A. Wilson, Ms Joan Allen). The dam was founded on bedrock according to Mr A. Wilson who worked on the dam construction. Mr Wilson also indicated that no sand or gravel drains were installed during construction.

2.3 Operation

There are no control structures on this dam. There are no records of overflow or water levels at this dam.

2.4 Evaluation

- a. Availability. Engineering data on this dam was obtained from conversations with local residents, and from the visual inspection field visit.
- b. Adequacy. The field visit and visual inspection conducted for this report and presented herein, are considered adequate to support the conclusions of this Phase I report.

Seepage and stability analyses comparable to the requirements of the guidelines are not on record. This is a deficiency which should be rectified. These seepage and stability analyses should be performed for appropriate loading

conditions (including earthquake loads) and make a matter of record. These analyses should be performed by an engineer experienced in the design and construction of earth dams.

- c. **Validity.** The validity of the data obtained from the local residents is questionable in that it is based on personal recollections of events 18 to 20 years ago, and this data could not be independently verified.

2.5 Project Geology

The dam site is located on the northern flank of the Ozark Structural dome. The regional dip is to the north. Bedrock in the area is mapped on the Geologic Map of Missouri as Ordovician age Gasconade Formation (Fig 4), a light-grayish brown cherty dolomite with a frequently occurring basal sandstone. At the dam site, bedrock exposures are quite sandy, indicating the dam is founded on the basal Gunter member of the Gasconade Formation.

In the central Ozarks, caves and springs are common in the Gasconade Formation. However, limited exposures in the site area preclude an evaluation of solution activity. The visual inspection which was conducted did not disclose any signs of solution activity (e.g. water seeps or sinkholes) in the immediate proximity of the dam.

The soils in the site vicinity consist of a silty to fine sandy and gravelly clay (CL-CH). This soil appears to be a residual soil developed by weathering of the sandy Gasconade Formation. The gravel is chert and quartz typical of siliceous dolomite formations. The soil is mapped on the General Soils Map for Missouri (1979) as Union-Goss-Gascondade Peridge Association. The soil profiles exposed appeared relatively thin in the vicinity of the dam, on the order of 3 to 6 ft thick.

The principal northwest-southwest trending branch of the Ditch Creek Fault System is mapped less than 1/2 mile northeast of the dam (Fig. 4). The fault is mapped as approximately 11 miles long on the Structural Features Map of Missouri, north side down, and offsets the Cambrian age Eminence and Potosi Formations and the

Ordovician age Gasconade and Roubidoux Formations at the surface. This fault, like most others in the Ozarks area, is not considered to be a seismically active structure.

SECTION 3 VISUAL INSPECTION

3.1 Findings

- a. General. A field visit and visual inspection was made of Lake Aggravation Dam on 2 June, 1980. On the basis of this inspection, the dam is judged to be in an unsatisfactory condition.
- b. Dam. The dam is constructed of gravelly clay, with about 30 percent angular cherty gravel in a dark red, very plastic residual clay (CH).

Several small animal burrows (2 in. diameter, unknown depth), were noted on the crest of the dam. Vegetation on the crest and downstream face of the dam is limited to grass. The grass cover offers moderate erosion resistance to the embankment. No displacement of the vertical or horizontal alignment of the dam crest was noted during the inspection.

Three small slump-type slope movements were identified on the downstream face of the dam. At the center of the toe of the dam, a slide with a volume of approximately 60 yd³ was noted. The material for this slide has been subsequently eroded away. Minor seepage (less than 1 gal/min) was noted in this scarp.

Another slump was observed along the road which crosses the face of the dam. This slide, estimated at less than 20 yd³, probably resulted from oversteepening the bank on the uphill side of the road. Minor seepage, estimated at less than 1 gal/min, was noted at the toe of this slump.

A hummocky, wet area, suggestive of landslide debris, was identified near the right abutment, adjacent to the spillway and discharge channel. This area appears to be covered with a pile of end-dumped rock (6 to 12 in. diameter). Seepage, estimated at 5 gal/min at the time of the inspection, was noted exiting from the pile of dumped rock (Photo 5). This seepage appeared to be

carrying fine sand. This seepage appeared to be a leak around the spillway. An elevation difference of 6.5 to 7 ft was measured between the reservoir water level and the top of the seepage area.

Seepage was noted along the entire toe of the dam embankment. Total seepage from the right abutment is estimated at 20 gal/min. Seepage from the toe of the left abutment also totals approximately 20 gal/min.

Discolored, muddy water was noted in the upstream end of the lake immediately below Lake Aggravation Dam (Photo 6). This discoloration could be due to seepage carrying fines exiting underwater in this lower lake.

The upstream face of the dam has been eroded by wave action (Photo 7). Locally, this erosion extends to within 2 ft of the top of the dam. The eroded portion slopes at approximately 1 horizontal to 1 vertical. This erosion is most pronounced from the center of the dam to a point about 100 ft east of the center.

c. Appurtenant structures

1. Spillway. The spillway crest consists of a trapezoidal concrete weir. Minor cracking and spalling of the concrete was noted during the field inspection. Substantial leakage of 10 to 15 gal/min was occurring through a crack at the base of the concrete weir at the time of the inspection (Photo 3). Vertical holes in the top of the concrete weir indicate the weir may be pinned with reinforcing bars to the underlying bedrock. However, this could not be verified. Minor erosion was noted at the junction of the spillway weir and the embankment (Photo 2). Riprap up to 3 ft in diameter had been placed near the spillway for erosion control.

2. Outlet works. The ungated spillway is the only designed outlet for this reservoir.

d. Reservoir area. The slopes surrounding the reservoir are for the most part wooded with scattered permanent residences and summer homes. The slopes are generally flatter than 5 horizontal to 1 vertical. Evidence of unstable

slopes surrounding the reservoir was not noted during the field investigation. Post-construction changes around the reservoir consist of limited clearing of trees for home construction, and gravel road building for access to these homes. No significant siltation was noted in the reservoir.

- e. Downstream channel. Lake Aggravation Dam does not have a downstream channel per se. The spillway discharge channel empties into the upstream end of a lake immediately below the toe of Lake Aggravation Dam. The discharge channel below the spillway is lined with shotcrete or gunite. This lining has been eroded through in places, resulting in holes up to at least 1 foot deep eroded beneath the lining (Photo 4). A tree is growing at the toe of the lined section in the center of the discharge channel. The discharge channel below the lined area consists of exposed bedrock and does not appear to be subject to significant erosion.

3.2 Evaluation

The visual inspection identified a number of items which will require a more thorough evaluation and possibly remedial action, specifically the slump at the toe of the dam, the slump on the face of the dam along the road, the apparent slump on the embankment adjacent to the spillway, the seepage carrying fine sand from the area adjacent to the spillway and the general seepage from the entire toe of the dam. Recommendations for further work and remedial measures are presented in Section 7.

SECTION 4 OPERATIONAL PROCEDURES

4.1 Procedures

So far as could be determined by our inspection and evaluation, there are no written operational procedures for this dam. The water level is controlled by the crest of the ungated concrete weir of the spillway.

4.2 Maintenance of Dam

No records of maintenance on this facility were available.

Evidence of minimal or no maintenance efforts on this facility include wave-cut erosion on the upstream bank of the dam, cracked and spalled concrete on the weir, trees growing in the discharge channel, and holes eroded through the discharge channel lining.

Some remedial work has apparently been done adjacent to the spillway where a truck load of rock was dumped in the area of an apparent landslide and seepage.

4.3 Maintenance of Operating Facilities

Our inspection did not identify any operating facilities at this dam requiring maintenance.

4.4 Description of Any Warning System in Effect

Our inspection did not identify any warning system in effect at this facility.

4.5 Evaluation

There is apparently no maintenance program in effect at this facility. In view of the condition of the spillway discharge channel, the erosion of the upstream bank,

and particularly the several slump-type landslides which were identified on the embankment, it is recommended a maintenance program and warning system be established for this dam and appurtenant facilities.

SECTION 5 HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

- a. **Design data.** No hydrologic or hydraulic design information was available for evaluation of the dam or the reservoir. Pertinent dimensions of the dam and reservoir were surveyed on 30 May 1980, measured during the visual inspection, or estimated from topographic map. The map used in the analysis is the advance copy of the USGS 7.5 minute Richwoods NE, quadrangle sheet.
- b. **Experience data.** No recorded rainfall, runoff, discharge or pool stage data was available for this reservoir or watershed.
- c. **Visual observation.** The watershed is predominately rural with scattered vacation and permanent residences. The area of the reservoir pool surface is approximately 3 percent of the total watershed area of 1.22 mi².

A portion of the drainage area above the main dam is controlled by Lonedell Lake Dam and associated reservoir. An outlet structure at Lonedell Lake Dam consisting of an 8 in. diameter pipe was noted to be blocked and inoperative. As a result of the overtopping analysis, Lonedell Lake Dam is considered to be capable of passing 85 percent of the Probable Maximum Flood.

Other visual observations regarding the dam and spillway at Lake Aggravation Dam are presented in Section 3, Visual Inspection.

The magnitude of seepage through this dam is not hydrologically significant to the overtopping potential.

- d. **Overtopping potential.** Hydrologic analysis of the dam using the data and method presented and described in Appendix B, Hydraulic/Hydrologic Data and Analyses, indicate that a flood of greater than 35 percent of the Probable Maximum Flood (PMF) will effectively overtop the dam. The PMF is defined

as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

A flood with 1 percent chance of occurrence (100-year flood) will be contained within the spillway without overtopping the dam.

The following data were computed for various flood events:

Precipitation Event	Maximum Depth of Overtopping ft	Maximum Lake Elev. ft (MSL)	Maximum Outflow ft^3/s	Duration of Overtop hr
25% PMF	0	771.34	1363	0
35% PMF	0	772.29	1959	0
50% PMF	0.62	772.92	3091	1.50
75% PMF	1.14	773.44	4691	3.00
100% PMF	1.54	773.84	6298	4.50

The grass cover on the downstream face of this dam offers only moderate erosion protection. It would not prevent erosion for overtopping flows resulting from flood events greater than 40 or 50 percent of PMF.

SECTION 6 STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

- a. **Visual observations.** The visual inspection of Lake Aggravation Dam revealed no evidence of horizontal or vertical displacement of the dam crest alignment. However, the several landslide slumps noted on the face of the embankment, and the seepage noted along the toe of the embankment, particularly the seepage carrying fine sand in the area adjacent to the spillway, indicate further study will be necessary to evaluate the long-term stability of this dam.

It is noteworthy that the thickness of the dam cross-section diminishes adjacent to the spillway. Thus the apparent landslide and seepage may significantly affect the stability of this portion of the dam. The lack of any design or construction plans or records further inhibits the assessment of the structural stability.

The spillway and discharge channel appeared to be in fair condition at the time of the inspection. Deficiencies noted on these facilities include the cracks and leakage through the concrete weir and the holes in the discharge channel lining.

- b. **Design and construction data.** No design or construction data were available on this dam, other than recollections of an individual who worked on the dam construction 18 to 20 years ago. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available. This is deficiency which should be corrected to meet the recommended guidelines.
- c. **Operating records.** No operating records or water level records are maintained for this facility.

- d. **Post construction changes.** The lack of design and construction reports precludes any positive identification of post construction changes in the dam. A topographic map (Richwoods 15 minute quadrangle) dated 1949, shows a road crossing the stream at the approximate location of the dam; this road may correspond to the present road at mid downstream slope. Widening of this road across the face of the dam could have resulted in oversteepening of the slope and caused the observed slump along the road.

Other changes in the area surrounding the reservoir are likely limited to lot clearing for scattered residences and summer homes and gravel road building for access to these homes.

- e. **Seismic stability.** The dam is in Seismic Zone 2, to which the guidelines assign a moderate seismic damage potential. In view of the gravelly clay used in the construction of the dam, liquefaction is unlikely during a seismic event. However, since a static stability analysis was not available for review, the seismic stability of the dam could not be evaluated.

SECTION 7 ASSESSMENT/REMEDIAL MEASURES

7.1 Dam Assessment

- a. **Safety.** Based on the visual inspection, Lake Aggravation Dam is judged to be in an unsatisfactory condition.

This judgment is based on evidence of slumping in the dam embankment, particularly the slump adjacent to the spillway, and the associated seepage that appeared to be carrying fine sand. The presence of other slumps and seepage noted along the toe of the dam further indicate the need for a more comprehensive assessment of the stability of this dam.

Hydrologic analysis of the spillway and reservoir storage indicates the spillway will pass only 35 percent of the PMF without overtopping the dam. The spillway discharge capacity is calculated at 1971 ft³/sec.

- b. **Adequacy of information.** The visual inspection provided a reasonable base of information for the conclusions and recommendations presented in this Phase I report.

The lack of stability and seepage analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" is a deficiency which should be rectified to meet the recommended guidelines.

- c. **Urgency.** The deficiencies described in this report could affect the safety of the dam. Corrective actions should be initiated promptly.
- d. **Necessity for Phase II.** In accordance with the "Recommended Guidelines for Safety Inspections of Dams", the subject investigation was a minimum study. This study revealed that additional in-depth investigations are needed to complete the assessment of the safety of the dam. Those investigations which should be performed without undue delay are described in Section 7.2.b. It is

our understanding from discussions with the St Louis District that any additional investigations are the responsibility of the owner.

7.2 Remedial Measures

- a. **Alternatives.** There are several general options which may be considered to reduce the possibility of dam failure. Some of these options are:
 1. Remove the dam, or breach it to prevent storage of water.
 2. Increase the height of the dam and/or the size of the spillway to pass the Probable Maximum Flood without overtopping the dam.
 3. Purchase downstream land that would be adversely impacted by dam failure, and restrict human occupancy.
 4. Enhance the stability of the dam to permit overtopping by the Probable Maximum Flood without failure.
 5. Provide a highly reliable flood warning system (generally does not prevent damage but decreases chances of loss of life).

- b. **Recommendations.** Based on our inspection of Lake Aggravation Dam, it is recommended that further study be conducted without undue delay under the guidance of an engineer experienced in design and construction of dams to evaluate, as a minimum, the following topics:
 1. Spillway size and/or height of dam should be increased to pass the appropriate spillway design flood. In either case, the spillway should be protected to prevent erosion.
 2. Seepage and stability analyses comparable to the requirements of the recommended guidelines are not on record and should be made to evaluate the slumping and seepage adjacent to the spillway. The seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads).

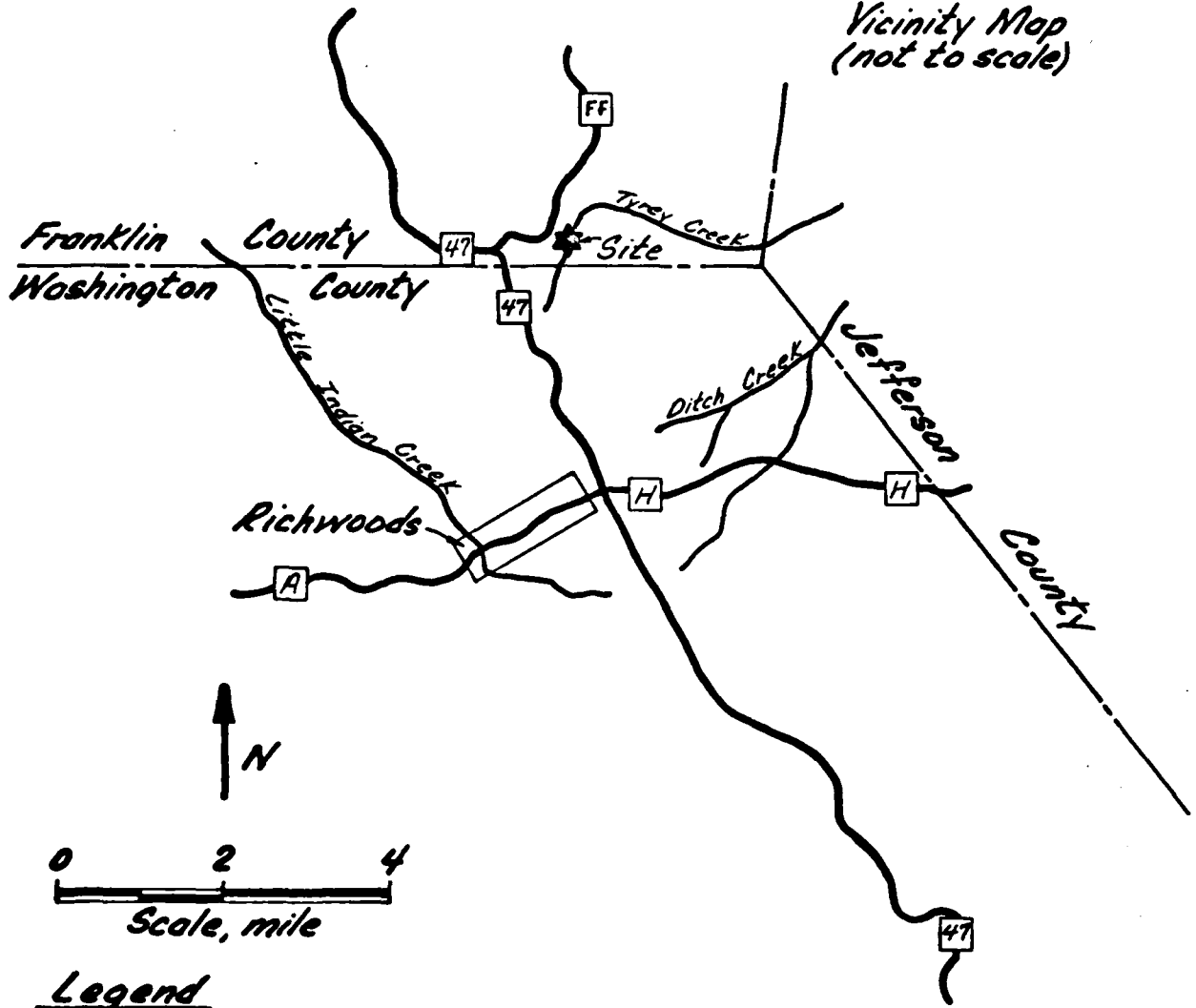
- c. Operation and maintenance procedures. The potential for deterioration of the stability of the dam indicates a program of periodic inspections should be designed and implemented for this facility. Any deterioration of the dam conditions should be called to the attention of an engineer experienced in design and construction of dams. This program should include, as a minimum:
1. Making periodic observations of the condition of the downstream face of the dam for detection of:
 - a. further slumping;
 - b. increase in seepage rate and turbidity of seepage water; and
 - c. erosion of spillway.
 2. Performing maintenance work as needed on the basis of the recommended periodic inspection program. Immediate maintenance should be undertaken to repair cracked and leaking areas on the concrete weir of the spillway, to fill and patch holes eroded through the spillway discharge channel lining, and to remove the tree growing in the center of the discharge channel.

REFERENCES

- Allgood, Ferris P., and Persinger, Ivan, D., 1979, "Missouri General Soil Map and Soil Association Descriptions," US Department of Agriculture, Soil Conservation Service and Missouri Agricultural Experiment Station.
- Department of the Army, Office of the Chief of Engineers, 1977, EC 1110-2-188, "National Program of Inspection of Non-Federal Dams".
- Department of the Army, Office of the Chief of Engineers, 1979, ER 1110-2-106, "National Program of Inspection of Non-Federal Dams".
- Hydrologic Engineering Center, US Army Corps of Engineers, 1978, "Flood Hydrograph Package (HEC-1) Users Manual for Dam Safety Investigations".
- McCracken, Mary H., 1971, Structural Features Map of Missouri: Missouri Geological Survey, Scale 1:500,000.
- Missouri Geological Survey, 1979, Geologic Map of Missouri: Missouri Geological Survey, Scale 1:500,000.
- St Louis District, US Army Corps of Engineers, 1979, "Hydrologic/Hydraulic Standards, Phase I Safety Inspection of Non-Federal Dams".
- US Department of Commerce, US Weather Bureau, 1956, "Seasonal Variation of the Probable Maximum Precipitation East of the 105th Meridian for Areas from 10 to 1,000 Square Miles and Durations of 6, 12, 24 and 48 Hours," Hydrometeorological Report No. 33.
- US Soil Conservation Service, 1971, "National Engineering Handbook," Section 4, Hydrology, 1971.



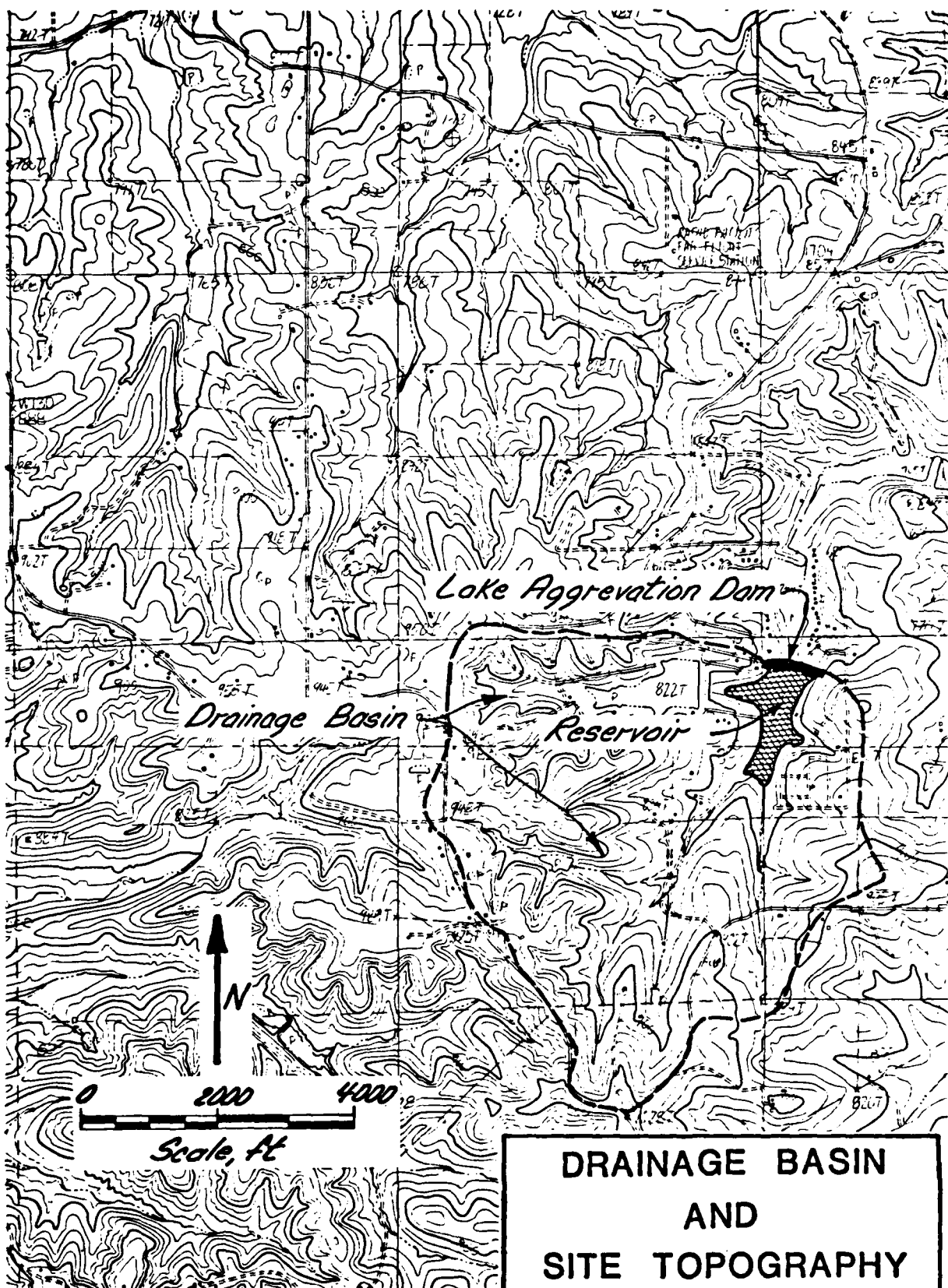
Vicinity Map
(not to scale)



Legend

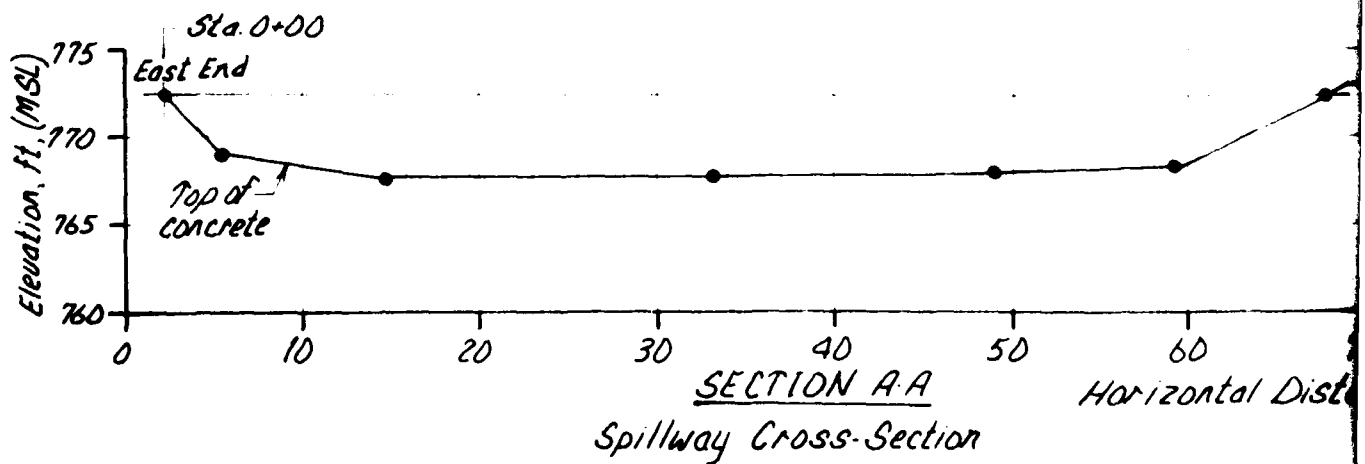
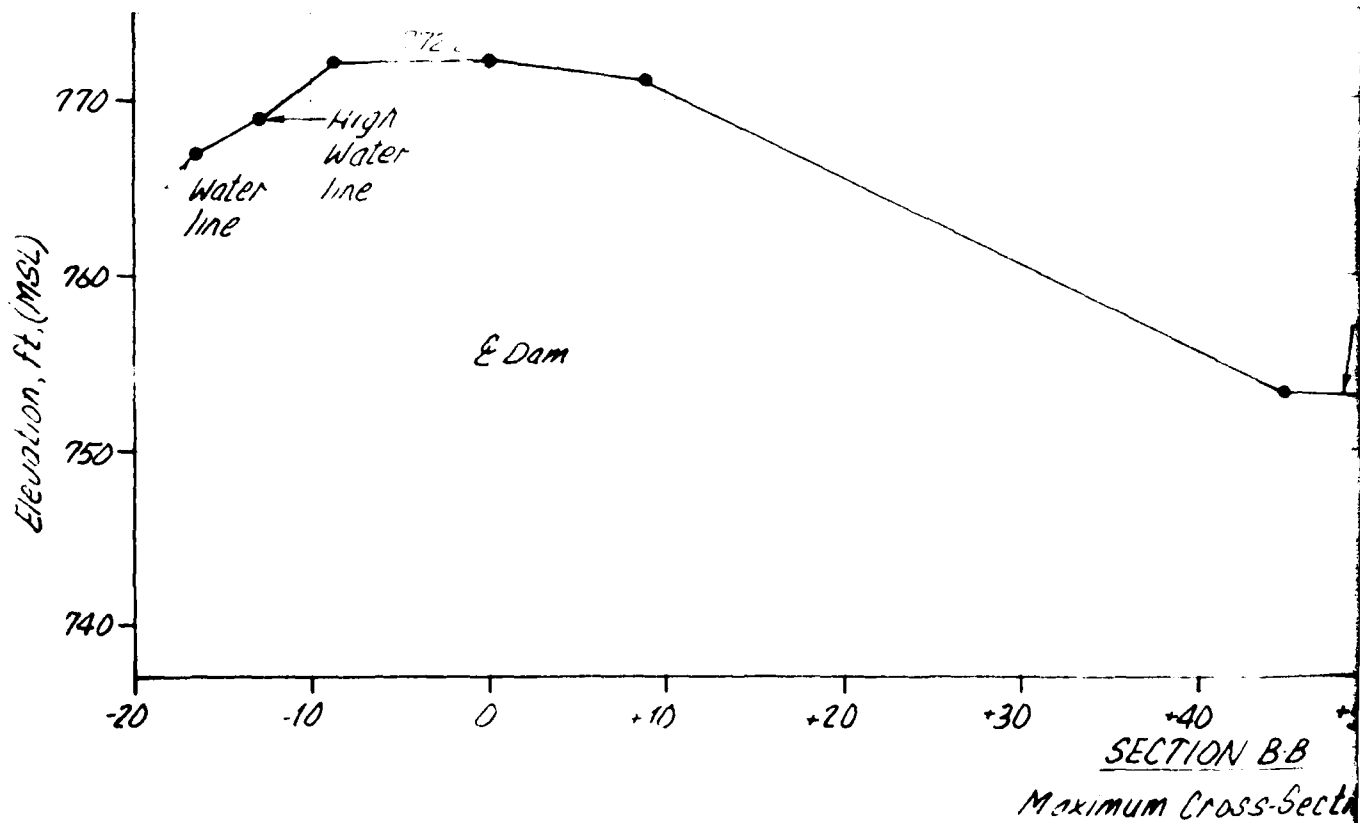
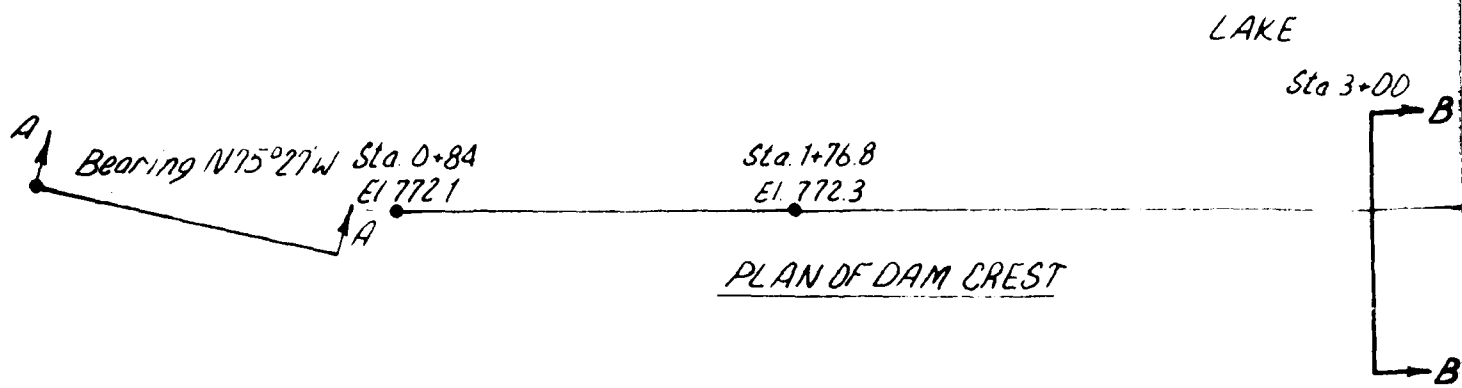
- County line
- State highway and Route No.
- River or creek
- City or town
- Project location

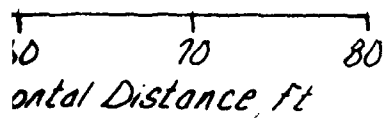
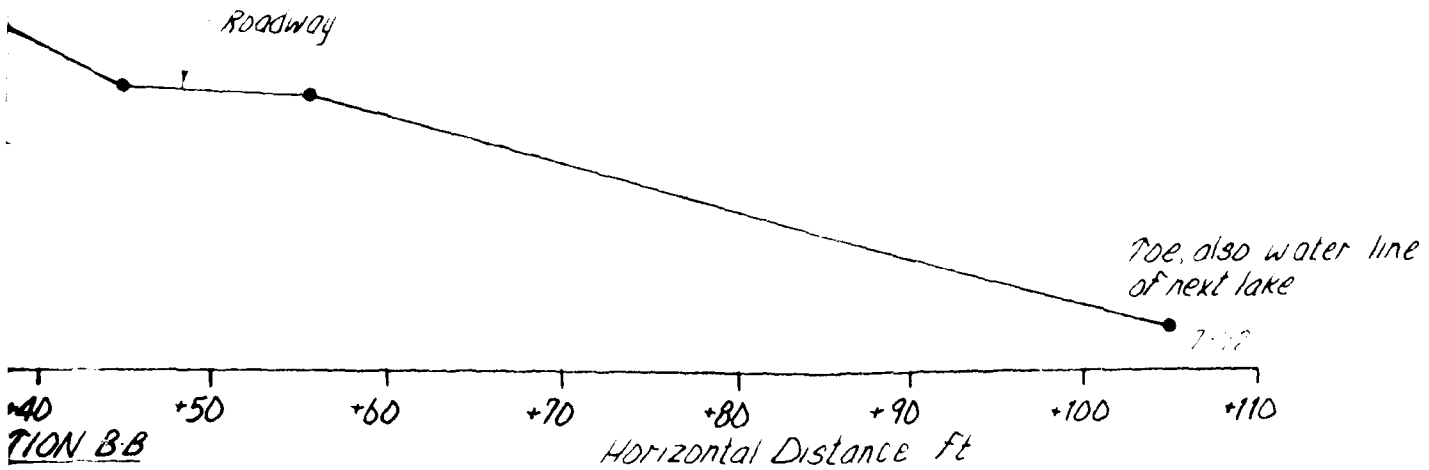
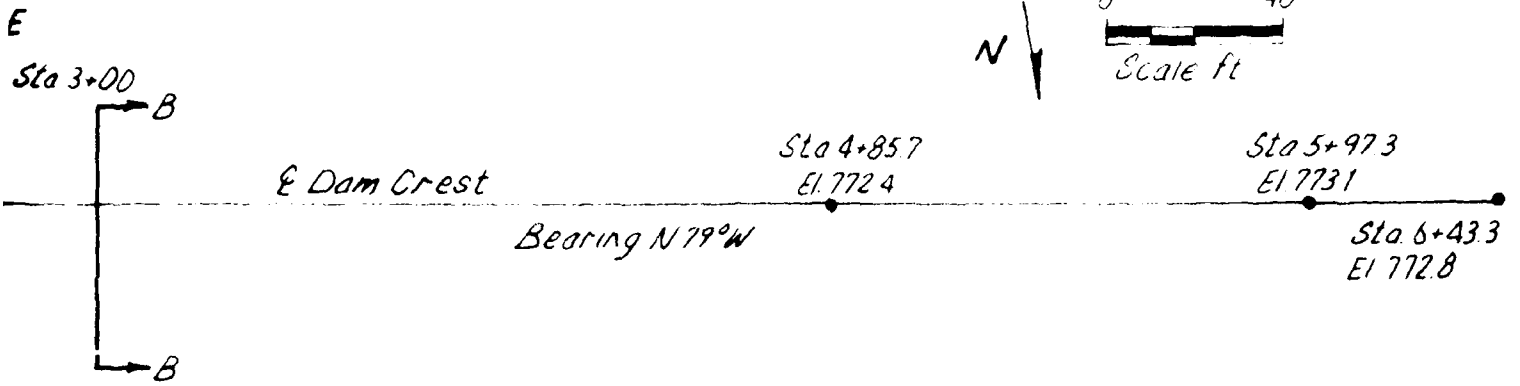
SITE LOCATION MAP	
LAKE AGGRAVATION DAM	
MO. 30557	Fig. 1



1. Topography obtained from
 U.S.G.S. Richwoods N.E.
 7 1/2 minute quadrangle
 map.

DRAINAGE BASIN AND SITE TOPOGRAPHY	
LAKE AGGRAVATION DAM	
MO. 30557	Fig. 2



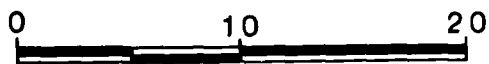
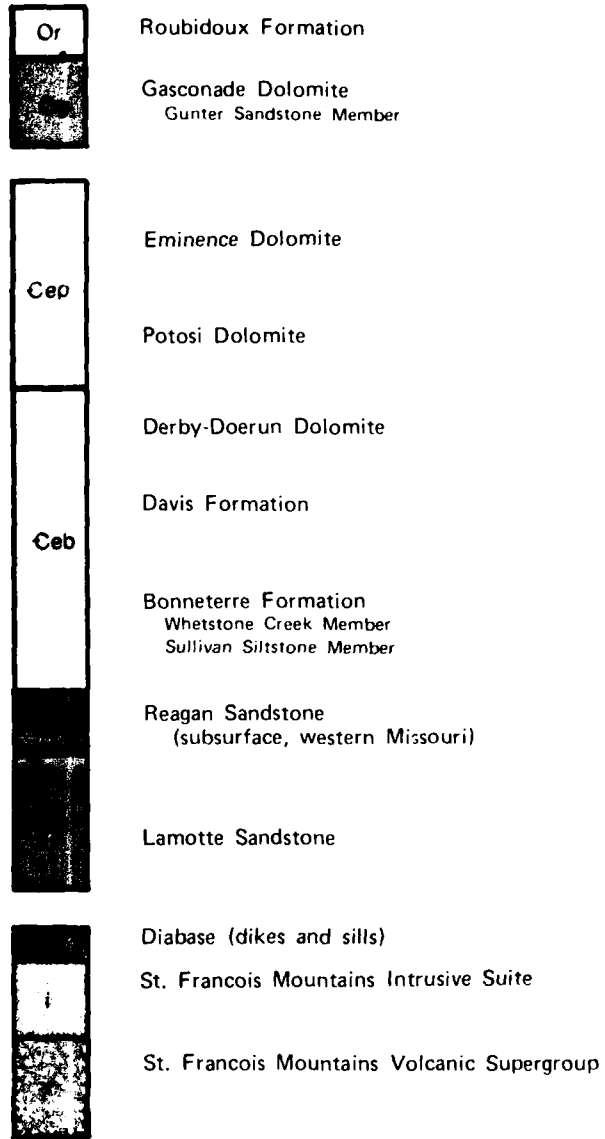


DAM AND SPILLWAY CROSS-SECTIONS AND PLAN	
LAKE AGGRAVATION DAM	
MO. 30557	Fig. 3

Dam Location



Legend



Scale, mile

REGIONAL
GEOLOGIC MAP

LAKE AGGRAVATION DAM

MO 30557

Fig. 4

APPENDIX A

Photographs

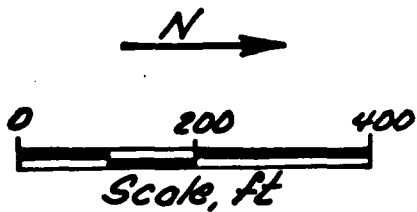
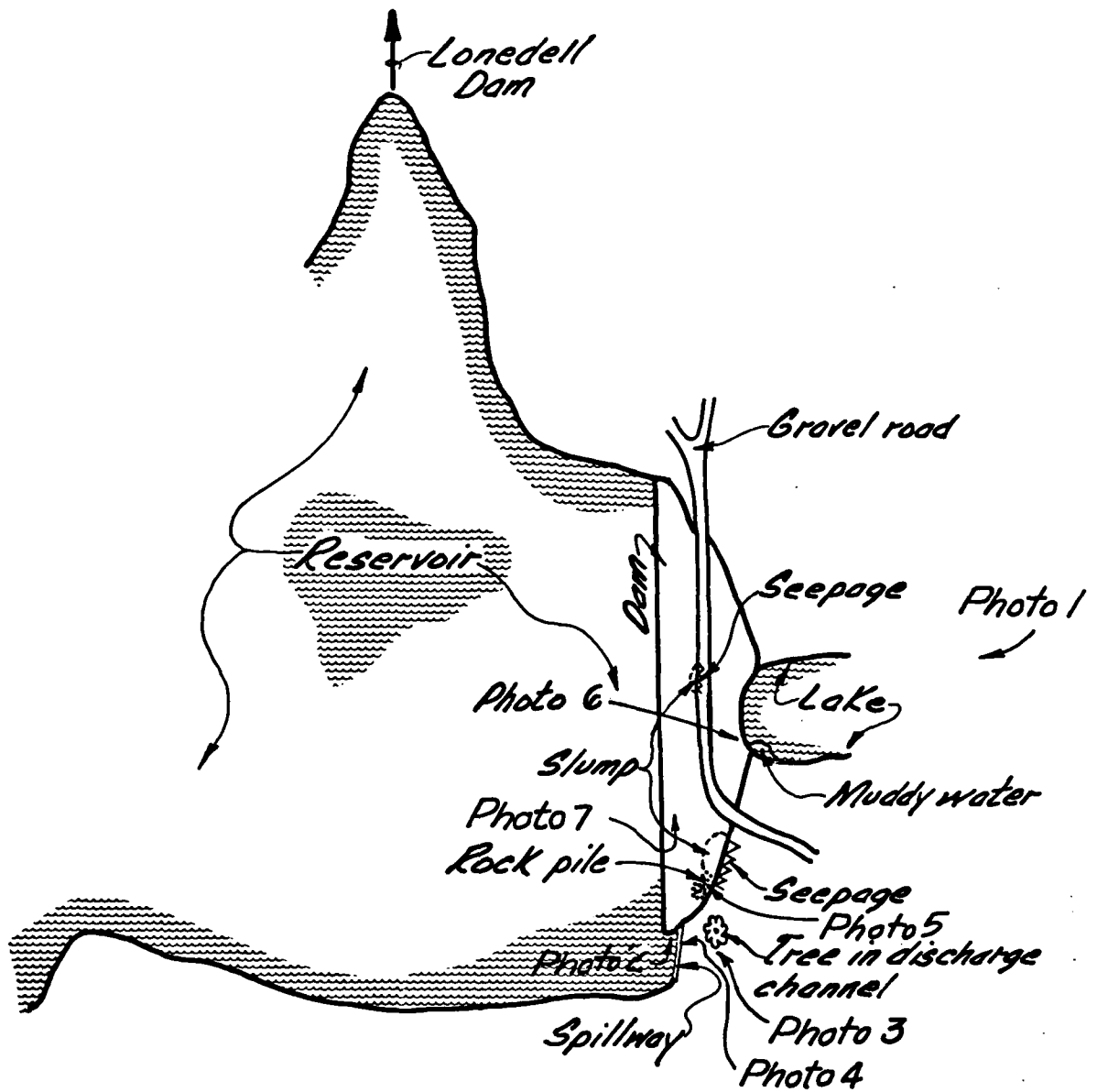


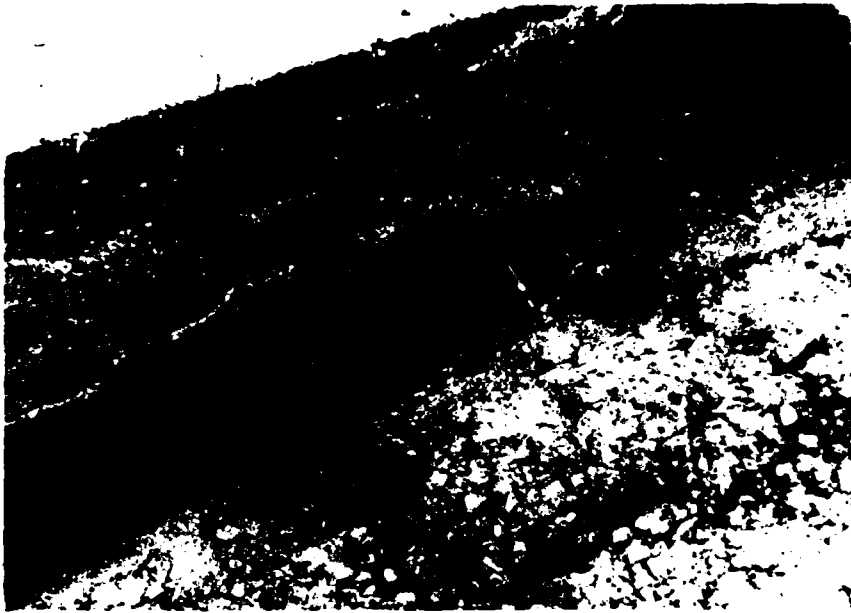
PHOTO LOCATION SKETCH	
LAKE AGGRAVATION DAM	
MO. 30557	Fig. A-1



1. Downstream hazards below Lake Aggravation Dam; looking south.



2. Erosion below rip rap at spillway; looking west.



3. Crack and leakage at spillway weir looking upstream



4. Hole eroded through concrete lining of discharge channel.



5. Seepage from base of rock pile adjacent to spillway.



6. Discolored water in lake below dam, possibly seepage exiting underwater.



7. 2 ft wave-cut erosion on upstream edge of Lake Aggravation Dam; looking west.

APPENDIX B

Hydraulic/Hydrologic Data and Analyses

APPENDIX B

Hydraulic/Hydrologic Analyses

B.1 Procedures

- a. **General.** The hydraulic/hydrologic analyses were performed using the "HEC-1, Dam Safety Version (1 Apr 80)" computer program. Inflow hydrographs were developed by applying various precipitation events to a synthetic unit hydrographs. The inflow hydrographs, thus obtained, were then routed through the reservoir and appurtenant structures by the modified Puls reservoir routing method used in the HEC-I program to determine overtopping potential.
- b. **Precipitation events.** Various percentages including 100 percent of the Probable Maximum Precipitation (PMP) and the 1 and 10 percent probability-of-occurrence events were used in the analyses. The PMP was determined from regional charts prepared by the US Weather Bureau (1956). The 1 and 10 percent probability-of-occurrence events were provided by SLD.
- c. **Unit hydrograph.** The Soil Conservation Service (SCS) unit hydrograph (SCS, 1971) for a storm duration of 48 hrs was used to develop the inflow hydrograph. The unit hydrograph was divided into 10 min increments.
- d. **Infiltration losses.** The SCS curve number (CN) loss function was used to compute infiltration losses. Curve numbers were selected on the basis of antecedent moisture conditions in accordance with the guidelines, present land usage and hydrologic soil group of the soils in the drainage basin. Where more than one soil group was present, the group giving the highest CN was used for the entire basin.
- e. **Lag time.** Lag time was computed by the SCS method (National Engineering Handbook 4, Equation 15-4).

B.2 Pertinent Data

- a. **Drainage area:** 1.22 mi² including 0.28 mi² for upstream Lonedell Lake Dam (MO 31395) and 0.94 mi² for Aggravation Lake Dam proper.
- b. **Lag time:** 1.00 hrs
- c. **Hydrologic soil group:** B
- d. **SCS curve numbers.**
 1. For PMF: 75 (AMC III)
 2. For 1 and 10 percent probability-of-occurrence events: 57 (AMCII)

- e. **Storage.** Elevation-area data were developed by planimetering areas at various elevation contours on the USGS Richwoods NE 7.5-minute quadrangle map. The data were entered on the \$A and \$E cards so that the HEC-I program could compute storage volumes.
- f. **Outflow capacity.** The spillway rating curve was computed by the intrinsic formula within the HEC-I program. Pertinent spillway data required by the program were entered on the \$\$ card.
- g. **Outflow over crest.** As the profile of the dam crest is irregular, flow over the crest cannot be determined by conventional weir formulas. Crest length-elevation data and hydraulic constants for the crest were entered on \$D, \$L and \$V cards.
- h. **Reservoir elevations.** For all fractions of the PMF, the starting reservoir elevation was the spillway crest elevation of 767.6 ft. For the 1 and 10 percent probability-of-occurrence events, the starting reservoir elevation was also 767.6 ft.

B.3 Results

Results of the analyses, as well as the input values to the HEC-I program pertaining to various fractions of the Probable Maximum Flood (PMF), follow in this Appendix. Only results summaries are included, not intermediate output. Complete copies of the HEC-I input and output are available in the project file.

 FLOWM HYDROGRAPH PACKAGE (MEC-1)
 DAM SAFETY VERSION JULY 1978
 LAST MODIFICATION 01 APR 80

1 DAM NO. 31395 - LONDELL LAKE, FRANKLIN COUNTY, MISSOURI.
 2 MCDONALD-CLYDE CONSULTANTS, HOUSTON JOB 79CH099.
 3 PROBABLE MAXIMUM FLOOD (PMF) ANALYSIS.

4 288 0 10 -0 -0 -0 -0 -0
 5 5

7 J1 .25 .50 .75 1.00
 8 K 0 0-INI

9 LONDELL L. DAM NO. 31395, MULTI-RATIO PMF RUNOFF COMPUTATIONS. 1
 10 P 1 2 0.281
 11 M 0 26. 102 120 130 140
 12

13 W2 0.504
 14 X -2 -0.05 5
 15 K 1 DAM1

16 LONDELL L. DAM NO. 31395, MULTI-RATIO PMF CAPACITY/OVERTOPPING ANALYSIS.
 17 V 1 1

19 SA 9. 1.7 5.7 8.9 9.7 13.6 19.6
 20 SE 788. 800. 810. 820. 822.3 830. 840.
 21 SD 827.4 827.4 827.4 827.4 827.4 827.4 827.4

22 SL 48. 200. 405. 800.
 23 SK 27.5 824.0 824.0 824.0

24 K 0 0-INI
 25 K1 LAKE AGGRAVATION DAM NO. 30557, MULTI-RATIO PMF RUNOFF COMPUTATIONS. 1
 26 M 1 2 0.441
 27 P 0 26. 102 120 130 140
 28 T 1

29 X -2 -0.05 5
 30 K 2 0-INI
 31 K 1 DAM2

32 K1 LAKE AGGRAVATION - PMF COMBINED HYDROGRAPH CAPACITY AND OVERTOPPING ANALYSIS.
 33 V 1 1

34 SA 0 2.3 9.7 17.6 20.6 23.5 38.9
 35 SE 744. 750. 760. 767.6 770. 772.3 780.
 36 SD 772.3 772.3 772.3 772.3 772.3 772.3 772.3

37 SL 0 440. 880. 880.
 38 SK 372. 772.3 772.3 772.3

Input Data
 Various PMF Events
 Aggravation Lake Dam
 MO 30557

1.01	2.50	17	.00	.03	.00	1.	1.02	2.50	161	.03	.07	.01	.07
1.01	3.00	18	.00	.00	.00	0.	1.02	3.00	162	.03	.02	.01	.67
1.01	3.10	19	.00	.00	.00	0.	1.02	3.10	163	.03	.07	.01	.68
1.01	3.20	20	.00	.00	.00	0.	1.02	3.20	164	.03	.07	.01	.69
1.01	3.30	21	.00	.00	.00	0.	1.02	3.30	165	.03	.02	.01	.70
1.01	3.40	22	.00	.00	.00	0.	1.02	3.40	166	.03	.02	.01	.71
1.01	3.50	23	.00	.00	.00	0.	1.02	3.50	167	.03	.02	.01	.71
1.01	4.00	24	.00	.00	.00	0.	1.02	4.00	168	.03	.02	.01	.71
1.01	4.10	25	.00	.00	.00	0.	1.02	4.10	169	.03	.02	.01	.71
1.01	4.20	26	.00	.00	.00	0.	1.02	4.20	170	.03	.02	.01	.72
1.01	4.30	27	.00	.00	.00	0.	1.02	4.30	171	.03	.02	.01	.72
1.01	4.40	28	.00	.00	.00	0.	1.02	4.40	172	.03	.02	.01	.73
1.01	4.50	29	.00	.00	.00	0.	1.02	4.50	173	.03	.02	.01	.73
1.01	5.00	30	.00	.00	.00	0.	1.02	5.00	174	.03	.02	.01	.73
1.01	5.10	31	.00	.00	.00	0.	1.02	5.10	175	.03	.02	.01	.74
1.01	5.20	32	.00	.00	.00	0.	1.02	5.20	176	.03	.02	.01	.74
1.01	5.30	33	.00	.00	.00	0.	1.02	5.30	177	.03	.02	.01	.74
1.01	5.40	34	.00	.00	.00	0.	1.02	5.40	178	.03	.02	.01	.75
1.01	5.50	35	.00	.00	.00	0.	1.02	5.50	179	.03	.02	.01	.75
1.01	6.00	36	.00	.00	.00	0.	1.02	6.00	180	.03	.02	.01	.75
1.01	6.10	37	.01	.00	.01	0.	1.02	6.10	181	.13	.10	.03	.78
1.01	6.20	38	.01	.00	.01	0.	1.02	6.20	182	.13	.10	.03	.84
1.01	6.30	39	.01	.00	.01	1.	1.02	6.30	183	.13	.10	.03	.97
1.01	6.40	40	.01	.00	.01	1.	1.02	6.40	184	.13	.10	.03	1.19
1.01	6.50	41	.01	.00	.01	1.	1.02	6.50	185	.13	.10	.03	1.40
1.01	7.00	42	.01	.00	.01	1.	1.02	7.00	186	.13	.10	.03	1.81
1.01	7.10	43	.01	.00	.01	1.	1.02	7.10	187	.13	.10	.03	2.14
1.01	7.20	44	.01	.00	.01	1.	1.02	7.20	188	.13	.10	.03	2.45
1.01	7.30	45	.01	.00	.01	1.	1.02	7.30	189	.13	.11	.02	2.79
1.01	7.40	46	.01	.00	.01	1.	1.02	7.40	190	.13	.11	.02	2.95
1.01	7.50	47	.01	.00	.01	2.	1.02	7.50	191	.13	.11	.02	3.13
1.01	8.00	48	.01	.00	.01	2.	1.02	8.00	192	.13	.11	.02	3.28
1.01	8.10	49	.01	.00	.01	2.	1.02	8.10	193	.13	.11	.02	3.40
1.01	8.20	50	.01	.00	.01	2.	1.02	8.20	194	.13	.11	.02	3.60
1.01	8.30	51	.01	.00	.01	2.	1.02	8.30	195	.13	.11	.02	3.99
1.01	8.40	52	.01	.00	.01	2.	1.02	8.40	196	.13	.11	.02	3.66
1.01	8.50	53	.01	.00	.01	2.	1.02	8.50	197	.13	.11	.02	3.72
1.01	9.00	54	.01	.00	.01	2.	1.02	9.00	198	.13	.11	.02	3.78
1.01	9.10	55	.01	.00	.01	2.	1.02	9.10	199	.13	.11	.02	3.87
1.01	9.20	56	.01	.00	.01	2.	1.02	9.20	200	.13	.11	.02	3.87
1.01	9.30	57	.01	.00	.01	2.	1.02	9.30	201	.13	.11	.02	3.81
1.01	9.40	58	.01	.00	.01	2.	1.02	9.40	202	.13	.11	.02	3.94
1.01	9.50	59	.01	.00	.01	2.	1.02	9.50	203	.13	.11	.02	3.92
1.01	10.00	60	.01	.00	.01	2.	1.02	10.00	204	.13	.11	.02	4.00
1.01	10.10	61	.01	.00	.01	2.	1.02	10.10	205	.13	.11	.02	4.03
1.01	10.20	62	.01	.00	.01	2.	1.02	10.20	206	.13	.11	.01	4.05
1.01	10.30	63	.01	.00	.01	2.	1.02	10.30	207	.13	.12	.01	4.07
1.01	10.40	64	.01	.00	.01	2.	1.02	10.40	208	.13	.12	.01	4.09
1.01	10.50	65	.01	.00	.01	2.	1.02	10.50	209	.13	.12	.01	4.11
1.01	11.00	66	.01	.00	.01	2.	1.02	11.00	210	.13	.12	.01	4.13

Input Data
Various PMF Events
Aggravation Lake Dam
MO 30557

1.01 11.00	66	.01	.00	.01	2.	1.02 11.00	210	.13	.17	.01	417.
1.01 11.10	67	.01	.00	.01	2.	1.02 11.10	211	.13	.17	.01	415.
1.01 11.20	68	.01	.00	.01	2.	1.02 11.20	212	.13	.17	.01	413.
1.01 11.30	69	.01	.00	.01	2.	1.02 11.30	213	.13	.17	.01	411.
1.01 11.40	70	.01	.00	.01	2.	1.02 11.40	214	.13	.17	.01	420.
1.01 11.50	71	.01	.00	.01	2.	1.02 11.50	215	.13	.17	.01	421.
1.01 12.00	72	.01	.00	.01	2.	1.02 12.00	216	.13	.17	.01	422.
1.01 12.10	73	.03	.00	.03	2.	1.02 12.10	217	.44	.40	.04	432.
1.01 12.20	74	.03	.00	.03	2.	1.02 12.20	218	.44	.41	.03	431.
1.01 12.30	75	.03	.00	.03	2.	1.02 12.30	219	.44	.41	.03	508.
1.01 12.40	76	.03	.00	.03	3.	1.02 12.40	220	.44	.41	.03	592.
1.01 12.50	77	.03	.00	.03	3.	1.02 12.50	221	.44	.41	.03	702.
1.01 13.00	78	.03	.00	.03	3.	1.02 13.00	222	.44	.42	.03	874.
1.01 13.10	79	.04	.00	.04	4.	1.02 13.10	223	.53	.50	.03	949.
1.01 13.20	80	.04	.00	.04	4.	1.02 13.20	224	.53	.50	.03	1030.
1.01 13.30	81	.04	.00	.04	5.	1.02 13.30	225	.53	.51	.03	1165.
1.01 13.40	82	.04	.00	.04	6.	1.02 13.40	226	.53	.51	.02	1290.
1.01 13.50	83	.04	.01	.04	7.	1.02 13.50	227	.53	.51	.02	1384.
1.01 14.00	84	.04	.01	.03	8.	1.02 14.00	228	.53	.51	.02	1468.
1.01 14.10	85	.05	.01	.04	9.	1.02 14.10	229	.66	.64	.02	1547.
1.01 14.20	86	.05	.01	.04	11.	1.02 14.20	230	.66	.64	.02	1622.
1.01 14.30	87	.05	.01	.04	14.	1.02 14.30	231	.66	.64	.02	1699.
1.01 14.40	88	.05	.01	.04	17.	1.02 14.40	232	.66	.64	.02	1780.
1.01 14.50	89	.05	.01	.04	20.	1.02 14.50	233	.66	.65	.02	1863.
1.01 15.00	90	.05	.01	.04	23.	1.02 15.00	234	.66	.65	.02	1945.
1.01 15.10	91	.05	.01	.03	27.	1.02 15.10	235	.60	.59	.01	2019.
1.01 15.20	92	.08	.02	.05	31.	1.02 15.20	236	1.01	.99	.02	2094.
1.01 15.30	93	.14	.05	.09	37.	1.02 15.30	237	1.81	1.78	.04	2198.
1.01 15.40	94	.15	.15	.20	47.	1.02 15.40	238	4.53	4.47	.07	2439.
1.01 15.50	95	.10	.03	.03	82.	1.02 15.50	239	1.31	1.24	.02	2877.
1.01 16.00	96	.06	.03	.03	84.	1.02 16.00	240	.81	.80	.01	3349.
1.01 16.10	97	.05	.02	.02	109.	1.02 16.10	241	.62	.61	.01	4042.
1.01 16.20	98	.03	.02	.02	131.	1.02 16.20	242	.62	.61	.01	4751.
1.01 16.30	99	.05	.03	.02	144.	1.02 16.30	243	.62	.61	.01	4759.
1.01 16.40	100	.05	.03	.02	149.	1.02 16.40	244	.62	.61	.01	4746.
1.01 16.50	101	.03	.03	.02	147.	1.02 16.50	245	.62	.61	.01	4539.
1.01 17.00	102	.03	.03	.02	141.	1.02 17.00	246	.62	.61	.01	4226.
1.01 17.10	103	.04	.02	.02	132.	1.02 17.10	247	.49	.48	.00	3831.
1.01 17.20	104	.04	.02	.02	122.	1.02 17.20	248	.49	.48	.00	3432.
1.01 17.30	105	.04	.02	.02	115.	1.02 17.30	249	.49	.49	.00	3137.
1.01 17.40	106	.04	.02	.02	109.	1.02 17.40	250	.49	.48	.00	2885.
1.01 17.50	107	.04	.02	.02	104.	1.02 17.50	251	.49	.48	.00	2644.
1.01 18.00	108	.04	.02	.02	99.	1.02 18.00	252	.49	.48	.00	2503.

Input Data
Various PMF Events
Aggravation Lake Dam
MO 30557

1.01	17.20	104	.04	.02	.02	172	1.02	17.20	248	.44	.48	.00	3433
1.01	17.30	105	.04	.02	.02	115	1.02	17.30	249	.49	.48	.00	3133
1.01	17.40	106	.04	.02	.02	109	1.02	17.40	250	.49	.48	.00	2885
1.01	17.50	107	.04	.02	.02	104	1.02	17.50	251	.49	.48	.00	2684
1.01	18.00	108	.04	.02	.02	99	1.02	18.00	252	.49	.48	.00	2503
1.01	18.10	109	.00	.00	.00	95	1.02	18.10	253	.04	.04	.00	2336
1.01	18.20	110	.00	.00	.00	90	1.02	18.20	254	.04	.04	.00	2177
1.01	18.30	111	.00	.00	.00	84	1.02	18.30	255	.04	.04	.00	1993
1.01	18.40	112	.00	.00	.00	76	1.02	18.40	256	.04	.04	.00	1785
1.01	18.50	113	.00	.00	.00	67	1.02	18.50	257	.04	.04	.00	1558
1.01	19.00	114	.00	.00	.00	57	1.02	19.00	258	.04	.04	.00	1327
1.01	19.10	115	.00	.00	.00	48	1.02	19.10	259	.04	.04	.00	1107
1.01	19.20	116	.00	.00	.00	40	1.02	19.20	260	.04	.04	.00	811
1.01	19.30	117	.00	.00	.00	32	1.02	19.30	261	.04	.04	.00	742
1.01	19.40	118	.00	.00	.00	27	1.02	19.40	262	.04	.04	.00	607
1.01	19.50	119	.00	.00	.00	22	1.02	19.50	263	.04	.04	.00	507
1.01	20.00	120	.00	.00	.00	19	1.02	20.00	264	.04	.04	.00	430
1.01	20.10	121	.00	.00	.00	17	1.02	20.10	265	.04	.04	.00	370
1.01	20.20	122	.00	.00	.00	14	1.02	20.20	266	.04	.04	.00	322
1.01	20.30	123	.00	.00	.00	13	1.02	20.30	267	.04	.04	.00	283
1.01	20.40	124	.00	.00	.00	12	1.02	20.40	268	.04	.04	.00	253
1.01	20.50	125	.00	.00	.00	11	1.02	20.50	269	.04	.04	.00	229
1.01	21.00	126	.00	.00	.00	10	1.02	21.00	270	.04	.04	.00	211
1.01	21.10	127	.00	.00	.00	9	1.02	21.10	271	.04	.04	.00	198
1.01	21.20	128	.00	.00	.00	9	1.02	21.20	272	.04	.04	.00	188
1.01	21.30	129	.00	.00	.00	8	1.02	21.30	273	.04	.04	.00	181
1.01	21.40	130	.00	.00	.00	8	1.02	21.40	274	.04	.04	.00	175
1.01	21.50	131	.00	.00	.00	8	1.02	21.50	275	.04	.04	.00	170
1.01	22.00	132	.00	.00	.00	8	1.02	22.00	276	.04	.04	.00	167
1.01	22.10	133	.00	.00	.00	8	1.02	22.10	277	.04	.04	.00	164
1.01	22.20	134	.00	.00	.00	8	1.02	22.20	278	.04	.04	.00	162
1.01	22.30	135	.00	.00	.00	8	1.02	22.30	279	.04	.04	.00	160
1.01	22.40	136	.00	.00	.00	8	1.02	22.40	280	.04	.04	.00	159
1.01	22.50	137	.00	.00	.00	7	1.02	22.50	281	.04	.04	.00	157
1.01	23.00	138	.00	.00	.00	7	1.02	23.00	282	.04	.04	.00	157
1.01	23.10	139	.00	.00	.00	7	1.02	23.10	283	.04	.04	.00	157
1.01	23.20	140	.00	.00	.00	7	1.02	23.20	284	.04	.04	.00	157
1.01	23.30	141	.00	.00	.00	7	1.02	23.30	285	.04	.04	.00	157
1.01	23.40	142	.00	.00	.00	7	1.02	23.40	286	.04	.04	.00	157
1.01	23.50	143	.00	.00	.00	7	1.02	23.50	287	.04	.04	.00	157
1.02	0.	144	.00	.00	.00	7	1.03	0.	288	.04	.04	.00	157

SUN 30-00 32-07 3-59 11895
 (925.10 835.11 90.11 3357.09)

Input Data
 Various PMF Events
 Aggravation Lake Dam
 MO 30557

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

RATIOS APPLIED TO FLOWS

OPERATION STATION AREA PLAN RATIO 1 RATIO 2 RATIO 3 RATIO 4

0-141 (.731 (13.8211 16.5811 19.3411 22.1011

0-142 (.731 (20.5111 12.7711 15.0811 17.4211

0-143 (2.441 (33.6911 40.4211 47.1611 53.9011

0-144 (3.161 (44.2011 53.1911 62.2011 71.2111

0-145 (3.161 (38.6011 46.6811 55.4711 66.8911

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ELEVATION INITIAL VALUE SPILLWAY CREST TOP OF DAM
 STORAGE 767.60 767.60 772.30
 OUTFLOW 163. 163. 259.
 0. 0. 1971.

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
.25	771.34	0.	277.	1363.	0.	41.99	0.
.30	771.84	0.	249.	1648.	0.	41.00	0.
.35	772.29	0.	259.	1959.	0.	41.00	0.
.40	772.50	0.28	266.	2362.	1.00	40.83	0.

Output Summary
 Various PMF Events
 Aggravation Lake Dam
 MO 30557

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

OPERATION STATION AREA PLAN RATIO 1 RATIO 2 RATIO 3 RATIO 4 RATIOS APPLIED TO FLOWS

HYDROGRAPH AT	0-112	0.29	0.731	13.8211	27.6311	41.4511	95.2611
ROUTED TO	0-112	0.29	0.731	13.8211	27.6311	41.4511	95.2611
HYDROGRAPH AT	3-112	0.29	0.731	13.8211	27.6311	41.4511	95.2611
ROUTED TO	3-112	0.29	0.731	13.8211	27.6311	41.4511	95.2611

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 INITIAL VALUE SPILLWAY CREST TOP OF DAM
 STORAGE 163. 787.00 172.90
 OUTFLOW 0. 163. 259.
 1971.

RATIO	MAXIMUM RESERVOIR W.S. ELEV	MAXIMUM OUTFLOW OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
0.25	771.34	0.	237.	1383.	0.	41.00	0.
0.50	772.92	0.62	274.	3091.	1.50	40.67	0.
0.75	773.44	1.14	287.	4691.	3.00	40.67	0.
1.00	773.84	1.54	297.	6243.	4.50	40.50	0.

Output Summary
 Various PMF Events
 Aggravation Lake Dam
 MO 30557

ATE
LME