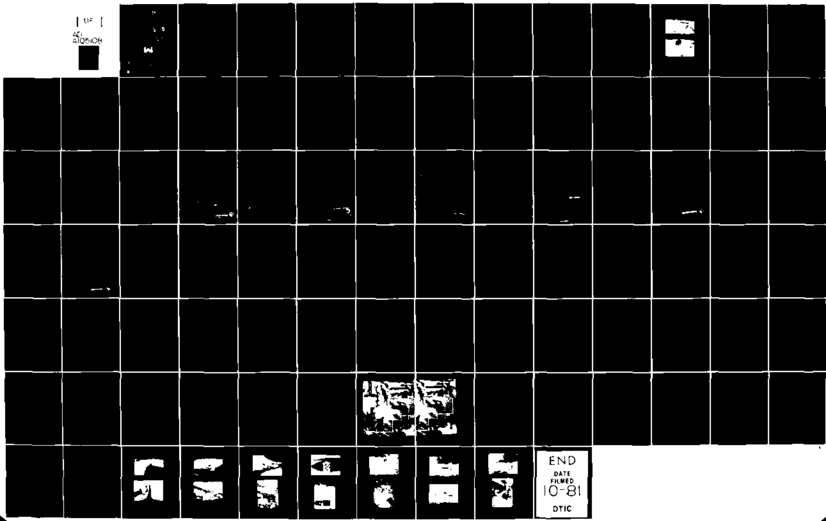
AD-A105 108 ANDERSON ENGINEERING INC SPRINGFIELD MO F/G 13/13
NATIONAL DAM SAFETY PROGRAM. BOWLING GREEN DAM, (MO 10262) MISS--ETC(U)
DEC 78 J M HEALY, S L BRADY DACW43-78-C-0166

UNCLASSIFIED NL

1 OF 1
AD
A105108



END
DATE
FILMED
10-81
DTIC

MISSISSIPPI - KASKASKIA - ST. LOUIS BASIN

BOWLING GREEN DAM
PIKE COUNTY, MISSOURI
MO 10262

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

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

FOR: STATE OF MISSOURI

DECEMBER 1978

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-A105 108	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Phase I Dam Inspection Report National Dam Safety Program Bowling Green Reservoir Dam (MO 10262) Pike County, Missouri		5. TYPE OF REPORT & PERIOD COVERED Final Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Anderson Engineering, Inc.		8. CONTRACT OR GRANT NUMBER(s) DACW43-78-C-0166
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 December 1978
		13. NUMBER OF PAGES Approximately 70
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

National Dam Safety Program. Bowling Green Dam, (MO 10262) Mississippi - Kaskaskia - St. Louis Basin, [redacted]; Pike County, Missouri. Phase I Inspection 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.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

412264

INSTRUCTIONS FOR PREPARATION OF REPORT DOCUMENTATION PAGE

RESPONSIBILITY. The controlling DoD office will be responsible for completion of the Report Documentation Page, DD Form 1473, in all technical reports prepared by or for DoD organizations.

CLASSIFICATION. Since this Report Documentation Page, DD Form 1473, is used in preparing announcements, bibliographies, and data banks, it should be unclassified if possible. If a classification is required, identify the classified items on the page by the appropriate symbol.

CC[illegible] LETION GUIDE

General. Make Blocks 1, 4, 5, 6, 7, 11, 13, 15, and 16 agree with the corresponding information on the report cover. Leave Blocks 2 and 3 blank.

Block 1. Report Number. Enter the unique alphanumeric report number shown on the cover.

Block 2. Government Accession No. Leave Blank. This space is for use by the Defense Documentation Center.

Block 3. Recipient's Catalog Number. Leave blank. This space is for the use of the report recipient to assist in future retrieval of the document.

Block 4. Title and Subtitle. Enter the title in all capital letters exactly as it appears on the publication. Titles should be unclassified whenever possible. Write out the English equivalent for Greek letters and mathematical symbols in the title *(see "Abstracting Scientific and Technical Reports of Defense-sponsored RDT/E," AD-667 000)*. If the report has a subtitle, this subtitle should follow the main title, be separated by a comma or semicolon if appropriate, and be *initially capitalized*. If a publication has a title in a foreign language, translate the title into English and follow the English translation with the title in the original language. Make every effort to simplify the title before publication.

Block 5. Type of Report and Period Covered. Indicate here whether report is interim, final, etc., and, if applicable, inclusive dates of period covered, such as the life of a contract covered in a final contractor report.

Block 6. Performing Organization Report Number. Only numbers other than the official report number shown in Block 1, such as series numbers for in-house reports or a contractor/grantee number assigned by him, will be placed in this space. If no such numbers are used, leave this space blank.

Block 7. Author*(s)*. Include corresponding information from the report cover. Give the name*(s)* of the author*(s)* in conventional order *(for example, John R. Doe or, if author prefers, J. Robert Doe)*. In addition, list the affiliation of an author if it differs from that of the performing organization.

Block 8. Contract or Grant Number*(s)*. For a contractor or grantee report, enter the complete contract or grant number*(s)* under which the work reported was accomplished. Leave blank in in-house reports.

Block 9. Performing Organization Name and Address. For in-house reports enter the name and address, including office symbol, of [illegible] performing activity. For contractor or grantee reports enter the name and address of the contractor or grantee who prepared the report and identify the appropriate corporate division, school, laboratory, etc., of the author. List city, state, and ZIP Code.

Block 10. Program Element, Project, Task Area, and Work Unit Numbers. Enter here the number code from the applicable Department of Defense form, such as the DD Form 1498, "Research and Technology Work Unit Summary" or the DD Form 1634. "Research and Development Planning Summary," which identifies the program element, project, task area, and work unit or equivalent under which the work was authorized.

Block 11. Controlling Office Name and Address. Enter the full, official name and address, including office symbol, of the controlling office. *(Equates to funding/sponsoring agency. For definition see DoD Directive 5200.20, "Distribution Statements on Technical Documents.")*

Block 12. Report Date. Enter here the day, month, and year or month and year as shown on the cover.

Block 13. Number of Pages. Enter the total number of pages.

Block 14. *Monitoring Agency Name and Address (if different from Controlling Office)*. For use when the controlling or funding office does not directly administer a project, contract, or grant, but delegates the administrative responsibility to another organization.

Blocks 15 & 15a. Security Classification of the Report: Declassification/Downgrading Schedule of the Report. Enter in 15 the highest classification of the report. If appropriate, enter in 15a the declassification/downgrading schedule of the report, using the abbreviations for declassification/downgrading schedules listed in paragraph 4-207 of DoD 5200.1-R.

Block 16. *Distribution Statement of the Report. Insert here the applicable distribution statement of the report from DoD* Directive 5200.20, "Distribution Statements on Technical Documents."

Block 17. Distribution Statement *(of the abstract entered in Block 20, if different from the distribution statement of the report)*. Insert here the applicable distribution statement of the abstract from DoD Directive 5200.20, "Distribution Statements on Technical Documents."

Block 18. Supplementary Notes. Enter information not included elsewhere but useful, such as: Prepared in cooperation with . . . [illegible]anslation of *(or by)* . . . Presented at conference of . . . To be published in . . .

Block 19. Key Words. Select terms or short phrases that identify the principal subjects covered in the report, and are sufficiently specific and precise to be used as index entries for cataloging, conforming to standard terminology. The DoD "Thesaurus of Engineering and Scientific Terms" *(TEST)*, AD-672 000, can be helpful.

Block 20. Abstract. The abstract should be a brief *(not to exceed 200 words)* factual summary of the most significant information contained in the report. If possible, the abstract of a classified report should be unclassified and the abstract to an unclassified report should consist of publicly- releasable information. If the report contains a significant bibliography or literature survey, mention it here. For information on preparing abstracts see "Abstracting Scientific and Technical Reports of Defense-Sponsored RDT&E," AD-667 000.

☆ U.S. G.P.O. 1980-665-141/1299

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

IN REPLY REFER TO

SUBJECT: Bowling Green Dam, MO ID No. 10262

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

SUBMITTED BY: SIGNED 9 FEB 1979
Chief, Engineering Division — Date

APPROVED BY: SIGNED 12 FEB 1979
Colonel, CE, District Engineer — Date

Accession For		
NTIS GRA&I	X	
DTIC TAB		
Unannounced		
Justification		
By		
Distribution/		
Availability Codes		
Dist	Avail and/or Special	
A		

BOWLING GREEN DAM

PIKE COUNTY, MISSOURI

MISSOURI INVENTORY NO. 10262

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

Prepared By

Anderson Engineering, Inc., Springfield, Missouri
Hanson Engineers, Inc., Springfield, Illinois

For

The Governor of Missouri

December, 1978

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam:	Bowling Green Dam
State Located:	Missouri
County Located:	Pike County
Stream:	Unnamed Tributary to Noix Creek
Date of Inspection:	27 September 1978

Bowling Green Dam was inspected by an interdisciplinary team of engineers from Anderson Engineering, Inc. of Springfield, Missouri and Hanson Engineers, Inc. of Springfield, Illinois. 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 they have been developed with the help of several Federal and State agencies, professional engineering organizations, and private engineers. Based on these guidelines, this dam has been classified by the St. Louis District Corps of Engineers as an intermediate size dam with a high downstream hazard potential. Their estimate of the damage zone extends 10 miles downstream of the dam. Within the damage zone are one house, eight farm complexes, one railroad bridge, one state highway bridge, and three improved road bridges.

Our inspection and evaluation indicates that the combined spillways do not meet the criteria set forth in the guidelines for a dam having the above size and hazard potential. The spillway will pass 45 percent of the Probable Maximum Flood without overtopping. The Probable Maximum Flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The guidelines require that a dam of intermediate size with a high downstream hazard potential pass 100 percent of the PMF. The spillway will pass a 100-year frequency flood without overtopping. The 100-year frequency flood is one that has a 1 percent chance of being exceeded in any given year.

The embankment and appurtenances inspected appear to be in good condition. Minor deficiencies, including erosion, seepage, and brush and tree growth were noted and should be corrected by the owner. Seepage analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is another deficiency that should be corrected. A detailed report describing the dam and these deficiencies is attached.

John M. Healy

John M. Healy, P.E.
Hanson Engineers, Inc.

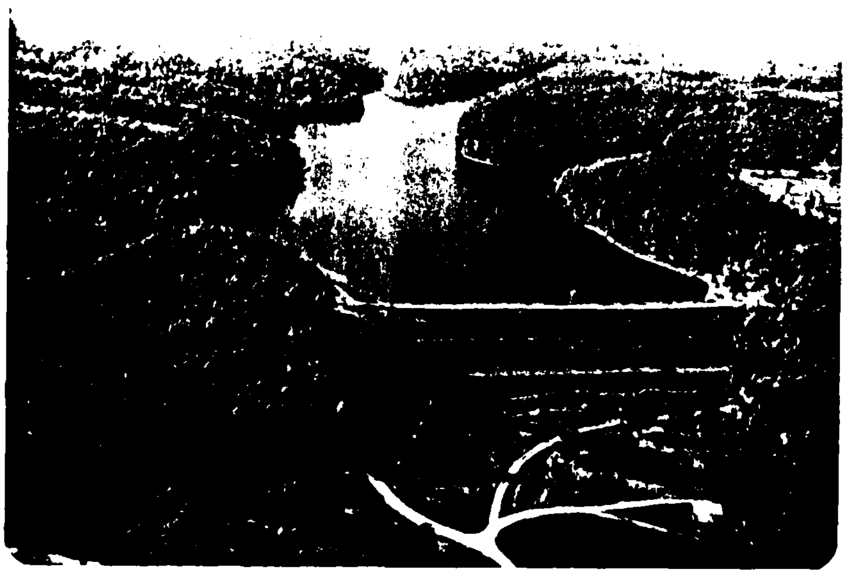
Steven L. Brady

Steven L. Brady, P.E.
Anderson Engineering, Inc.

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
BOWLING GREEN DAM - ID No. 10262

TABLE OF CONTENTS

APPENDICES



Aerial Views of the Lake and Dam

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 St. Louis District, Corps of Engineers, District Engineer directed that a safety inspection be made of Bowling Green Dam in Pike County, Missouri,

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 a 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, "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:

Bowling Green Dam is an earth fill structure approximately 73 ft high and 660 ft long at the crest. The appurtenant works consist of a water supply intake tower and 12 in. diameter cast-iron pipe which is located near the center of the dam, and a concrete chute spillway, which is located about 400 ft south of the east abutment. The water supply intake structure contains a valve which can be used for partial drawdown of the lake (to elevation 780.0). Two additional valves are located upstream of the intake tower for supplementary drawdown (intakes at elevations 760.0 and 739.5). Sheet 3 of Appendix A shows details of the intake tower, valves, and a transverse section of the embankment.

B. Location:

The dam is located in the central part of Pike County, Missouri on a small tributary of Noix Creek. The dam and lake are within the Bowling Green, Missouri quadrangle sheet, 2 miles east of Bowling Green (NW 1/4 Section 29, Twp. 53N, R2 W--latitude 39° 20.6'; longitude 91° 9.2'). Sheet 1 of Appendix A shows the general vicinity of the dam and a plan of the immediate area of the dam and lake.

C. Size Classification:

With an embankment height of 73 ft and a maximum storage capacity of approximately 1691 acre-ft, the dam is in the intermediate size category.

D. Hazard Classification:

The St. Louis District, Corps of Engineers has classified this dam as a high hazard dam. Their estimate of the damage zone extends 10 miles downstream of the dam. Within the damage zone are one house, eight farm complexes, one state highway bridge, one railroad bridge, and three improved road bridges.

E. Ownership:

The dam is owned by the City of Bowling Green, Missouri.

F. Purpose of Dam:

The purpose of the dam is to supply water to the city of Bowling Green, although some flood prevention is also provided.

G. Design and Construction History:

The dam was designed by Haskins, Riddle and Sharp Consulting Engineers of Kansas City, Missouri, constructed by L. W. Riney Construction Company of Hannibal, Missouri, and completed in 1954. Plans for construction are available (obtained from George Butler & Associates of Kansas City, Missouri) and have been used to prepare this report. There has been a significant problem concerning seepage through the west abutment since the dam was built. Extensive pressure grouting of the west abutment was done in 1959, and some grouting of the east abutment was also done. It is reported that the grouting operation reduced the amount of seepage from about 300,000 gallons per day to about 90,000 gallons per day. However, in April 1963, it was reported that the leakage was 200,000 gpd. A lean concrete fill was subsequently placed at the west abutment-dam contact (upstream) in a further attempt to reduce seepage. Recent measurements indicated the seepage to be between 30,000 and 70,000 gpd.

H. Normal Operating Procedure:

Normal outflow from the lake is carried by a 12 in. cast-iron pipe for water supply, whereas a concrete chute spillway would come into operation for floods. The concession stand operator at the site indicated that the chute spillway is used primarily in the spring of the year.

1.3 PERTINENT DATA:

Pertinent data about the dam, appurtenant works, and reservoir are presented in the following paragraphs. Sheet 2 of Appendix A is a plan of the embankment and spillway. Sheet 3 presents details of the inlet structure and a typical embankment section. Sheet 4 shows a plan and profile of the spillway. Presented on Sheet 5 are sections of the spillway.

A. Drainage Area:

The drainage area for this dam, as obtained from the Bowling Green, Missouri 15 minute quadrangle sheet, is equal to approximately 900 acres.

B. Elevations (Feet Above M.S.L.):

(1) Top of Dam (measured): West end 804.3; Center 801.3; East end 803.8; Lowest point 801.0.
Top of Dam (Plans for Construction): 805.0
(See Existing Top of Dam Profile-Sheet 6 of Appendix A)

(2) Spillway Crest: Plans for Construction 795.0; Measured 795.0.

(3) Spillway Outlet: Plans for Construction 770.0; Measured 769.8.

(4) Maximum Design Pool: 801.0.

(5) Pool on Date of Inspection: Measured 790.3.

(6) Apparent High Water Mark of Record: Reported 798 to 799.

(7) Streambed at Centerline of Dam: Plans for Construction 728.

(8) Maximum Tailwater: Unknown.

C. Discharge at Dam Site:

(1) All normal discharge at the dam site is through the 12 in. water supply pipe and an uncontrclled spillway.

(2) Estimated Discharge Capacity at Top of Dam (El. 801.0): 2525 cfs.

D. Reservoir Surface Areas:

(1) At Spillway Crest: Plans for Construction 45 acres.

(2) At Top of Dam: 54 acres.

E. Storage Capacities:

(1) At Spillway Crest (El. 795): Plans for Construction 1410 acre-ft.

(2) At Top of Dam (El. 801.0): 1691 acre-ft.

F. Reservoir Lengths:

(1) At Spillway Crest (Estimated from Plans for Construction): 3550 ft.

(2) At Top of Dam (Estimated from Plans for Construction): 4150 ft.

G. Dam:

(1) Type: Rolled earth.

(2) Length at Crest: 660 ft.

(3) Height: 73 ft.

(4) Top Width: 16 ft (measured).

(5) Side Slopes: 2.5H:1V. (Lower portion of downstream face is 3H:1V.).

(6) Zoning: Clays in main portion of embankment; "unselected materials" at downstream face (see Sheet 3, Appendix A).

(7) Cutoff: Apparently none.

(8) Antiseep Collars: Three concrete collars are provided around the water supply pipe upstream of the centerline of the dam.

H. Spillway:

(1) Location: 400 ft south of the east abutment of the dam.

(2) Type: Concrete chute (40 ft crest length).

SECTION 2 - ENGINEERING DATA

2.1 GENERAL:

Available design computations and reports for Bowling Green Dam include a site geology report prepared by the Missouri Geological Survey (Sheets 4 thru 10, Appendix B), design notes for seepage, embankment stability, and spillway adequacy, test results on embankment material (Atterberg limits, grain size, shear strength, compaction curve), and reports on the leakage through the west abutment and subsequent grouting operation (Sheets 11 through 32, Appendix B). In addition, the Plans for Construction contain test boring records and some hydrologic data. No documentations of construction inspection records have been obtained.

2.2 DESIGN:

A. Surveys:

The locations and elevations of two temporary benchmarks are shown on Sheet 2 of Appendix A. Neither of these two temporary benchmarks was located during the visual inspection. The crest of the spillway was used as a benchmark and was assumed to the same elevation as indicated on the plans for construction (795.0).

B. Geology and Subsurface Materials:

The area around Bowling Green Dam is characterized by rolling-to-hilly topography. The subsurface materials in upland areas generally consist of about 5 ft of loess underlain by residual soils and bedrock. Geological maps of the area indicate that the bedrock consists of the Burlington Limestone overlying the Hannibal shale formations (both of the Lower Mississippian system). The Burlington formation is a light-gray, coarse-grained, and massive limestone. The thickness of this formation ranges from 75 ft to 100 ft in this area. In many areas, the Burlington formation contains caves, sinkholes, springs and joints. The Hannibal formation underlying the Burlington, is a massive, blue-gray silty shale, generally about 80 or 90 ft thick. The contact between the Burlington-Hannibal formation is reported to be at elevation 780 in the area of the dam.

Classifications of the soils encountered in the borings are presented on Sheet 1 of Appendix B. The locations of these borings are included on Sheet 1 of Appendix A. The soils encountered in the borings are generally brown and yellow clays (with some gravel) over a green shale (bedrock). The maximum penetration of the borings was to approximately elevation 677.

A preliminary geology report prepared by the Missouri Geological Survey is presented on Sheets 4 through 10 of Appendix B.

C. Foundation and Embankment Design:

No foundation or embankment design reports for Bowling Green Dam were obtained. However, soil test results on potential borrow material and partial slope stability calculations were acquired from Mr. Clifford Sharp, P.E. Although seepage analyses were apparently performed, they were not available. A brief summary of the results of the embankment design calculations and recommendations for embankment construction are presented on Sheets 2 and 3 of Appendix B.

Sheet 3 of Appendix A shows a transverse section of the dam at the location of the water supply pipe (Station 2+55). No core trench is shown on the plans, and apparently no internal drainage system was provided. Only three anti-seep collars are provided around the water supply pipe, and these are located well upstream of the centerline of the dam. The transverse section shows a rock toe drain which was apparent from the visual inspection.

Because the water supply pipe passes through the dam to the pumping station, the full head of water impounded by the dam is acting entirely through the dam. The area around the water supply pipe at the downstream toe of the dam should be periodically inspected for seepage which might indicate a leak or rupture of the drain pipe and could eventually initiate a piping failure through the embankment. The water supply pipe has an upstream valve which is normally open, but could be shut off if leakage occurs.

Borrow material for the dam was obtained from the floor of the valley, both downstream and upstream of the dam. The only apparent zoning of the embankment can be seen on Sheet 3 of Appendix A. "Unselected materials" were to be used downstream of a line which extends from the downstream edge of the crest at a slope of 1.5H:1V toward the toe of the dam. "Selected materials, rolled in layers" are shown upstream of this line. No construction inspection test results have been obtained.

D. Hydrology and Hydraulics:

Some hydrologic and hydraulic design data have been provided, and the Plans for Construction also contain some hydrologic design data; these data are contained on Sheet 1 of Appendix A. Based on these data, a field check of spillway dimensions and embankment elevations, and a check of the drainage area on the U.S.G.S. quad sheet, a hydrologic analysis using U.S. Army Corps of Engineers guidelines was performed and appears in Appendix C, Sheets 1 to 6. It was concluded that the spillway will pass 45 percent of the Probable Maximum Flood.

E. Structure:

Structural design computations for appurtenant structures were not obtained. Details of the inlet structure and spillway are shown on the Plans for Construction and are presented on Sheets 3 through 5 of Appendix A.

2.3 CONSTRUCTION:

No construction inspection data have been obtained. Information regarding the pressure grouting which was performed in 1959 is included in Appendix B. No reports were available describing the concrete fill which was placed upstream at the west abutment-dam contact.

2.4 OPERATION AND MAINTENANCE:

Conversations with personnel at the Bowling Green water treatment plant indicate that normal operation consists of pumping about 500,000 gallons per day out of the reservoir for water supply. This rate of usage is expected to double with the construction of a new water treatment plant and the addition of new users. The water level fluctuates as much as 15 ft during the course of a year. Inspection indicates that maintenance of the dam (mowing the grass and brush removal) is done periodically.

2.5 EVALUATION:

The available engineering data listed in Section 2.1 do not include sufficient seepage or stability analyses nor any construction test data, and thus were inadequate to make a detailed assessment of the design, construction and operation of Bowling Green Dam. No valid engineering data on design or construction of the embankment were found.

Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dam's" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

SECTION 3 - VISUAL INSPECTION

3.1 GENERAL:

The field inspection was made on 27 September 1978. The inspection team consisted of personnel from Anderson Engineering, Inc. of Springfield, Missouri and Hanson Engineers, Inc. of Springfield, Illinois. The team members were:

Louis Williams - Anderson Engineering (Instrument Man)
Steve Brady - Anderson Engineering (Civil Engineer)
Dave Daniels - Hanson Engineers (Geotechnical & Hydraulics Engineer)
Dan Kerns - Hanson Engineers (Geotechnical Engineer)

3.2 DAM:

The dam is an earth fill embankment constructed from borrow material obtained from the valley both upstream and downstream of the dam. Based on the soil borings and soil test results, the fill material would be expected to consist of medium to high plasticity clays.

The embankment is grass-covered and appears to be in good condition. Considerable seepage was noted at the west abutment. Some erosion (small gullies, 8 in. to 12 in. deep) and small tree and brush growth was present at the dam and west abutment contact as a result of this seepage. A small slide (20 ft to 30 ft in areal extent) was evident above the pumping station which is located at the toe of the dam near the west end. This slide did not appear to be active.

It appeared that the seepage was generally exiting through the abutment, not at the abutment-dam contact. The flow in a ditch immediately north of the pumping station was estimated to be about 40,000 gallons per day. It is believed that the entire flow in this ditch was seepage exiting from various locations at the west abutment.

Brush and some small tree growth is present on the upstream face of the dam and through the rock toe drain. Brush and reed growth and some erosion was noted at the contact between the dam and the east abutment. Although some seepage has been reported at the east abutment, and the presence of reeds indicates that the area has been wet, no seepage was observed at the time the inspection was made.

The horizontal alignment of the dam appeared as shown on the plans. There is a shallow depression in the crest near the west abutment. No surface cracking or unusual movement was obvious. It should be noted, however, that the elevations along the top of the dam which were obtained in the field were as much as 4.0 ft lower than as indicated on the Plans for Construction (see Section 1.3.B of this report). All other elevations obtained in the field agreed fairly well with those indicated on the Plans for Construction.

No instrumentation (monuments, piezometers, etc.) was observed.

A. Spillway:

The concrete chute spillway was generally in good condition. There was a 1 in. wide joint separation in the right spillway wall at the point where the spillway begins to slope downward. A similar crack was evident in the left wall at the same location, although not as wide. A small void was present under the left drain pipe just below the spillway crest. The Plans for Construction (Sheets 4 and 5 of Appendix A) show vertical walls on the 40 ft wide spillway. However, the spillway was built with side walls sloping at 1H:1V.

A road which is built to the spillway crest constricts the approach channel somewhat. Tree growth at the sides of the approach channel also could restrict flow.

A plunge pool has been formed out of the underlying shale. The pool is about 12 ft deep and appears to be eroding back toward the spillway exit. The discharge channel has been eroded into the overburden and shale.

3.3 RESERVOIR AND WATERSHED:

The immediate periphery of the lake was timber-covered with moderate slopes. No sloughing or serious erosion of reservoir banks was noted.

The concession stand operator indicated that the high pool was 3 or 4 ft above the crest of the spillway (1973).

3.4 EVALUATION:

Small tree and brush growths noted at both abutments, on the upstream face and at the rock toe drain of the dam, should be removed, and all future growth should be removed on a yearly basis. An engineer experienced in the design and construction of dams should study and recommend means of correcting and/or controlling the observed seepage, erosion and slide.

To reduce entrance restrictions, trees along the sides of the spillway approach channel should be removed. It is believed that the road leading to the spillway crest restricts the passage of low flows only, and does not constrict the entrance during periods of high flows. The cracks in the spillway wall and the void below the left spillway drain pipe should be filled and sealed.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES:

Information furnished by personnel at the Bowling Green water treatment plant indicates that about 500,000 gallons of water per day are drawn from the reservoir for water supply. This rate of usage is expected to double in the near future.

4.2 MAINTENANCE OF DAM:

No maintenance information was available. Inspection indicated that maintenance of the dam (mowing the grass and brush removal) is apparently done periodically.

4.3 MAINTENANCE OF OPERATING FACILITIES:

Although the water supply facilities appear to be in good condition, it is not known whether they are regularly maintained.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT:

The inspection team is unaware of any existing warning system for this dam.

4.5 EVALUATION:

Tree and brush growth should be removed from the dam on a yearly basis. Although not serious now, erosional areas at abutment-dam contacts will need some repair in the future.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES:

A. Design and Experience Data:

Some of the design data used by the Haskins, Riddle and Sharp Consulting Engineers to design this dam have been obtained. Some hydrologic data as shown in the Plans for Construction are presented on Sheet 1 of Appendix A. Based on this information, a field check of spillway dimensions and embankment elevations, and a check of the pool and drainage areas from the U.S.G.S. quad sheet (Bowling Green, Missouri quad sheet), a hydrologic analysis was performed using U.S. Army Corps of Engineers guidelines and appears in Appendix C, Sheets 1 to 6.

B. Visual Observations:

The concrete chute spillway generally appeared to be in good condition, although some cracks were noticed in the spillway walls. In addition, a small void was present at the left drain pipe just below the crest of the spillway. Trees at the edge of the approach channel could possibly restrict all flows to the spillway.

Facilities available to draw down the pool for water supply appeared to be in good condition. The spillway is located about 400 ft south of the east abutment. Spillway releases would not be expected to endanger the integrity of the dam.

C. Overtopping Potential:

Based on the hydrologic and hydraulic analysis as presented in Appendix C, the spillway will pass 45 percent of the Probable Maximum Flood. The Probable Maximum Flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The recommended guidelines from the Department of the Army, Office of the Chief of Engineers, require that this structure (intermediate size with high downstream hazard potential) pass 100 percent of the PMF, without overtopping. Fifty percent of the PMF will overtop the dam by .41 ft for a duration of .58 hours with a resultant peak outflow discharge of 2913 c.f.s. One hundred percent of the PMF will overtop the dam by 2.24 ft for a duration of 2.92 hours with a resultant peak outflow of 9990 cfs (see Sheet 6 of Appendix C). The structure will pass a 100-year frequency flood without overtopping.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY:

A. Visual Observations:

Although the seepage through the west abutment is detrimental in terms of water loss from the lake, we do not believe that this condition adversely affects the structural stability at this time. However, if left unchecked, the erosion at abutment-dam contact areas could cause some localized stability problems and possibly complete failure in the future. The seepage should be periodically checked for both quantity and turbidity. An increase in turbidity of the seepage water would indicate that embankment material is being washed away. If significant increases of seepage quantity or turbidity are noted, then immediate remedial measures should be initiated to attempt to stop the leakage. These remedial measures should be performed under the guidance of a professional engineer experienced in the design and construction of dams.

B. Design and Construction Data:

Stability analyses were performed by Haskins, Riddle and Sharp Consulting Engineers, and recommendations were made regarding side slopes and berm widths and elevations. Our site inspection indicates that the side slopes and berm widths and elevations were as shown on the plans. Seepage analyses comparable to requirements of the guidelines were unavailable and constitute a deficiency that should be rectified. No compaction specifications or construction records of the density of the earth fill have been obtained.

C. Operating Records:

Current water usage drawn from the reservoir is about 500,000 gallons per day. This usage, combined with the seepage and evaporation, results in a reservoir water level fluctuation of up to 15 ft during the year. These fluctuations of water level have apparently not affected the structural stability of the dam.

D. Post-Construction Changes:

The only known post construction changes at Bowling Green Dam were attempts to reduce or eliminate the seepage through the abutments of the dam. These attempts include a major pressure grouting program at the west abutment (and, to a lesser extent, at the east abutment) in 1959. This operation succeeded in reducing the quantity of seepage from 300,000 gallons per day to about 90,000 gallons per day. Later, the seepage was reported to be between 150,000 gpd and 200,000 gpd (May 1963 letter from MGS - Sheets 29 and 30 of Appendix B).

Subsequent attempts to stop the seepage were made by placing fresh concrete at the upstream face of the west abutment-dam contact in an area of suspected seepage entrance. This operation was successful to some degree. The present water superintendent indicated that the seepage was reduced to between 30,000 gpd and 70,000 gpd. Reports on the leakage and grouting operation are included as Sheets 11 through 32 of Appendix B.

E. Seismic Stability:

The structure is located in seismic zone 1, which is historically the least active zone in terms of occurrence and magnitude of earthquakes. The seismic loading prescribed for zone 1 is generally not critical for a well-constructed earth dam of this size.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT:

A. General:

This Phase I inspection and evaluation should not be considered as being comprehensive since the scope of work contracted for is far less detailed than would be required for an in-depth evaluation of dams. Latent deficiencies, which might be detected by a totally comprehensive investigation, could exist.

B. Safety:

The embankment itself is generally in good condition. The minor items which have been noted previously--such as brush and tree growth, and erosion--can and should be corrected and controlled. Other deficiencies which should be corrected include an inadequate spillway and lack of seepage analyses as required by the guidelines.

Several attempts to stop the abutment seepage have failed. This seepage should be monitored closely in the future, and records should be maintained. If the quantity or turbidity of the seepage water should significantly increase, then an immediate study of the problem and remedial measures should be initiated under the guidance of a professional engineer experienced in the design and construction of dams.

The dam will be overtopped by flows in excess of 45 percent of the Probable Maximum Flood. Overtopping of an earthen embankment could cause serious erosion and could possibly lead to failure of the structure.

C. Adequacy of Information:

The conclusions in this report were based on review of preliminary design notes and calculations, the Plans for Construction, the geological report prepared by the Missouri Geological Survey, the performance history as related by others, and visual observation of external conditions. The inspection team considers that these data are sufficient to support the conclusions herein.

D. Urgency:

The remedial measures recommended in paragraph 7.3 should be accomplished in the near future. If the minor deficiencies listed in paragraph B are not corrected and if good maintenance is not provided, the embankment condition will continue to deteriorate and possibly could become serious. Priority should be given to increasing the capacity of the spillway so that it is able to pass the PMF.

E. Necessity for Phase II:

Based on the result of the Phase I inspection, no Phase II inspection is recommended.

F. Seismic Stability:

The structure is located in seismic zone 1, which is historically the least active zone in terms of occurrence and magnitude of earthquakes. The seismic loading prescribed for zone 1 is generally not critical for a well-constructed earth dam of this size.

7.2 FURTHER INVESTIGATIONS:

The seepage from the west abutment should be monitored carefully with respect to both the quantity of flow and whether soil is being carried by the seepage water. Any substantial increase of quantity of flow or turbidity of the seepage water should be fully investigated immediately and corrective actions taken. Although this seepage is believed to be passing through the abutment and not the embankment or abutment-dam contact, it is a potentially dangerous situation which could endanger the embankment. All investigations should be performed under the guidance of a professional engineer experienced in the design and construction of dams.

7.3 REMEDIAL MEASURES:

The following remedial measures and maintenance procedures are recommended. All remedial measures should be performed under the guidance of a professional engineer experienced in the design and construction of dams.

(1) Remove the existing tree and brush growth on the upstream face of the dam, at the abutment-dam contacts, and at the rock toe drain, and remove all future tree and brush growth on a yearly basis.

(2) Remove the trees at the approach channel to the spillway. Repair the cracks in the spillway walls, and fill the void at the left drain pipe just below the spillway crest.

(3) Correct the minor erosion activity at the embankment-abutment contacts on the downstream side of the dam. Study and repair the small slide area above the pumping station and channelize the seepage water around the

pumping station. Periodically check the plunge pool for increased erosion toward the spillway, and take remedial measures if the spillway is threatened by undermining.

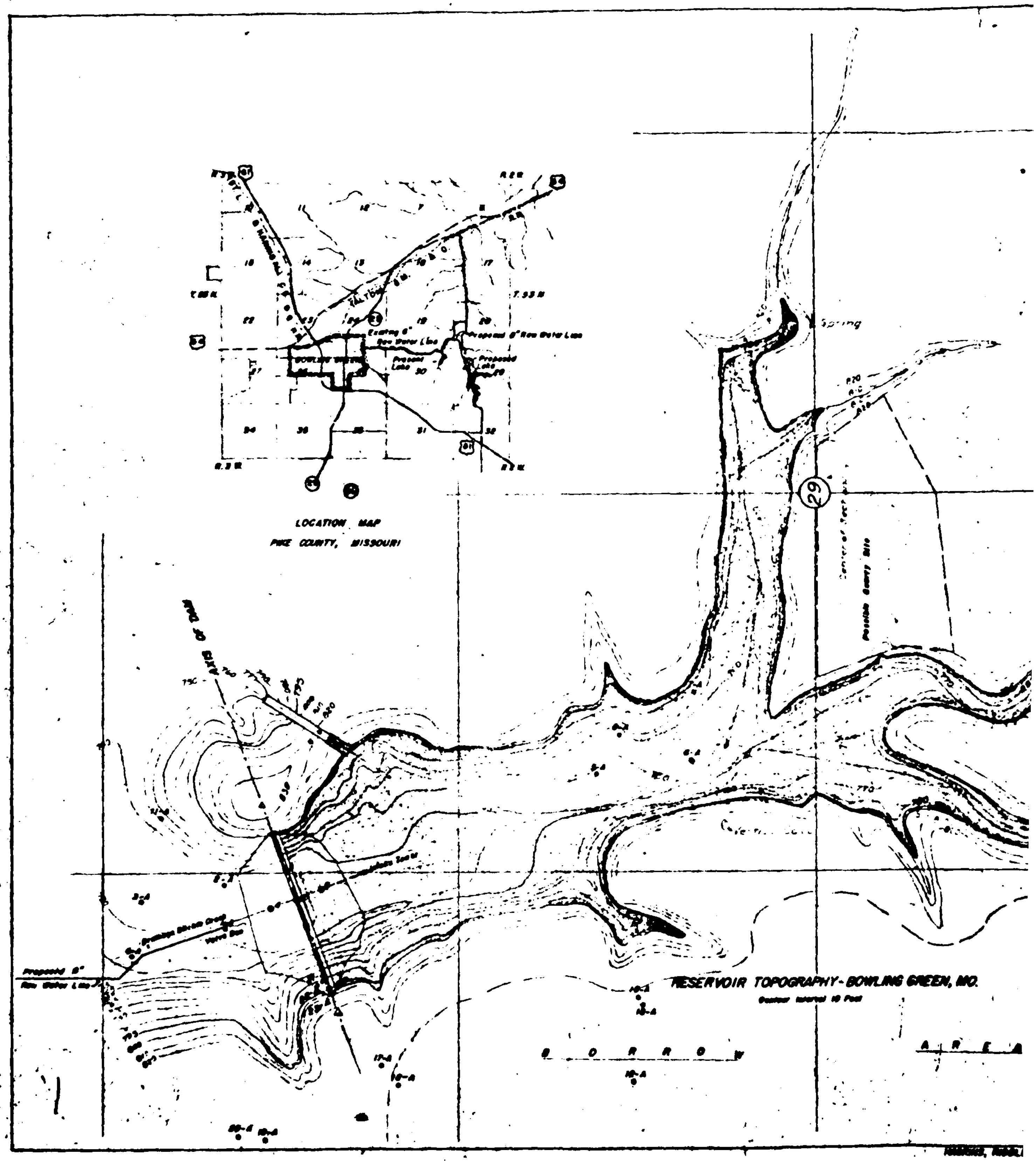
(4) The seepage water from the west abutment should be closely monitored for increased quantity or turbidity. Any significant increase of quantity or turbidity of seepage water should be immediately investigated, and corrective actions taken. Methods to correct and/or control the seepage should be studied and implemented.

(5) Check the downstream slope of the embankment periodically for seepage and stability problems, especially around the location of the water supply pipe at the downstream toe of the dam. If wet areas or seepage flows from the embankment are observed, or if sloughing is noted, then the dam should be inspected and the situation evaluated.

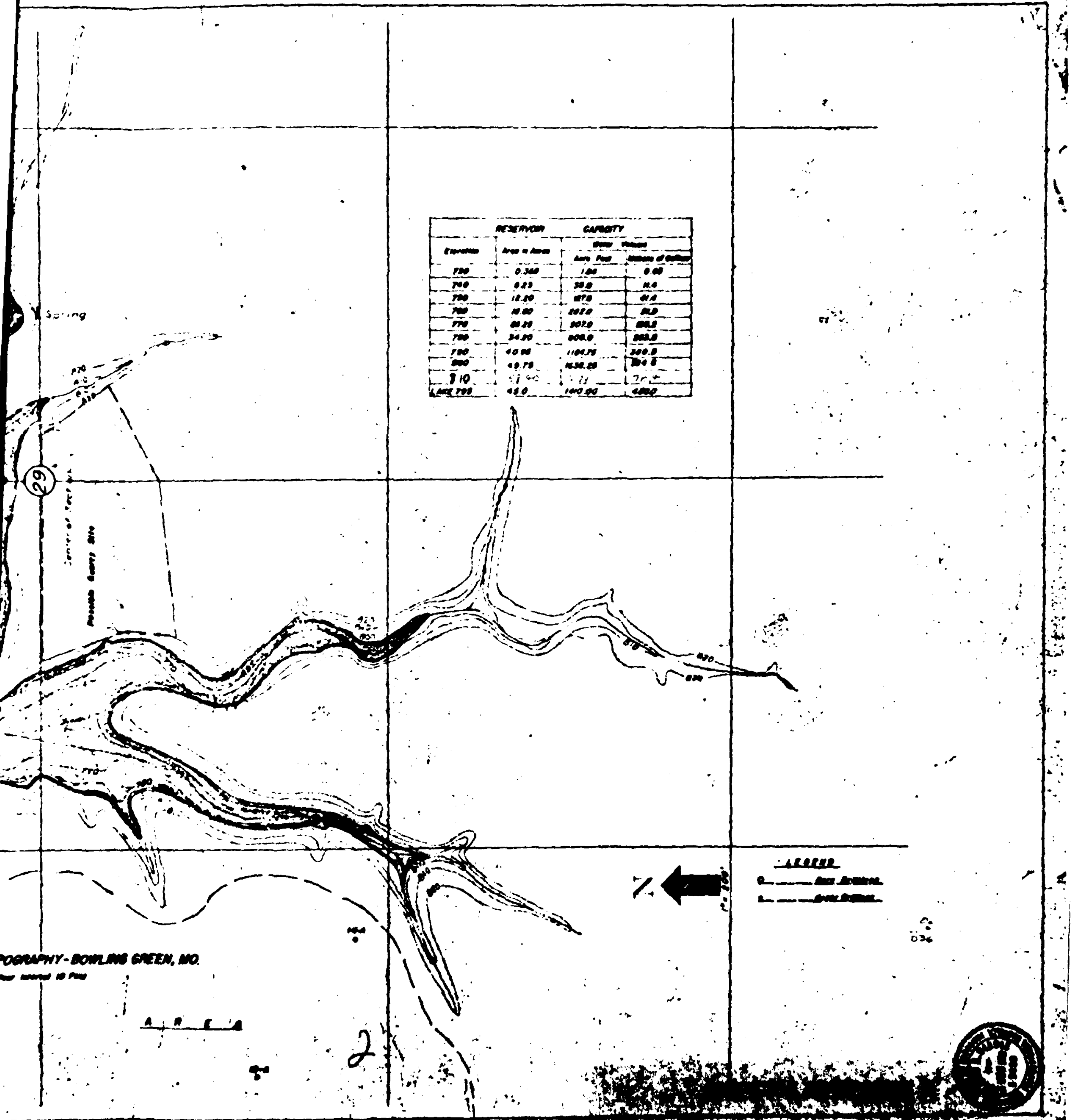
(6) A detailed inspection of the dam should be made periodically by an engineer experienced in the design and construction of dams. More frequent inspections may be required if additional slides, seeps, or other items of distress are observed.

(7) Spillway size and/or height of dam should be increased to pass the PMF. In either case, the spillway should be protected to prevent erosion. An increase in the height of the center portion of this dam to the original top of dam design elevation of 805.0 (make dam level from abutment to abutment) might increase the capacity of the structure to pass the PMF.

APPENDIX A

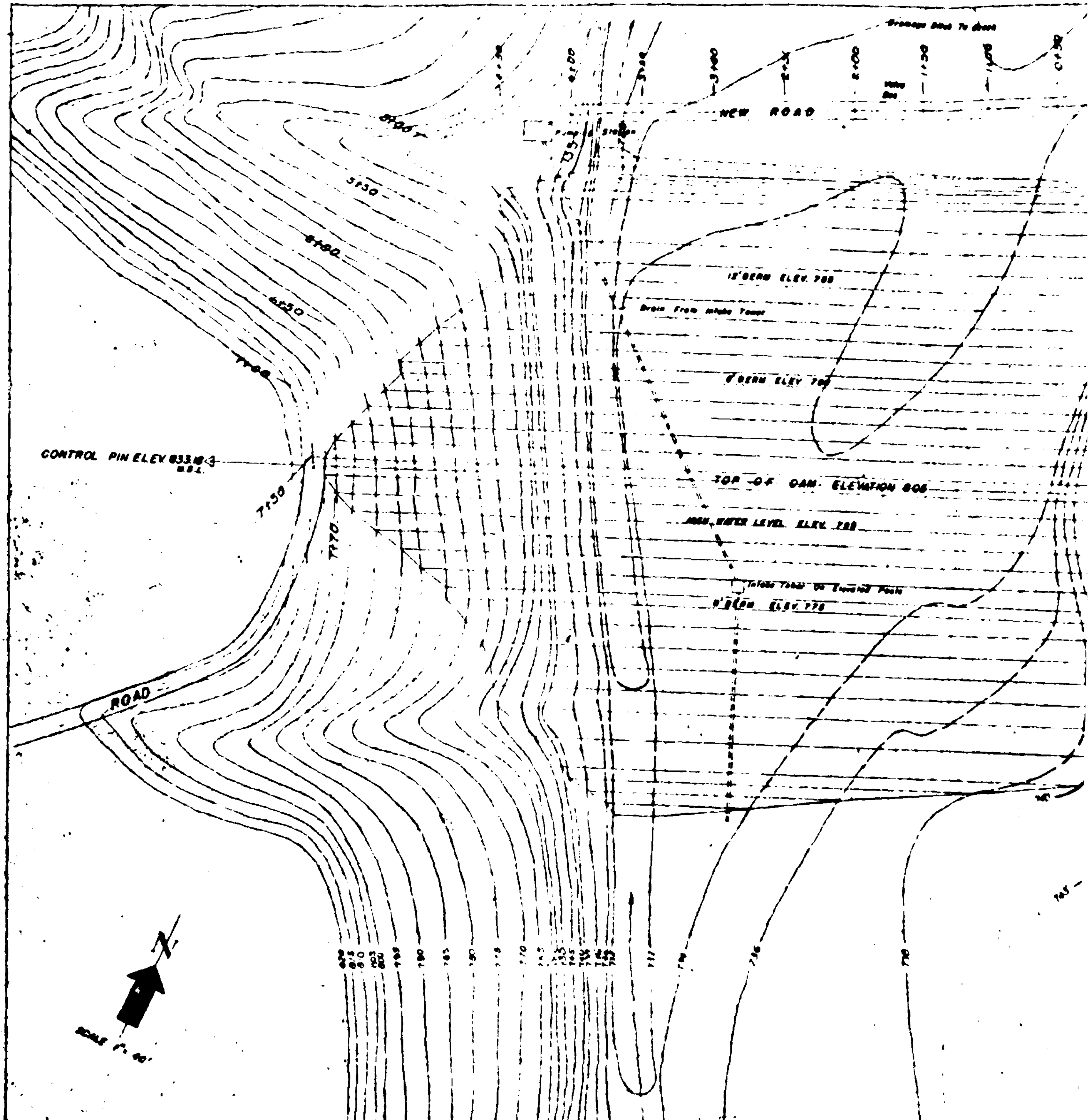


LOCATION MAP
PIKE COUNTY, MISSOURI
Spring
AXIS OF DAM
RESERVOIR TOPOGRAPHY - BOWLING GREEN, MO.
B O R R O W
A R E A

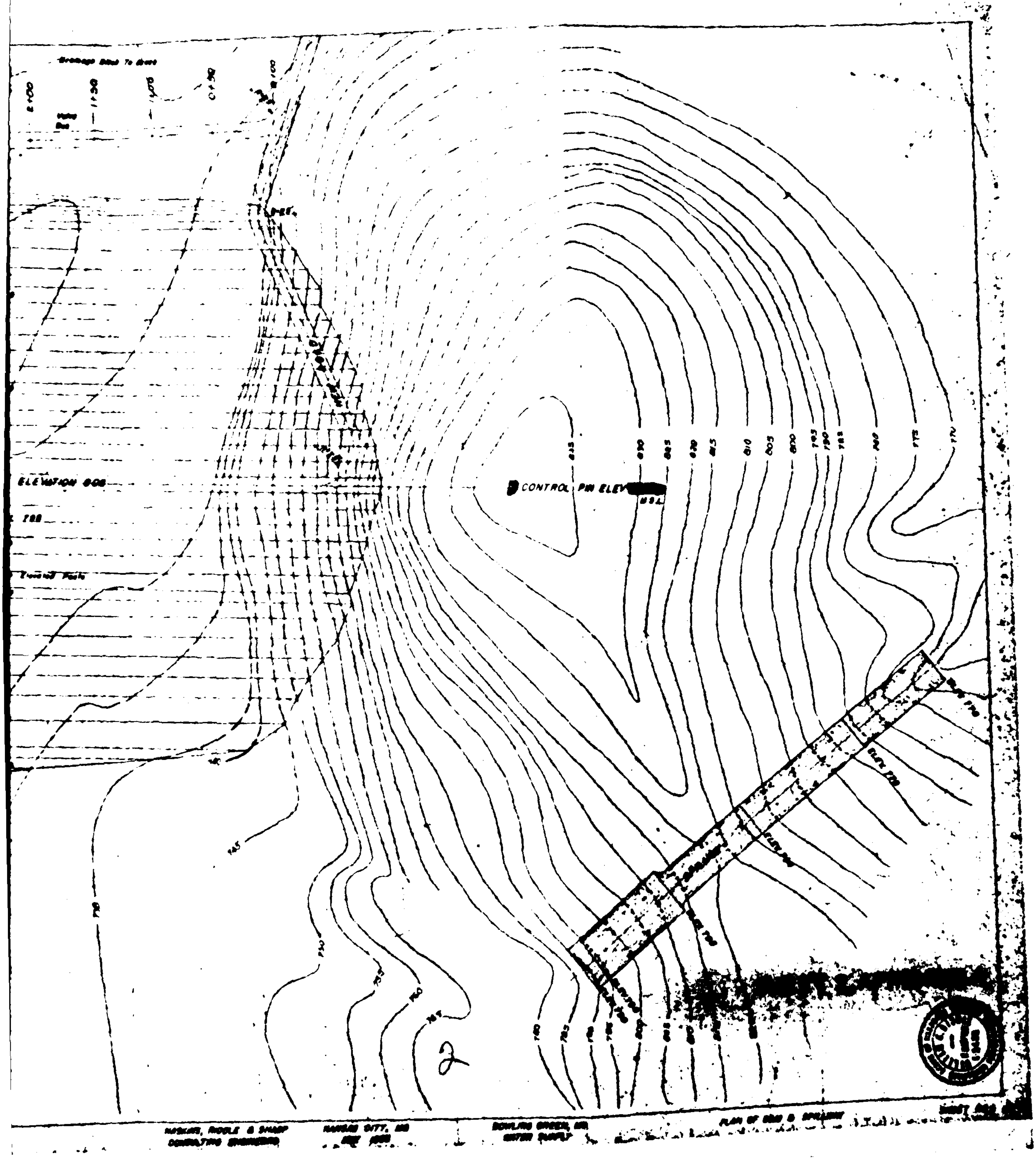


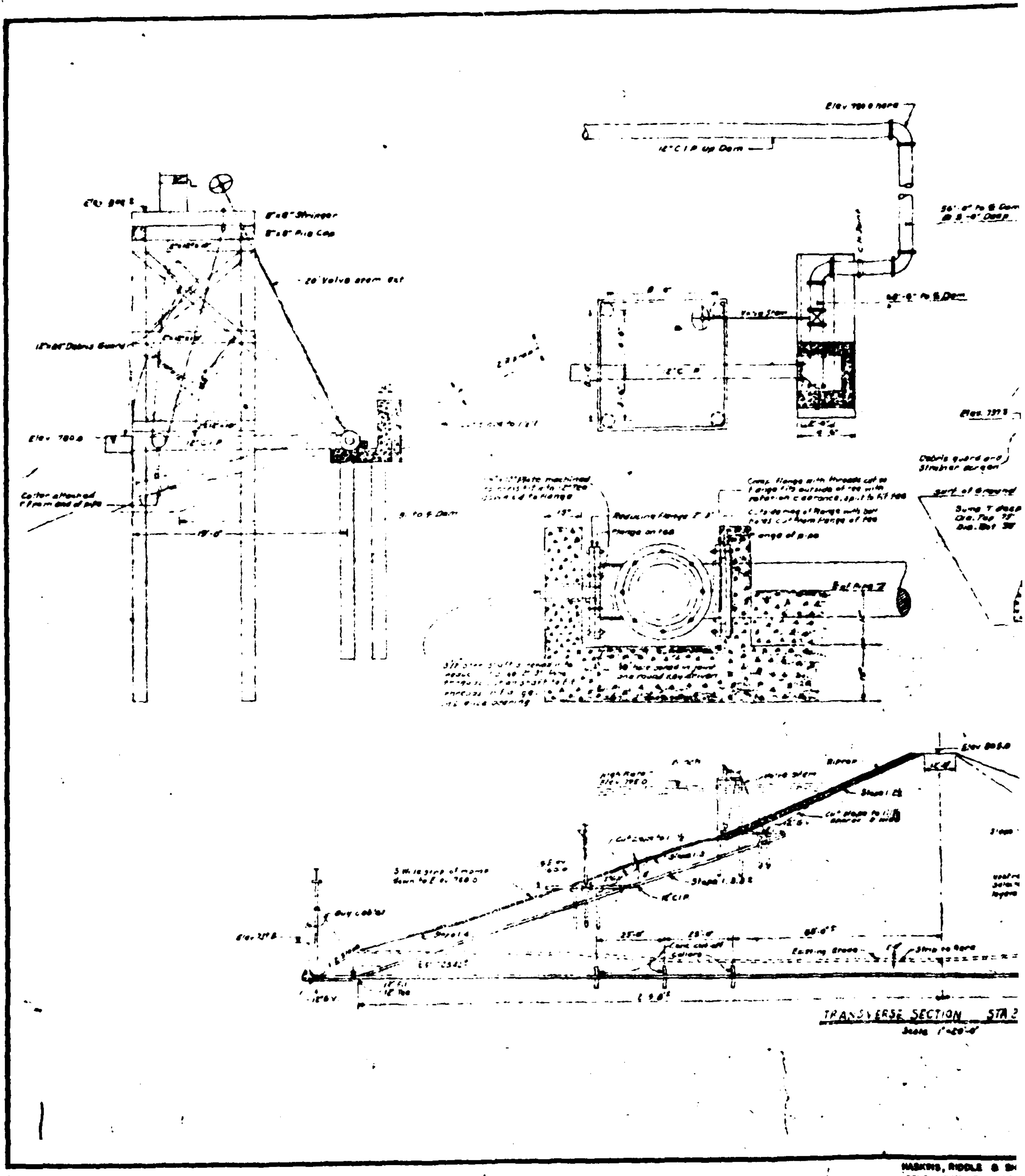
RESERVOIR CAPACITY			
Elevation	Area in Acres	Water Volume	
		Acre Feet	Millions of Gallons
730	0.360	1.06	[illegible]
740	6.23	35.0	[illegible]
750	12.20	127.0	41.4
760	18.80	282.0	[illegible]
770	[illegible]	507.0	[illegible]
780	34.20	800.0	[illegible]
790	40.95	1104.75	360.0
800	49.75	1536.25	[illegible]
810	[illegible]	[illegible]	[illegible]
LAKE 795	45.0	1410.00	[illegible]

HARRIS, RIGGLE & SHARP CONSULTING ENGINEERS — KANSAS CITY, MO. — BOWLING GREEN, MO.

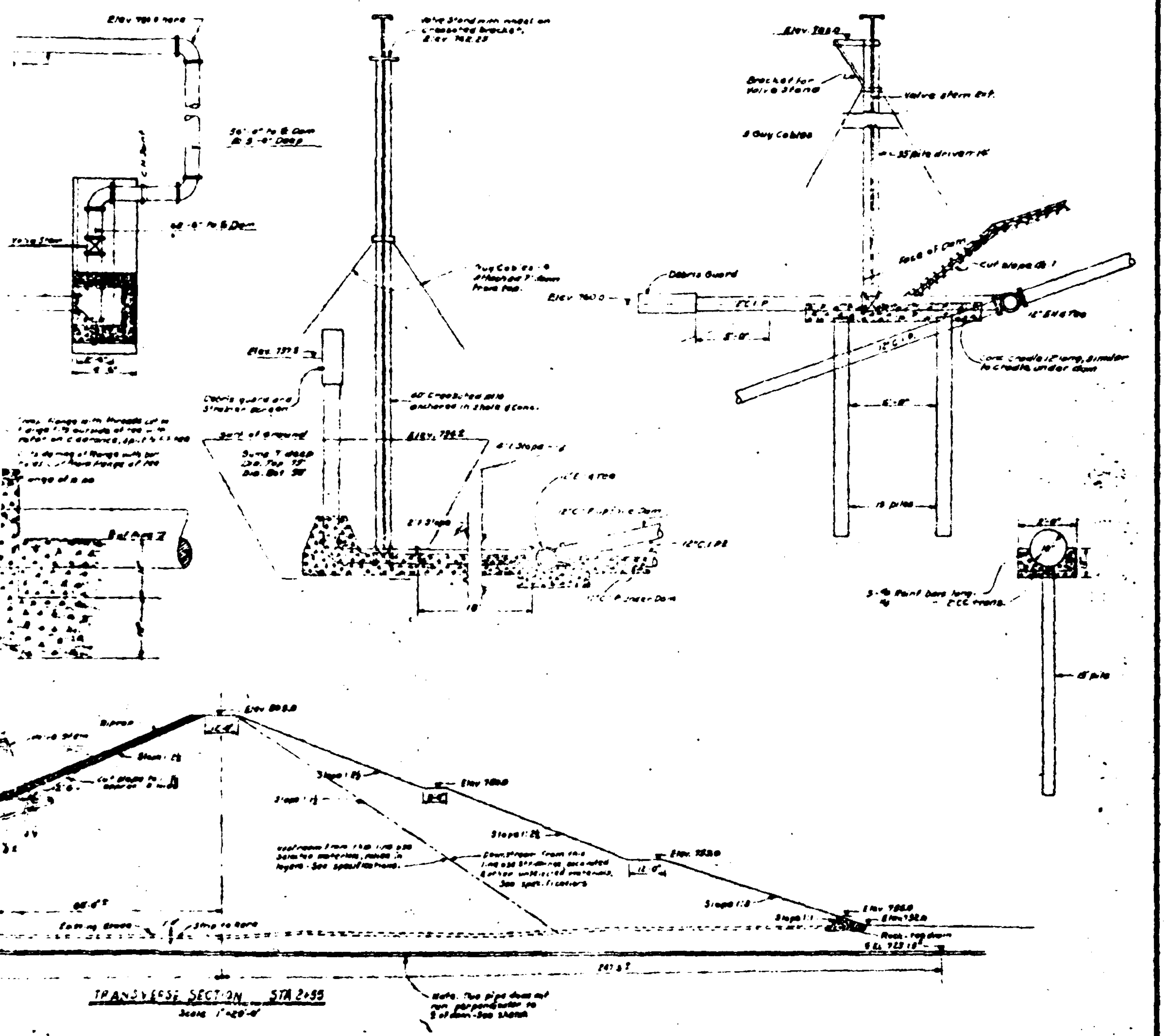


HASKINS, RIDDLE &
CONSULTING ENGIN


CONTROL PIN ELEV



HASKINS, RIDDLE & SH
CONSULTING ENGINEE



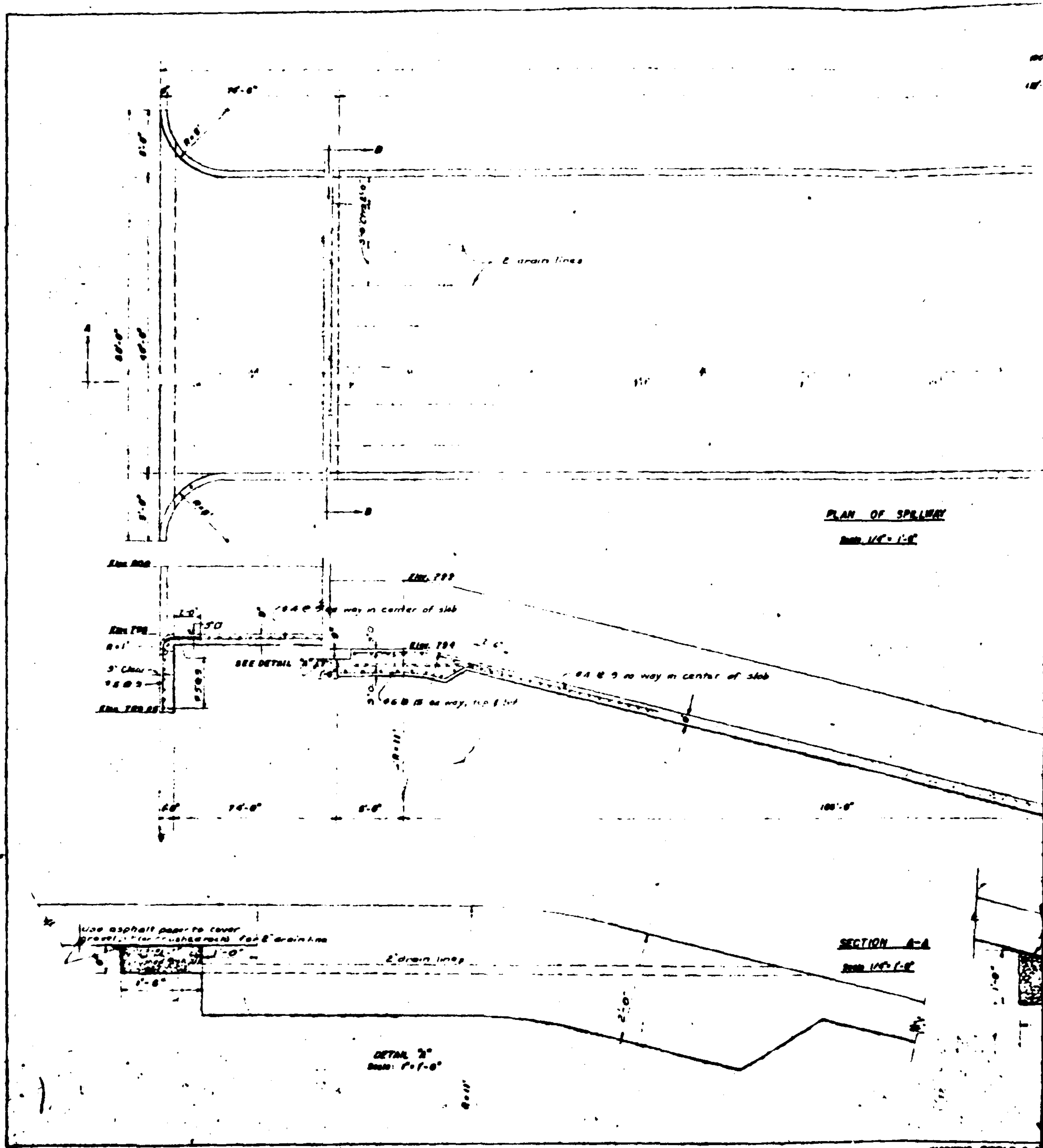
SHEET 3, APPENDIX A

HASKINS, RIDDLE & SHARP CONSULTING ENGINEERS

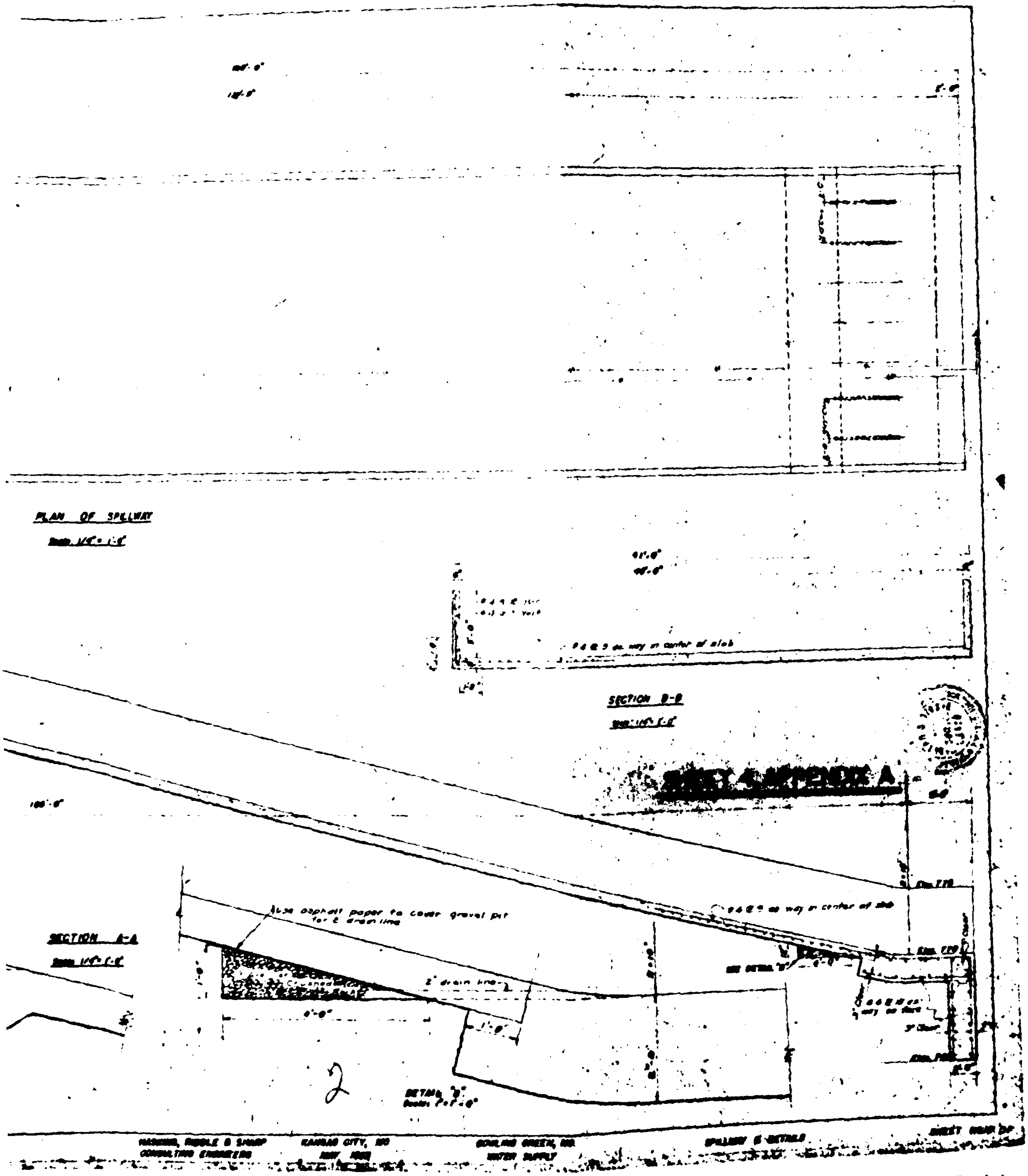
KANSAS CITY, MO.

BOWLING GREEN, MO. WATER SUPPLY

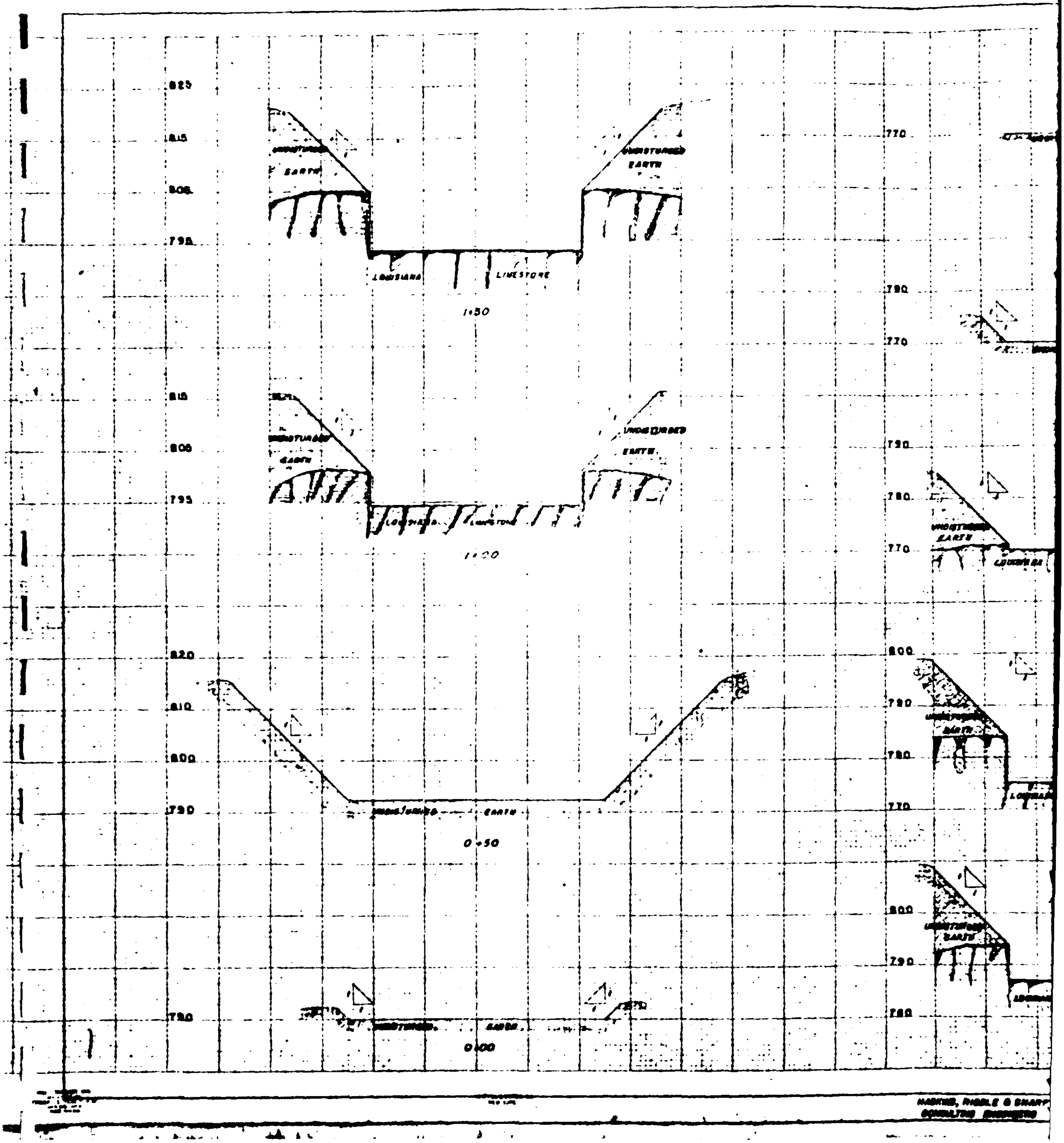
SECOND ALTERNATE INTAKE



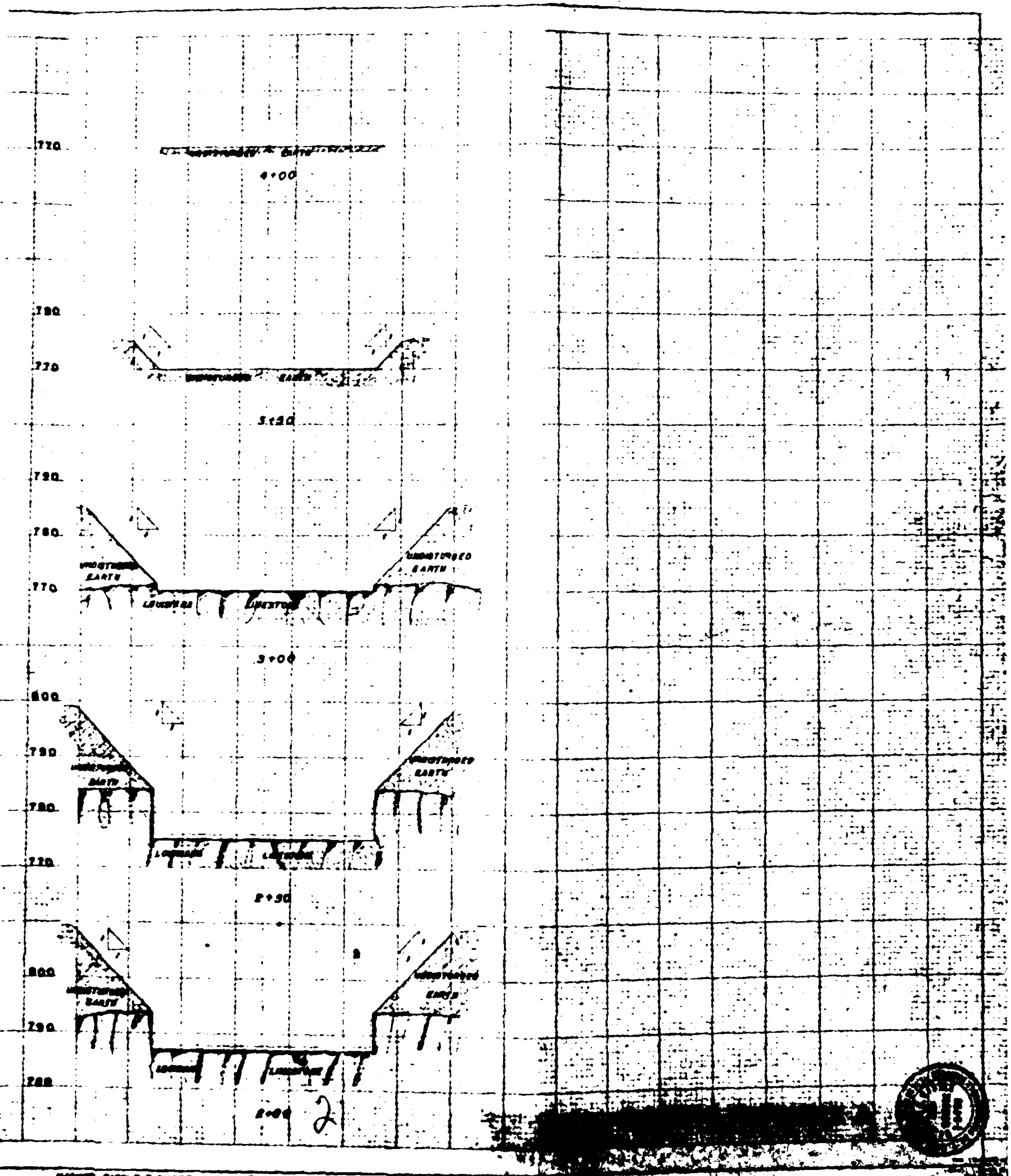
PLAN OF SPILLWAY
2" drain lines
Elev. 799
Elev. 794
SEE DETAIL "A"
#4 @ 9 ea way in center of slab
SECTION A-A
Use asphalt paper to cover gravel (or crushed rock) for 2" drain line
2" drain lines
DETAIL "A"



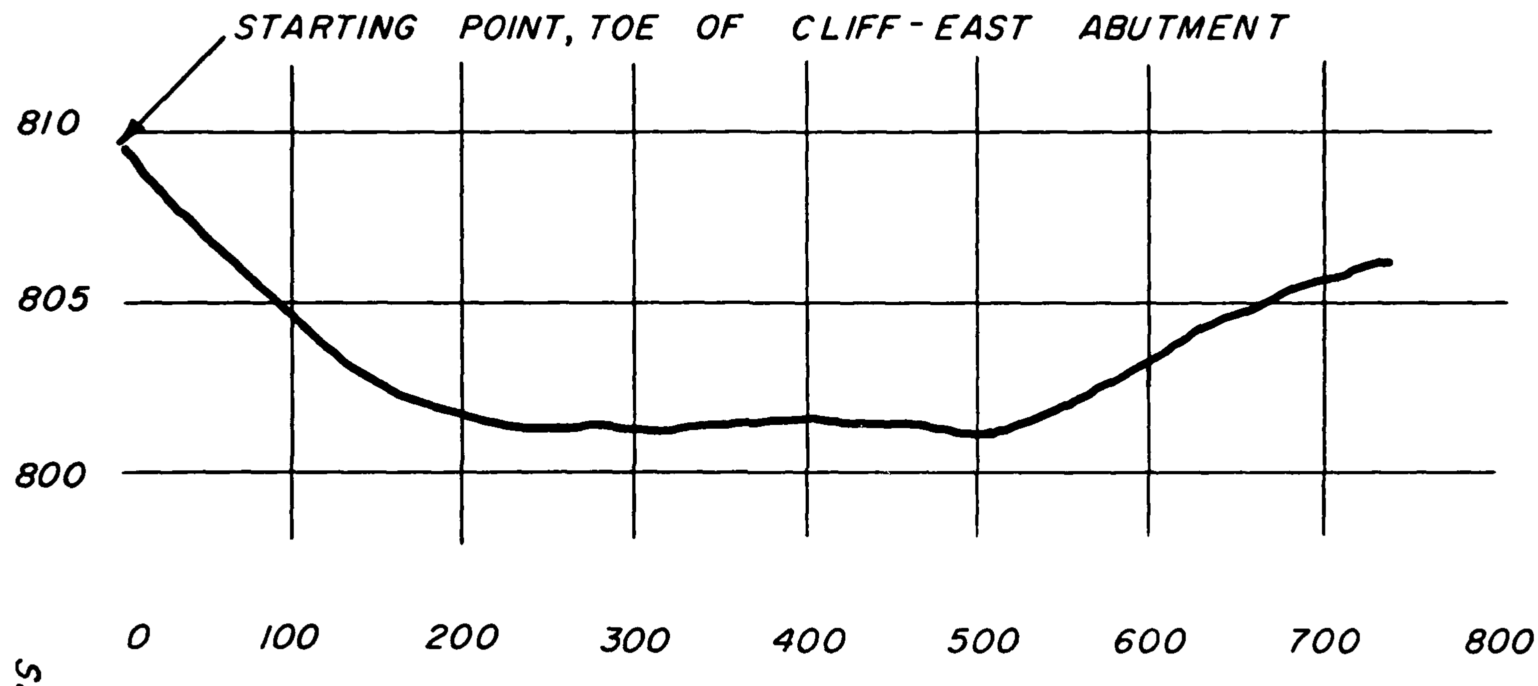
PLAN OF SPILLWAY
SECTION B-B
SECTION A-A
Use asphalt paper to cover gravel pit for 2" drain line
2" drain line
DETAIL "B"
SEE DETAIL "B"
SHEET 4 APPENDIX A
CONSULTING ENGINEERS
KANSAS CITY, MO
WATER SUPPLY
SPILLWAY & DETAILS



825
815
805
795
UNDISTURBED
EARTH
LOUISIANA
LIMESTONE
1+50
815
805
795
UNDISTURBED
EARTH
1+00
820
810
800
790
UNDISTURBED
EARTH
0+50
780
UNDISTURBED
SANDS
0+00
790
780
770
790
780
770
800
790
780
770
800
790
780
HASKINS, RIGGLE & SHARP
CONSULTING ENGINEERS



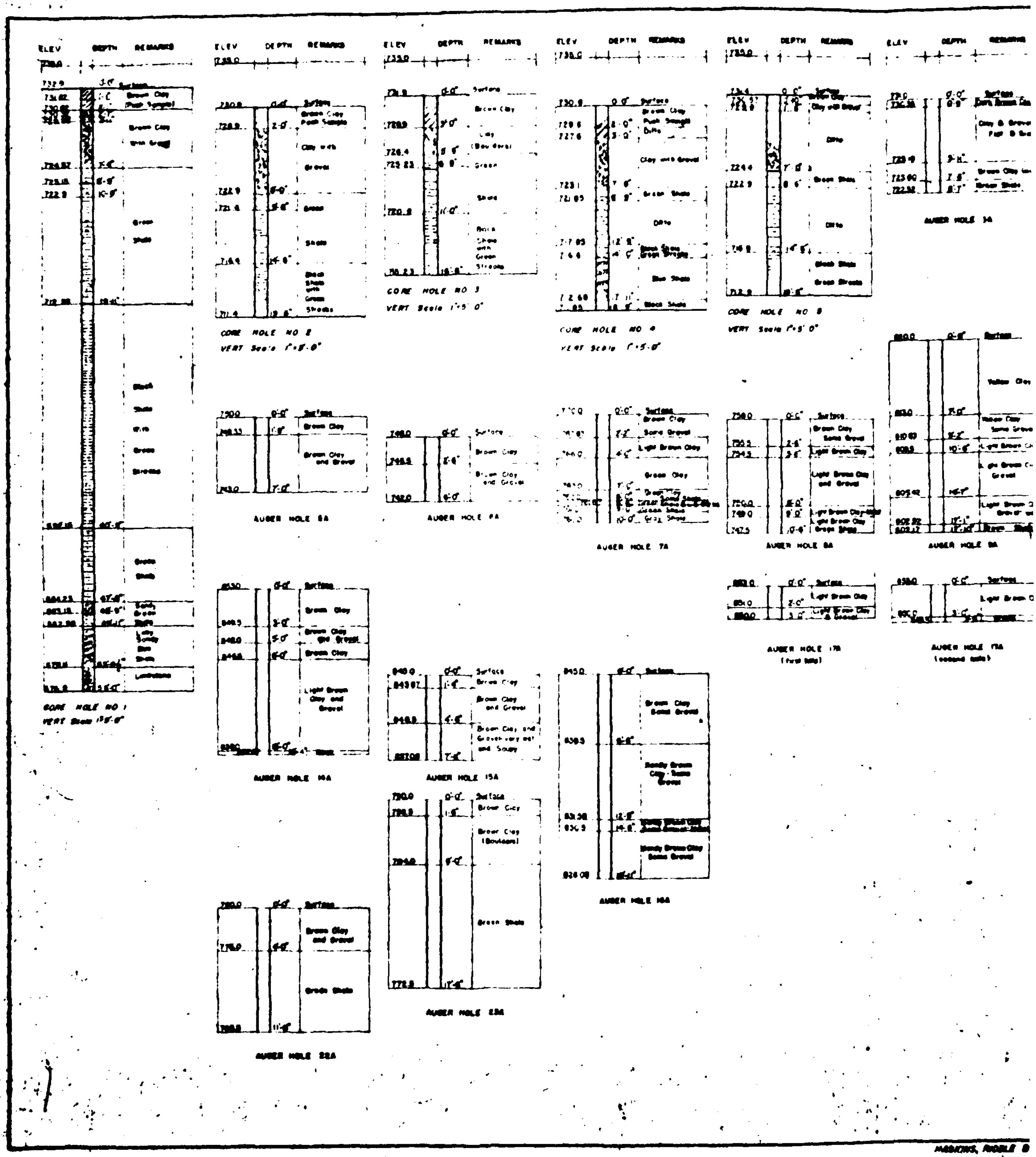
4+00
3+50
3+00
2+50
2+00
UNDISTURBED EARTH
LIMESTONE
800
790
780
770
2

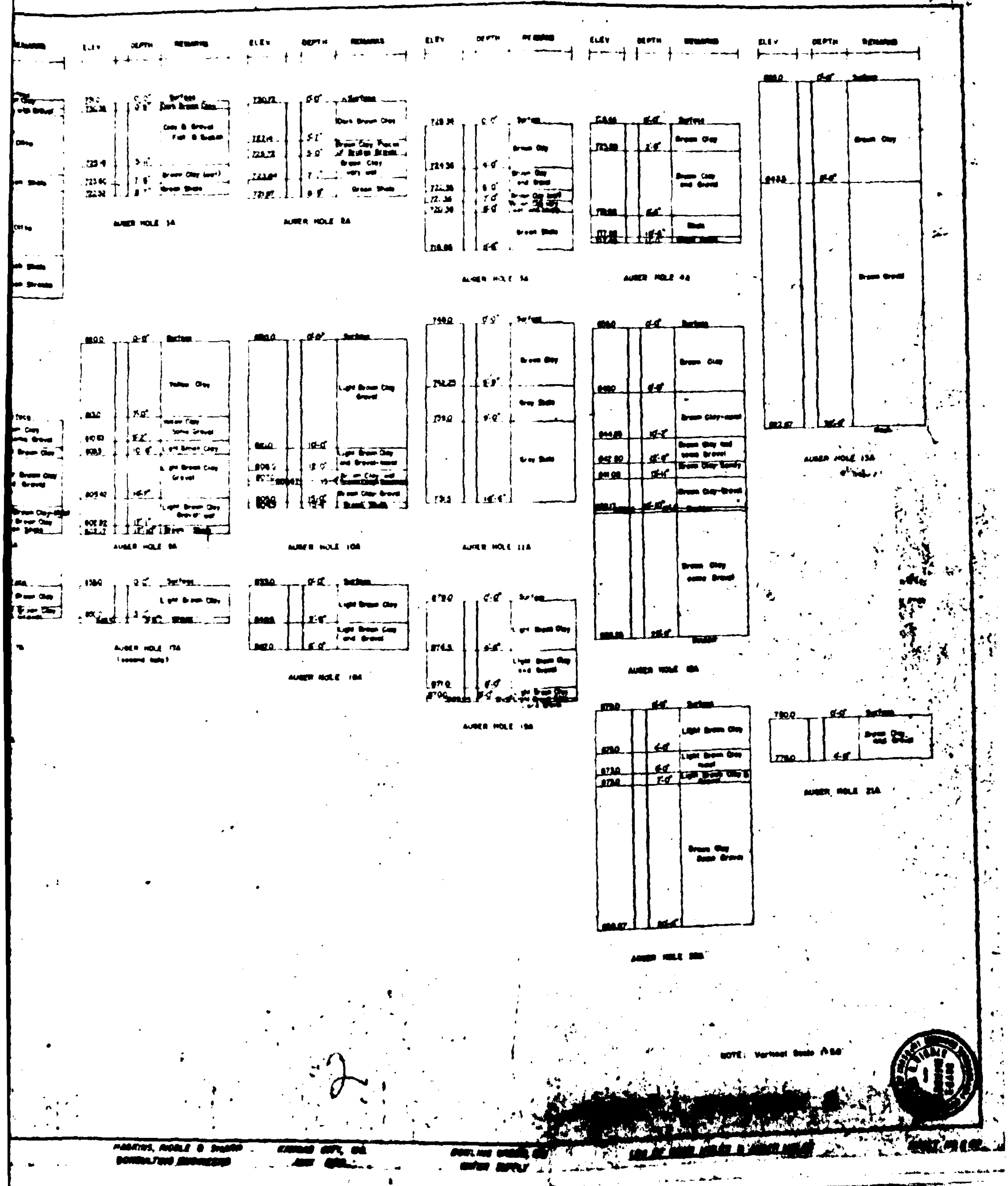


EXISTING TOP OF DAM PROFILE

(AS MEASURED 9-27-78)

APPENDIX B


ELEV DEPTH REMARKS
CORE HOLE NO 1
CORE HOLE NO 2
CORE HOLE NO 3
CORE HOLE NO 4
CORE HOLE NO 5
AUGER HOLE 3A
AUGER HOLE 5A
AUGER HOLE 6A
AUGER HOLE 7A
AUGER HOLE 8A
AUGER HOLE 9A
AUGER HOLE 14A
AUGER HOLE 15A
AUGER HOLE 16A
AUGER HOLE 17A
AUGER HOLE 22A
AUGER HOLE 23A
Surface
Brown Clay
Green Shale
Black Shale
Light Brown Clay
Clay with Gravel
Limestone


ELEV
DEPTH
REMARKS
AUGER HOLE 1A
AUGER HOLE 2A
AUGER HOLE 3A
AUGER HOLE 4A
AUGER HOLE 13A
AUGER HOLE 21A
Surface
Brown Clay
Brown Shale
Brown Gravel
Gray Shale
Light Brown Clay
Brown Clay and Gravel
NOTE: Vertical Scale

2

CHAS. A. HASKINS | JOB NO. | DATE 7-5-[illegible]3 | MADE BY [illegible]

CONSULTING ENGINEERS | CHECKED BY

KANSAS CITY, MISSOURI | Bowling Green Dam | PRELIMINARY ___ FINAL ___

Studies —

Curve A - Upstream slope stability based on 20' drawdown
S.F. = 1.35 See NET A. Sheets 4, 4A, 4B

Curve B - Downstream slope stability - Local slide under max adverse hydrostatic pressures. S.F. = 1.40
see sheets 23 + 24

Flow NET studies explained on sheet 2

Block + wedge studies to fix berms sheets 5 to 22
a) For no excavation of foundation, Large berm S.F. = 1.48 (whole berm slides)
b) For no excavation of foundation, Large berm, Slide thru berm S.F. = 1.5 −
c) For excavation of foundation material + smaller berm. Slide thru berm S.F. = 1.5 +
d) Same as (c) but whole berm sliding S.F. = 1.65

e) Construction condition.
No water pressures but [illegible] water [illegible] assumed to be present in foundation $\boxed{S.F. = 1.0 -}$

No flattening of slopes considered necessary.

Sheet 2, Appendix B

CHAS. A. HASKINS

CONSULTING ENGINEERS

KANSAS CITY, MISSOURI

CLIENT

JOB NO. DATE 7-5-[illegible]

PAGE [illegible]

MADE BY [illegible]

CHECKED BY

PRELIMINARY FINAL

Recommendations—

a) Use large berm downstream shown on following sheet

b) Use [illegible] upstream slope [illegible] with 8' berm to start riprap on.

c) Place waste berm upstream as shown particularly if poor material is found in foundation

d) Banded downstream slope as preliminary design [illegible] is ok.

e) cut-off is not necessary but won't hurt anything. See Flow nets A + C

f) Sand drain not considered economical because it in itself with cut off will only give S.F. = 1.27 So sand drain would have to extend under berm also required.

g) All borrow material [illegible] appears to be of good quality suggest compaction within range 3% under to 2% over optimum

GEOLOGICAL REPORT ON RESERVOIR FOR BOWLING GREEN, MISSOURI

by

James H. Williams, Geologist

Missouri Geological Survey and Water Resources

April 16, 1953

Abstract:

The study of rock formations at the four proposed reservoir sites indicates that Buckner Hollow Site and Site A are favorable. Surface features indicate more valley alluvium, silt, sand, and gravel would have to be excavated at Site A to key the dam in a solid rock formation, the Hannibal shale. Consequently, Buckner Hollow appears to be the best geologic location for a dam and reservoir. Site B is unfavorable because of rock formations that would underlie the dam. Peno Creek is not recommended due to danger of seepage at both the dam site and upstream.

Description of rock formations at the reservoir areas:

The illustrated geological columnar section (Plate I-A) diagrams the rock formations of the reservoir areas. This column presents the expected sequence of rocks that would be encountered if a well were drilled in the SW$\frac{1}{4}$ NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 29, T. 53 N., R. 2 W. at the Buckner Hollow spillway site. As these different rocks are laterally persistent, this same sequence can be seen by walking from the headwaters of Buckner Hollow, where the Burlington limestone crops out, to the mouth of Buckner Hollow, which is in Maquoketa shale.

These rock formations are described beginning with the oldest, the Maquoketa shale. It is exposed near the mouth of Buckner Hollow in the NE$\frac{1}{4}$ SW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 17, T. 53 N., R. 2 W. It is a massive, greenish-blue and blue shale. There are thin blue-gray limestone layers in the shale. The shale is easily affected by weathering and it is usually mantled with a thick cover of soil and vegetation. Fresh exposures under the influence of weathering "flow" and slide like mud. The upper contact of the Maquoketa shale with the Bowling Green dolomite is at 670 feet elevation. Therefore, the Maquoketa does not affect any of the reservoir sites. The overlying Bowling Green dolomite would affect dam construction at Site B.

The Bowling Green is a yellow-gray and blue-gray, fine-grained dolomite. It is massive and evenly bedded. When undercut by streams, it breaks off in large rectangular blocks which slump into the stream. The formation is approximately 20 feet thick. If a dam were built at Site B, it should be keyed in the Bowling Green. The Louisiana formation, which overlies the Bowling Green, would be an insecure foundation. For this reason Site B is not recommended.

The Louisiana is a thin-bedded, brittle, yellow-gray, fine-grained limestone and dolomite. It is non-resistant to weathering, and its surface exposures are usually mantled. The Louisiana is approximately 10 feet thick. Its contact with the overlying Hannibal, approximately 700 feet elevation, is marked by a two-foot thick sandy shale zone that is saturated with water. Site B is not recommended because of danger of water seepage at this contact zone, and because of the weakly-resistant Louisiana formation.

The Hannibal shale is massive, gray-blue, and silty. It breaks into small blocky pieces. The Hannibal is much more resistant to weathering than the Maquoketa, and it does not "flow" like mud when water soaked. The Hannibal is from 80 to 90 feet thick. The silt content and the consolidation of the Hannibal make it suitable as a foundation for the dam at Buckner Hollow or at Site A. Its impermeability to water will reduce water seepage from the reservoir at either location. The Hannibal could be used as the dam foundation at Peno Creek were it not for the unfavorable characteristics of the overlying Burlington limestone in this area.

The topmost formation, the Burlington, is a light-gray, coarse-grained, and massive limestone. In many areas, it contains caves, sinkholes, springs, joints, and other features that would cause water seepage. This is true in the Peno Creek area. There are solution features, caves and springs, in Buckner Hollow, but they are above 800 feet elevation. There are no features below 800 feet in the lower Burlington limestone or associated with the Burlington-Hannibal contact that would indicate solution and possible water seepage.

Buckner Hollow:

The diagramed profile and geologic cross-section of the Buckner Hollow dam site (Plate I-B) illustrates the rock formations and their relation to the dam.

It is recommended that there be three core-drill holes at the Buckner Hollow dam site. Two should be made on the alluvium where the key will be, one near each abutment. The third one should be upstream, 600 feet north of the dam site. One of the holes at the dam site should be cored through the valley alluvium, the lower Hannibal shale, the Louisiana, and into the

Bowling Green. If conditions are found to be satisfactory in this core, the other three need go only to the top of the Louisiana.

Site A:

Site A is a favorable dam site and reservoir location. The dam would be keyed in the Hannibal shale, as recommended at the Buckner Hollow Site. Since Site A is geologically similar to the Buckner Hollow Site, the relationship of the rock formations to the dam and reservoir is similar.

The greater thickness of mantle at the dam site would require more excavation and would necessitate four core-drill holes on the valley alluvium. Two should be near the abutments of the key and one evenly spaced between them. The fourth one should be 600 feet upstream. The center hole at the key should be cored into the Bowling Green dolomite. If this is a satisfactory core, the other three need go only to the top of the Louisiana.

Site B:

This location is not recommended for a dam site. A reservoir here would have a water-permeable zone, the Louisiana-Hannibal contact, near the base of the dam. The Hannibal, if present at all, is not thick enough to be a dam foundation here, and the underlying Louisiana would be a very insecure foundation. The dam could be keyed in the Bowling Green, but that would require excavation of the Louisiana formation.

Peno Creek:

Peno Creek is an unfavorable reservoir and dam site due to the danger of seepage in the Burlington limestone. There ar several caves and springs that would be submerged with a resulting loss of water. Sinkholes in the upland indicate a network of subsurface drainage. Joints in the Burlington limestone indicate water passageways that would cause water seepage if submerged. A dam at the Peno Creek Site would be keyed in the Hannibal shale. The Burlington-Hannibal contact would be approximately 30 feet above the base of the dam. The joints and fractures of the Burlington would cause construction difficulties for the upper part of the dam.

Excavation and Core Fill:

It may be possible to remove the upper few feet of the Hannibal shale for the trench at the dam site with scoops and other heavy machinery without blasting. Blasting should be avoided if possible, as it might produce unwanted cracks and fissures. The Hannibal shale will probably be unsuitable as a core filler. Its tendency to break into blocks and chunks, rather than fine particles, would hinder compaction even with heavy machinery. The clay soils from the ridges above the Burlington limestone would be more suitable.

Concrete Aggregate and Riprap:

The Burlington limestone would be suitable as concrete aggregate and riprap. There are several small potential quarry sites in the SW$\frac{1}{4}$ SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 19, T. 53 N., R. 2 W., near a large spring at 800 feet elevation, and in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 29, T. 53 N., R. 2 W., near Open Mouth Cave and Three Rooms Cave. The floor of the quarry should not be below the 800 foot elevation because of the underlying Burlington-Hannibal contact. The potential quarry site could be sampled by chipping small pieces of rock from unweathered portions of the limestone exposures.

Gravel Deposits:

There are several gravel deposits along Noix Creek that extend from SE$\frac{1}{4}$ NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 18, T. 53 N., R. 2 W. downstream to Vera. They will supply the need for 5,000 to 6,000 cubic yards. These deposits will average from 30% to 40% sand. Approximately 8% to 10% of the material is from 6 to 8 inches in diameter. The rest of the material, 40% to 50%, varies from one-half inch to two inches in diameter. The sand is predominately quartz and the larger material is chert.

Summary:

The Buckner Hollow Site and Site A are favorable geological locations for a dam and reservoir. Buckner Hollow is the more suitable due to a greater thickness of mantle at Site A. The increased mantle thickness at Site A would require excavation and core-drilling.

Site B is not recommended because of possible seepage and an unsuitable dam foundation. Peno Creek is unfavorable due to possible water seepage in the Burlington limestone and construction difficulties at the dam site.

Nearby sources of core fill, concrete aggregate, riprap, and gravel deposits are available for use at the Buckner Hollow Site or Site A. The Buckner Hollow Site is closer to the concrete aggregate and riprap sources.

A geological map of the Buckner Hollow Site, Site A, and Site B accompanies this report (Plate I-C).

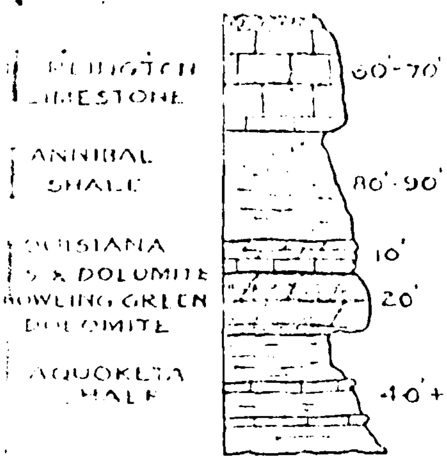


FIG. A
COLUMNAR SECTION
BUCKNER HOLLOW

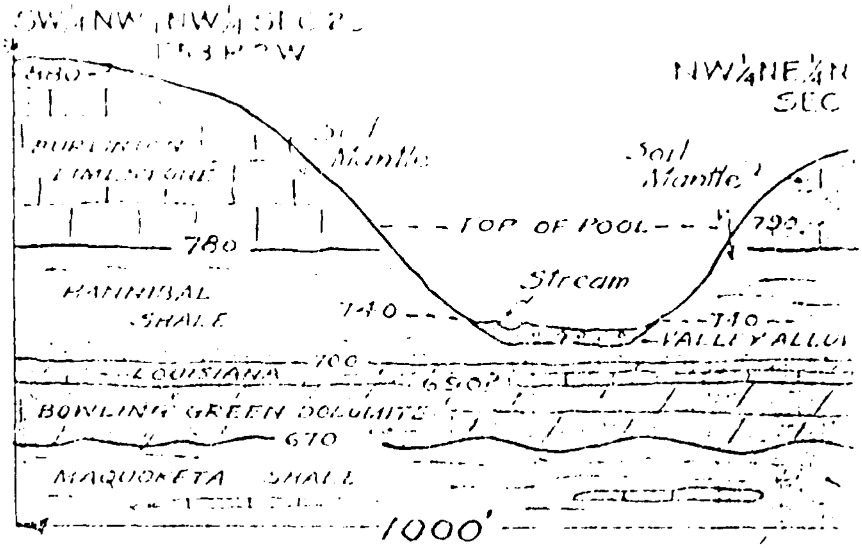
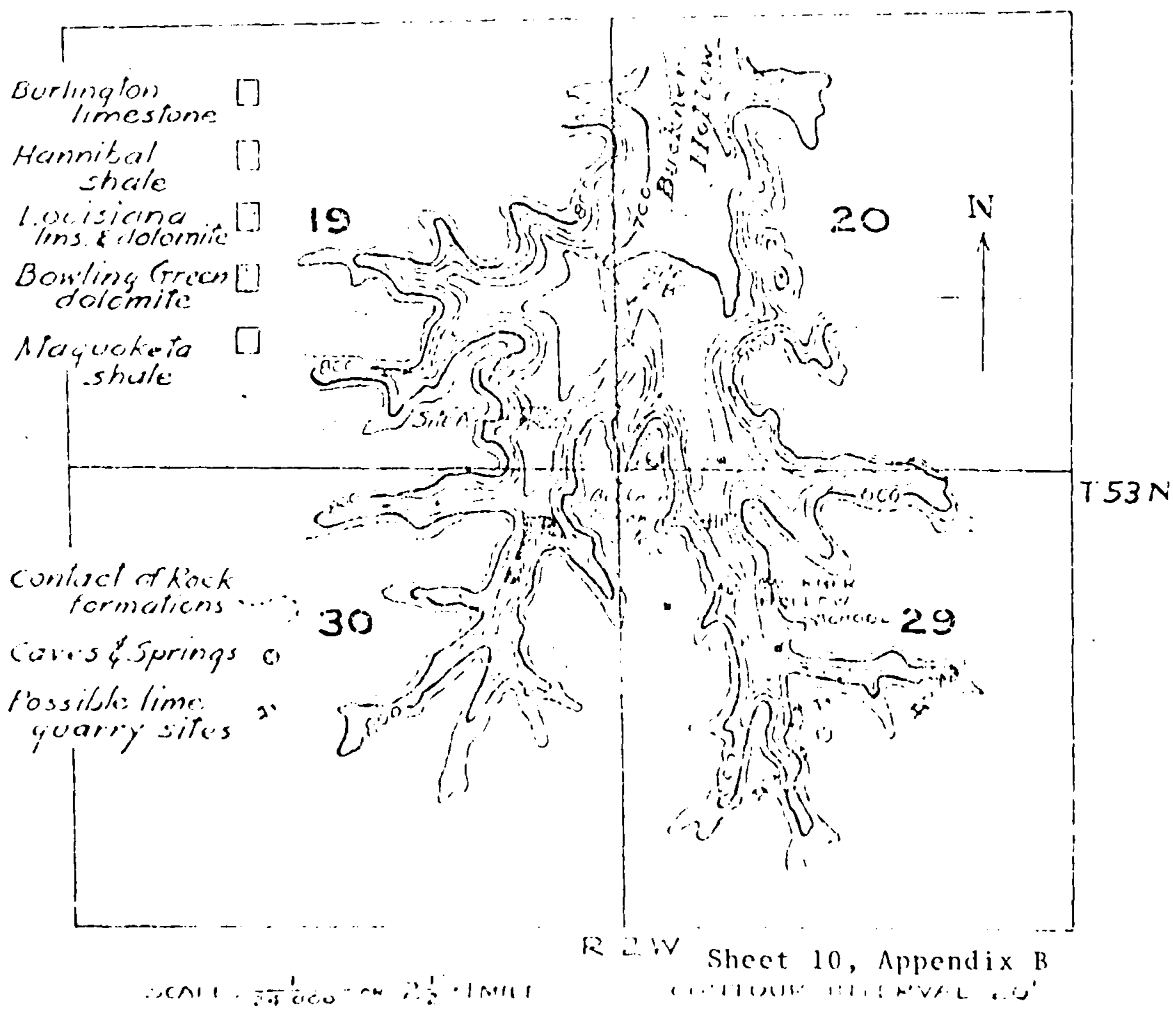


FIG B
PROFILE AND GEOLOGICAL CROSS-SECTION
AT PROPOSED BUCKNER HOLLOW DAM SITE



Sheet 10, Appendix B

FIG C GEOLOGICAL MAP OF THE BUCKNER HOLLOW AREA

REPORT ON

INSPECTION OF BUCKNER HOLLOW DAM

BOWLING GREEN, MISSOURI

Sheet 11, Appendix B

REPORT ON

INSPECTION OF BUCKNER HOLLOW DAM

BOWLING GREEN, MISSOURI

On May 11, 1[illegible]7, in the company of Messrs. William G. Riddle and Charles Brooks, of the firm of Haskins, Riddle & Sharp, Consulting Engineers, Kansas City, Missouri, the undersigned made an inspection of the water supply dam on Buckner Creek near Bowling Green, Missouri.

The following conditions were observed:

(a) Visible seepage appeared to be confined to the abutments. The area downstream of the dam was firm and dry.

(b) The seepage around the left abutment (West) appeared to be somewhat greater than that around the right abutment (East). From a history of the seepage occurrence, apparently the first evidences appeared in the left abutment.

(c) The highest point of seepage on either abutment appeared to be at approximately the same elevation as the water surface in the reservoir.

(d) The slides are shallow, confined primarily to the thin mantle of overburden in the natural abutment slopes. The slides are not in the dam structure proper.

(e) The reservoir on the top of the hill above the left abutment had some water in it at the time of the inspection.

From the above observed conditions, it is my opinion that:

(a) Most of the seepage is passing through the Hannibal shale formation, which is interlaced with limestone stringers. This formation forms most of the abutment contact for the dam. The leakage appears to be approximately horizontal through these limestone stringers. I believe the seepage appeared first in the left abutment because of the exposure of the Hannibal formation in nearly vertical faces in the old creek bank, which is located adjacent to the left abutment at the dam site and in the gully immediately upstream of the dam in the left abutment. The lower part of the right abutment is blanketed with clay overburden, while it is thin or absent higher up in the abutment. Therefore, the seepage did not appear until after the reservoir reached these higher elevations.

(b) The reservoir in the left abutment located high above the dam has little, if any, affect on the seepage. Obviously, it doesn't affect the right abutment seepage.

(c) In future wet weather, a slide above the pump building downstream of the left abutment may form and could actually thrust against the pump house structure. This slide is also located in the natural abutment, but might cause movement of some embankment material adjacent to the slide.

(d) Repair of the road on the right abutment should be effected by relocation away from the present location. If repair of the present roadway slide is attempted, it should be by construction of a much flattented slope from the base up and not by dumping from the roadway, as this procedure would likely cause greater slide movement and might enlarge the slide.

(e) I did not observe any structural deficiency in the dam in my investigation on May 11, 1957.

Sheet 13, Appendix B

Correction of the seepage condition:

If the seepage quantity appears to decrease with rising reservoir and time, some deposition of silt over these exposed surfaces and in the seepage channels is probably taking place, and the seepage is likely to decrease further with time and eventually stop.

If the seepage does not decrease or increases, I believe a grout curtain should be drilled and pumped into place in both abutments without delay. In this connection, I understand that the seepage appears to have decreased somewhat with rise of the reservoir level, which indicates that it is probably good judgment to further observe the condition before proceeding with any action.

F. J. Spiegel
Consulting Engineer
3322 East 60th Street
Kansas City, Missouri

PD [illegible]-2237

Sheet 14, Appendix B

March 26, 1959

Honorable Edward V. Long
Lieutenant Governor of Missouri
Missouri State Capitol
Jefferson City, Missouri

Dear Governor Long:

Enclosed is a copy of my letter to Mr. Bell regarding leakage at the Bowling Green reservoir. I feel that this leakage can be stopped and will continue to give the problem my personal attention.

Also enclosed are copies of the Bowling Green and Silex quadrangles, I. C. 15, *Topographic Maps of Missouri*, R. I. 22, *Geology of the Bowling Green quadrangle*, and R. I. 21, *Northeast Missouri's Oil Possibilities Improve*. The geology of the Bowling Green area has been of interest to geologists and industry for many years because of the limestone and shale deposits, the groundwater problems, and because of the great variety of formations which crop out. Should you wish additional copies of any of these publications, please do not hesitate to call on me.

I very much enjoyed the trip to Bowling Green and hope the proposed solution will solve the leakage problem.

Very truly yours,

Thomas R. Beveridge
State Geologist

TRB:VJ

Enclosures

March 26, 1959

Mr. Olin N. Bell
Bowling Green, Missouri

Dear Mr. Bell:

This letter is to confirm my statements made yesterday during our visit to the Bowling Green reservoir, located in Buckner Hollow.

I feel quite certain that the leakage at the west end of the dam is through the brown beds of the Burlington limestone. These brown beds lie on the olive-colored Hannibal shales which form the floor and all but the upper 10 to 15 feet of the reservoir. The brown beds of the Burlington tend to be fractured and to contain cavities caused by the solution of the limestone. These fractures and solution cavities are, in my opinion, the sources of leakage.

The Hannibal-Burlington contact may be seen in the south side of the draw west of the pumphouse and it is quite evident that the brown beds are below the present surface level of the reservoir.

My recommendations for sealing the leakage are as follows:

(1) Hand excavate along the junction of the dam and the bluff along the downstream slope of the dam to make certain that there is no leakage where the dam abuts the bluff. It is my understanding from our conversation that the dam was not keyed into the bluff--thus there may be leakage at the contact of the dam with the brown beds in the bluff.

(2) Drill the brown beds from the elevation of the top of the dam down one foot into the Hannibal shale and pressure grout the drill holes. Drilling should start at the bluff where it intersects the axis of the dam and continue north and west barely into the draw west of the pumphouse. Since there is no evidence of leakage in the draw, drilling need not extend very far up the draw.

(3) Alternate for (2). Clean off the brown beds starting at the down stream side of the dam and following around the point barely into the draw. The scalping should include at least a foot of the Hannibal shale. Such scalping may reveal the source or sources of leakage in the brown beds and these leaks could be patched on an individual basis by pressure grouting.

Solution (2) is the more ideal one, whereas (3) is probably cheaper. As we agreed yesterday, the selection of the alternate should rest with the City Council, but I will be glad to confer with them should you wish. Also, should any further questions arise, please do not hesitate to call on me. It does appear that your problem is one which can be solved, and I will be most interested in the progress and outcome.

With personal regards,

Thomas R. Beveridge
State Geologist

TRB:VJ

cc: Lt. Governor Long
Mayor Willard Middleton

HASKINS, RIDDLE & SHARP
CONSULTING ENGINEERS
1009 BALTIMORE AVENUE
KANSAS CITY 5, MO.
TEL. GRAND 1-7730

CHAS. A. HASKINS (1922-1956)
WM. G. RIDDLE
P. CLIFFORD SHARP
L. E. ORDELHEIDE

COPY

October 12, 1959

Mr. Olin Bell, Chairman
Board of Public Works
City Hall
Bowling Green, Missouri

Re: Pressure Grouting
Bowling Green Dam

Dear Mr. Bell:

In response to our request, the Layne-Western Company, who have just completed pressure grouting activities on the Bowling Green water supply dam, have forwarded their report No. 2 entitled "Final Construction Report" relative to this grouting work. In accordance with their suggestion, a copy is being forwarded to the Missouri Geological Survey to the attention of Mr. Tom Beveridge, Director, and a copy is attached hereto.

We are enclosing a letter with two copies pertaining to the necessity for having this repair work done, and also are enclosing our statement for services performed during this work.

Naturally, we would have preferred to see the grouting activity result in a bottle-tight abuttment; however, we are pleased that the leakage has been reduced as much as it has and also that apparently all leakage which could be presumed to affect structural characteristics of the dam itself apparently have been stopped. We have gone over the entire job, including the report transmitted herewith, with our soil mechanics consultant, who is pleased with the result of the grouting work and is of the opinion that no further grouting is indicated at this time. In light of the substantial reductions which have been made and more paticularly the fact that such circuitous abuttment leakage as continues, they do not appear to be of any concern as far as the dam itself goes.

If there is anything further which you or your board needs of us in this matter, please let us know.

Yours very truly,

HASKINS, RIDDLE & SHARP

W. G. Riddle

WGR:db
Enc.
cc: Mr. Tom Beveridge

PRESSURE GROUTING AT BOWLING GREEN, MISSOURI

MUNICIPAL RESERVOIR

REPORT NO. 2

FINAL CONSTRUCTION REPORT

October 1, 1959

PURPOSE The purpose of this report is to summarize the work performed in pressure-grouting the Bowling Green Municipal Reservoir.

WORK COMPLETED

After 6½ weeks work, the Contractor has completed drilling and grouting operations as set forth in the original estimate. The results of this work are as follows:

(1.) 21 holes drilled to an average depth of 30 ft. into the broken rock formation adjacent to the west end of the dam.

(2) Approximately 200 ft. of 2" cementing pipe sealed into these holes.

(3) Green Fluorescent Dye traced from drill hole to leak below dam.

(4) 5000 bags of cement pumped through 21 injection holes into the leak zone.

(5) Leakage through the west bluff reduced from 300,000 gallons per day at the start of the project to about 90,000 gallons per day at present (at a 68.5% reduction).

DETAILS OF WORK

A. Phase 1: Test Drilling

Three test holes were drilled in the West bluff at the Dam to determine the characteristics of the underlying rock formation. These holes were logged as follows:

Hole Number	Location	Depth below Dam of drilling fluid loss	Character of Rock	Bottom of Broken Zone Below Dam
1	50' E. of W. Bluff on dam	20'-4"	Limestone, broken and fractured	28'-0"
2	Base of W. Bluff on dam	13'-6"	Limestone, broken and fractured	27'-0"
3	50' W. of W. Bluff on hill	3'-4"	Limestone, broken and fractured	17'-4"

From an examination of the formation log, rock core samples, and drilling fluid loss characteristics, the apparent leaking zones were located within the broken limestone as had been predicted by the State Geologist.

The drilling fluid record showed a complete loss of circulation as soon as the limestone rock underlying the dam was penetrated. No fluid loss was experienced while drilling through the dam itself. Core samples of the limestone showed a badly broken and fractured structure with numerous solution cavities and evidence of water erosion. Cores of the shale underlying the limestone showed a solid, impervious structure which would not be conductive to the percolation of water. While drilling through the dam itself, no change of water level in the holes was observed. However, as soon as the limestone was penetrated, the static water level fell to the same elevation as the surface of the lake. Phase I required 1½ weeks for completion.

Test Drilling Results

From this information the following conclusions were reached:

1. No leakage is evident through the fill of the dam itself.

2. No leakage is evident through the solid shale which underlies the major portion of the lake below the limestone layers.

3. The leaking zones are apparently confined to the layers of broken limestone which form approximately the upper 15 feet of rock bordering the lake.

4. A considerable portion of the leakage is in that limestone formation immediately adjacent to and underlying the west end of the dam.

D. DRILLING AND GROUTING PROGRAM

Based upon the information gathered by test drilling, a program was then established to pressure cement the leaking rock zones and thereby seal off as much flow as possible. Particularly, it was desired to seal those leaks flowing out on the down-stream dam face which might possibly cause structural damage.

Curtain-Wall Grouting

The procedure followed in pressure-cementing the leaking zones was the curtain-wall grouting technique. This technique was established and perfected by the U. S. Bureau of Reclamation through years of experience sealing the underlying rock strata at numerous public dams throughout the country. The Grand Coulee Dam is one example of this type of work on a tremendous scale. Briefly, the curtain-wall technique involves drilling and pressure cementing a series of holes across the leaking areas. Following this, intermediate holes are drilled and cemented, and this procedure continued until a tight curtain wall of cement has been forced in place across the leak. Naturally, the amount of reduction in flow depends upon the tightness of the cement wall, and the extent of its coverage. This reduction therefore depends directly upon the quantity and distribution of sealing cement which can be economically justified for a given situation.

Grouting Work

To implement the grouting program outlined above, three additional operational phases were added to the original test drilling phase 1.

Phase 2 included a series of 10-foot spaced cemented holes starting at the eastern end of the limestone projection under the west end of the dam, and continuing westward about 75 ft. to the bluff. These were holes 1 through 8.

Phase 3 included a series of 10-foot spaced holes starting at the bluff and extending south-west, a distance of 80 ft. along the upper road. These were holes 10 through 17.

Phase 4 included a series of closing holes drilled between the most successful efforts in phase 2 and 3. These were holes 18 through 22, and were located between holes 1 through 10.

Flow Measurement-Dam

Throughout the grouting operations, daily records were kept of the total leakage flow as measured over a Vee-notch weir installed below the dam. Periodic applications of Fluorescent Green dye were added to the drilling fluid, and the weir pond checked to determine if any of the dye could be traced from the drill-hole to the leaks. Dye placed in hole #7 showed recognizable green color in the pond below.

Flow Rates:

The flow rates shown in this report are correct for all leaks flowing on the North side of the pump house road. The figures reported earlier on progress report #1 were later found to exclude a portion of the flow which was by-passing the measuring weir through an upstream branch. This bypass stream has now been diverted so that it too flows over the weir. The result is that all previously reported flow rates have been adjusted to the amounts shown herein.

C. Phase 2: Drilling and Grouting along the Dam

A series of cementing holes was drilled on approximately 10-foot centers along the center line of the Dam for a distance of 75 ft. from the west bluff. All holes were drilled to an average depth of 30 ft. to assure complete penetration of the broken formation. After the holes were drilled and cementing pipe sealed into them, neat cement was introduced until the formation refused additional cement at 15 lb. pressure. Cement use was as follows (holes listed in sequence east to west):

C. Phase 2 continued

Hole Number	Bags of Cement (1 cu. ft.)
4	1/2
5	65
1	200
6	98
7	192
8	504
2	832
	1891½ Total

Daily records of leakage showed that considerable reduction in flow was accomplished by this work. The cement pumped into these holes resulted in a reduction of 49% in the original leakage. Flow rate over the measuring weir was 152,000 GPD at the completion of this phase. Phase 2 operations required 2 weeks for completion.

D. Phase 3: Drilling and Grouting along the Road

The second series of cementing holes were drilled on 10 foot centers along the west edge of the road which leads to the top of the west bluff. Eight holes were drilled: numbers 10 thru 17, and cementing pipe sealed into each. All holes were drilled to a depth of 26 to 30 feet to assure complete penetration of the broken formation. After the holes were drilled, and cementing pipe sealed into them, neat cement was introduced into the formation. The porosity of the rock encountered in this area was so great that it was not possible to build up adequate pressures without consuming much larger quantities of cement. Heavy mixtures, bentonite, and lost circulation material were of no value. Cement use was as follows: (holes listed in sequence starting closest to the dam):

Hole Number	Bags of Cement
10	1107
11	376
12	355
13	200
14	382
15	171
16	90
17	119

Total reduction in leakage flow from phase 3 was small in comparison to the amount of cement consumed. The cement pumped into these holes resulted in a reduction of 14.5% in the original leakage. Phase 2 operations required 2½ weeks for completion.

E. Phase 4: Closing holes

The final phase of the cementing operation involved intermediate holes drilled and grouted between holes 1 through 10. The purpose of these holes was to further seal off that zone of rock immediately underlying the dam to further insure against possible damage in the area. These holes were considered to be filling in the empty spaces in the curtain wall. All holes were drilled to a depth of 26 to 30 ft. to assure complete penetration of the broken formation. After the holes were drilled and cementing pipe sealed into them, neat cement was introduced into the formation until refusal at 15 pounds pressure. Cement use was as follows (holes in order east to west):

Hole number	Bags of Cement
18	1/2
19	1/2
20	131
21	68
22	20
	220 Total

Total reduction in leakage flow from phase 4 was 5% of the original leakage. Phase 4 operations required 1 week for completion.

CONCLUSIONS

1. Leakage reduction by original grouting along the dam was very successful. 1091½ bags of cement caused a 49% reduction (leakage reduced from 300,000 GPD to 152,000 GPD).

2. Leakage reduction by grouting along the hill road and by intermediate holes along the dam was disappointing: 3040 bags of cement caused a 19.5% reduction (leakage finally reduced to 92,000 GPD).

3. Examination of the downstream face of the dam indicates that the leaks which had been flowing from the face of the dam have been either stopped completely or reduced to a very small quantity, while leaks flowing out of the bluff from 50 ft. west of the pump house on up the canyon are still flowing, although at a reduced rate.

It can be concluded that, while leakage has been ~~generally reduced~~ generally reduced along the entire downstream side, the water which had been observed flowing from the lower face of the dam has been largely stopped or reduced to a sufficiently small magnitude.

4. Since the greatest effect of the grouting has been indicated in the area opposite the holes [illegible] along the dam (1 through 8), it appears that the majority of the leakage through that particular zone may have been sealed off. If this is true, then it can be concluded that most of the remaining leakage is through the zone of rock crevices along the bluff. It is also probable that the majority of this leakage is through the deeper-lying limestone zone bounded by holes 10 thru 14.

5. It has been conclusively demonstrated that the fractured and creviced area penetrated by holes 10 thru 17 is far too porous for effective grouting operations using 10-foot spacings between holes. To seal this area effectively, it would probably require hole spacing on the order of 2-feet, with large quantities of extra-heavy grout mixtures. This would require a considerable expenditure of both labor and materials. Since leakage through this zone is apparently not affecting the dam structure, such an expenditure is probably not justified at this time.

RECOMMENDATIONS

1. It is recommended that grouting operations be suspended at this time. It appears from the poor results of the latter stages of grouting that it would not be economically reasonable to continue the work at this time.

2. It is suggested, however, that regular weekly checks be made on the measuring weir, and these readings be recorded on a permanent record sheet. It will probably be necessary to line the front of the weir pond with cement or bentonite to prevent washouts.

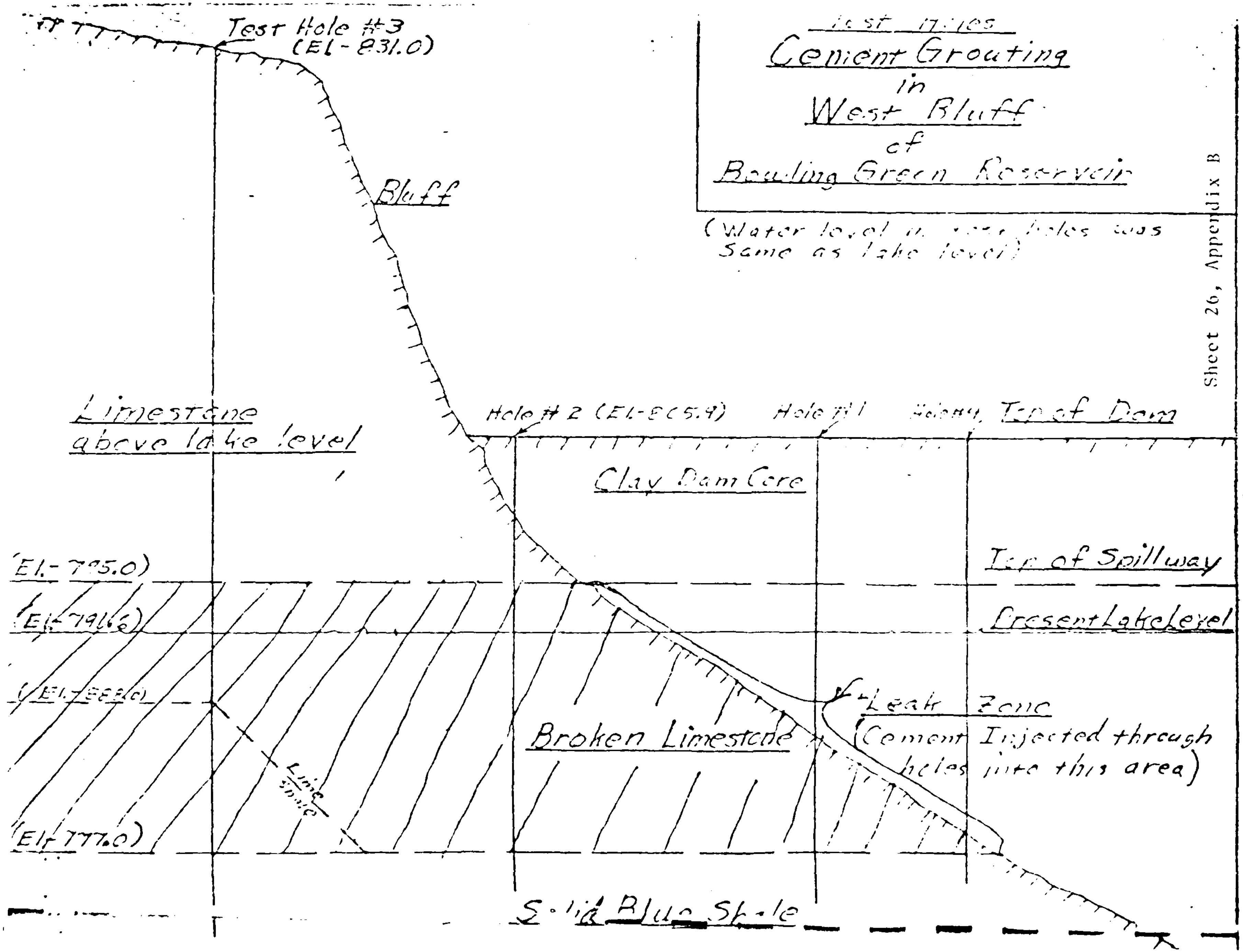
3. It is further suggested that periodic checks be continued in the downstream area to keep track of the individual remaining leaks.

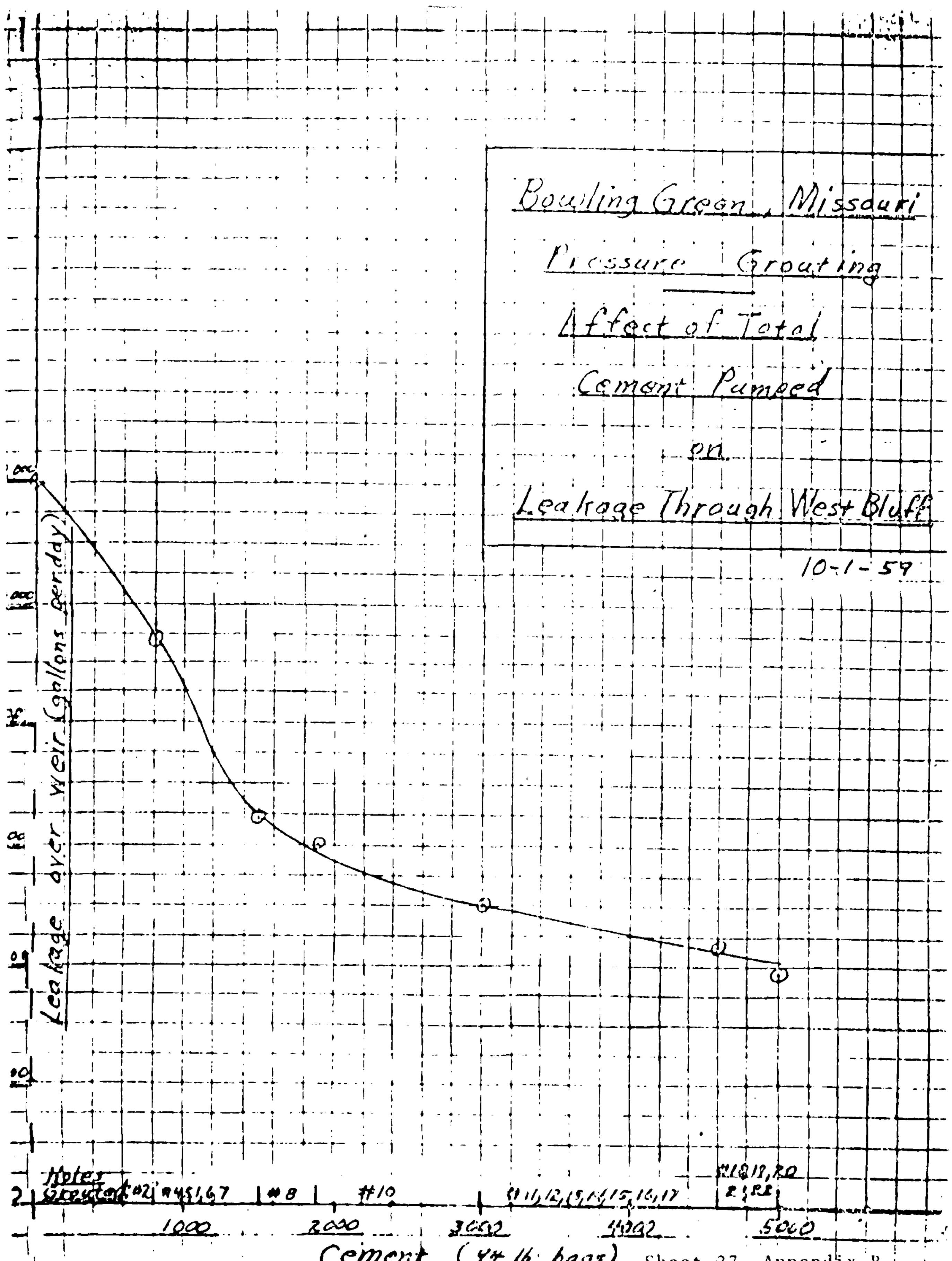
Layne-Western Company
By Richard [illegible]

[illegible] CR[illegible]K, MISSOURI

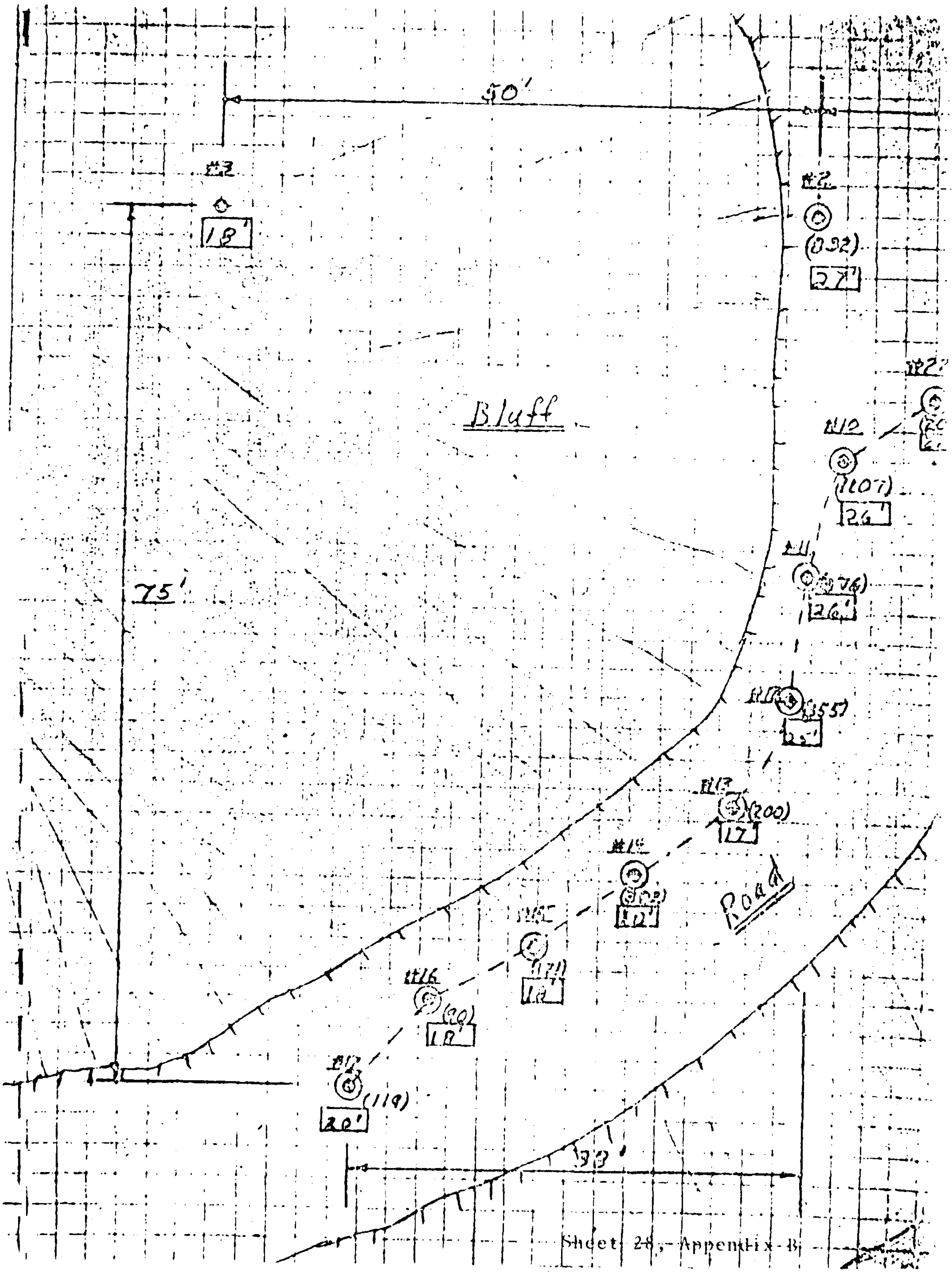
CEMENTING RECORD 10-1-59

HOLES CEMENTED	BAGS CEMENT REQUIRED	LEAKAGE FLOW: WEIR	GPD	GPM	% REDUCTION
		6"	300,000	206	0
#2 (10-13'	803	5½"	236,000	165	20%
#4	1/2	5½	236,000	165	20%
#5	65	5½"	236,000	165	20%
#1	100	5½"	236,000	165	20%
#6	98	4-3/4"	168,000	114	44%
#7	192				
#2 (13-26')	28	4-5/8"	152,000	105	49%
#8	504				
#10	1107	4¼"	125,000	87	58%
#11	376				
#12	355				
#13	200				
#14	382				
#15	171				
#16	90				
#17	129	4"	108,000	75	63.5%
#18	1/2				
#19	1/2				
#20	131	3-1/4"	92,000	65	68.5%
#21	88				
#22	20				


Cement Grouting
in
West Bluff
of
Bowling Green Reservoir
Test Hole #3
(El- 831.0)
Bluff
Limestone
above lake level
Hole #2 (El-805.9)
Hole #1
Top of Dam
Clay Dam Core
Top of Spillway
Present Lake Level
(El- 795.0)
(El- 791.6)
(El- 777.0)
Leak Zone
(Cement Injected through
holes into this area)
Broken Limestone
Solid Blue Shale



Bowling Green, Missouri
Pressure Grouting
Affect of Total
Cement Pumped
on
Leakage Through West Bluff
10-1-59
Leakage over weir (gallons per day)
Holes Grouted
1000
2000
3000
4000
5000
Cement (94 lb bags)



Sheet 28, Appendix B

File Water Pike Co
Bowling Green Reservoir
([illegible] report [illegible] to city)

Report on the Water Loss at the City of Bowling Green Reservoir,
Pike County, Missouri

The Bowling Green Municipal Reservoir was visited on the 25th of April, 1963, at the request of Mr. Donald Sissons Water Superintendent, City of Bowling Green. Other personnel involved in the investigation included Mr. Heckman, Layne and Western; Mayor Willard Middleton, Mr. Bankhead and Dr. Wilcox of the City Public Works and the custodian of the lake site. In 1959 approximately 300,000 gallon per day water loss had been reduced almost 50% by grout holes completed by Layne and Western. Grouting was done to some extent on the eastern abutment and extensively on the west abutment. Grout holes extended from the western edge of the dam westward onto the rock abutment and were spaced on 10 foot centers. Grouting was done at 15 pounds pressure. However, in the early part of April 1963, active water loss was noted in the western abutment where one or more openings were draining approximately 200,000 gallons a day out of the reservoir which is almost equal to the amount used by the city for municipal purposes. The water loss as observed in the present investigation was occurring along the water line, approximately 790 feet in elevation, which is 10 feet above the Burlington-Hannibal contact. This is the approximate level of water loss that has been noted in previous years.

Since the grouting done by Layne and Western had not completely halted the water loss, and from the present appearance of this loss in April, it appears that water is moving around the grout curtain toward the interior of the abutment and then reappearing on the downstream side. Water is not seeping through the grout curtain which had been completed by Layne-Western. Therefore, if the grout curtain had been extended further into the abutment toward the west the water loss might have been stopped. This would have been an additional expense which the city did not wish to undertake. On the basis of cost and present water loss conditions it was decided that the line of present water loss along the western edge of the dam be cleaned by bulldozers or similar equipment, and a cement apron be poured over this area of loss. The apron would reach from about 5 feet below the present water line which would be approximately 5 feet above the Burlington-Hannibal contact, and extend upward above the water line to approximately 10 feet above the zone of water loss. It was noted that this apron of cement should be poured on a compacted cushion of coarse graded, approximately 2 inch diameter, crushed rock. This rock should contain no fine material since its purpose is to aid in free drainage of subsurface water underneath the concrete. In addition, perforated reinforcement pipes would be driven vertically into the ground and would act as a stabilizing influence plus an aid in draining accumulated waters from underneath the concrete apron. The concrete apron, which would average approximately 8 inches thick, will be reinforced by wire mesh.

A considerable amount of fluorescein dye was poured into the water loss holes, but the dye did not reappear during the time of investigation on the downstream side. Water was flowing at the rate of 150,000 gallons per day in the downstream area of the dam from the western abutment, but apparently this water must pond within the broken rock of the western abutment and does not reappear downstream immediately after disappearance in the water loss holes along the margin of the lake near the dam and abutment. It is not believed that water loss occurs further upstream in the lake area inasmuch as the original investigation indicated that the Burlington-Hannibal contact here, as it does regionally, develops a perched water table. Numerous springs occur at or above the Burlington-Hannibal contact which reflect the ponding of the Hannibal held ground waters that appear when this contact is cut by present drainage channels. Therefore, this groundwater within the basal Burlington limestone would aid in recharge of the reservoir.

May 1, 1963

James H. Williams

James H. Williams
Engineering Geologist

ENGINEERING GEOLOGIC REPORT ON CITY LAKE SITE

Pike County, Mo.

LOCATION: SW¼, Sec. 20, T. 53 N., R. 2 W., Bowling Green Quadrangle.

GEOLOGIC SETTING:

Reports on the geologic setting have been completed on previous examinations. These are attached for review if desired.

RECOMMENDATIONS:

The leak, although seriously affecting reservoir storage, is not a hazardous condition to the dam structure. There is no indication from a geologic aspect that the dam is being weakened by the leakage. As described previously, the leakage is considered to be water movement through the lower portion of the Burlington Limestone. It moves through the abutment on the west (left) side of the dam. It does not move through the earthen dam or at the contact of the dam and abutment. The examination on 17 July 1976, showed no evidence of any type of structural weakness of the dam. As could be remembered from previous examinations there is no apparent increase in leakage. Rather as mentioned by Mr. Haley during the examination, leakage gradually deminishes as water level reduces.

The gradual reduction in leakage as water level reduces is common in this setting. The volume of water being lost decreases as the head is lessened. Also the volume of water in the surrounding bedrock is less due to cessation of rainfall.

Attempts to repair this leakage are difficult. The Burlington Limestone is not broken by uniform vertical and horizontal fractures. Rather the openings are random. Grouting is one method that is used to attempt to seal those openings. If the drilling efforts are fortunate, the grout injected into the drill holes will find a bedrock opening in which water is moving. However, more common occurrences are that such holes or at least portions of these holes are missed during the grouting operation. Since the holes do not interconnect, it is difficult to seal all of them.

Plans to excavate the area of the present leakage and backfill with cement is the best alternative in this type of a situation. By opening the area where the present leakage is occurring, a more direct access to the water loss openings should be obtained. This offers the opportunity to place cement directly into at least one of the holes causing leakage from the lake. It is suggested that the grout placed be mostly a sand-cement mixture rather than including excessive amounts of gravel aggregatt. Because the cement will be free falling, there will be segregation of the cement from the gravel at least in the beginning of the effort to seal this area. This segregation of cement from the gravel could cause temporary blockage. This temporary blockage may have the same results as previous attempts in sealing the area with gravel and clay. Both will temporarily reduce the leakage, but over an extended period, the seal will deteriorate.

There is no guarantee that this suggested method will be totally successful. It does have the favorable aspect that at least one known opening can be sealed. There may be only one important opening and the plugging of this hole could help immensely. While it is unlikely there is only one point of water loss, it is urged that the attempt to seal be made. The indications are that it will at least have moderate success at a relatively reduced cost.

Dr. J. Hadley Williams, Chief
Applied Engineering & Urban Geology
Missouri Geological Survey
July 25, 1975

cc: Jack Haley
Water Supertindent
City Utilities
Bowling Green, Mo. 63334

Everett Baker
DNR Macon Regional Office
P. O. Box 489
Macon, Mo. 63552

APPENDIX C

N
BOWLING GREEN LAKE
Scale 1" = 1000'
900
900
900
900
DRAINAGE A
M
61

Sheet 1,
Appendix C

2

HYDRAULICS AND HYDROLOGIC DATA

Design Data: From Contract Drawings and Field Measurements.

Experience Data: Hydraulic Design computation from Chas. A. Haskins was used to compute spillway rating curve, elevation-surface area-storage relationahip, watershed area, etc.

We obtained some information from Mr. Jack Haley who is the water superintendent of Bowling Green. According to Mr. Haley, the maximum depth above the spillway crest (elev. 795.0) has been 3 to 4 ft in 1972 and 1973. Normally, the spillway operates only during the spring runoff. A restriction at the entrance of the spillway approach channel, caused by a roadway that passes through the dam and some big trees, was analyzed. The cross sections taken by surveying the area indicate that this restriction will reduce the discharge capability of the spillway, mainly during low flows. Nevertheless, we recommend that those trees should be cut and the approach channel entrance maintained clear.

Visual Inspection: At the time of inspection, the pool elevation was 790.32, about 4.68 ft below normal pool (elev. 795.0).

Overtopping Potential: Flood routings were performed to determine the overtopping potential. Since the dam is of intermediate size with a high hazard rating, a spillway design storm of 100 percent Probable Maximum Flood was prescribed by the guidelines. The PMF is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The watershed drainage and the reservoir surface areas were obtained from the hydraulic computation and checked by planimetering the U.S.G.S. 15 min. Bowling Greem, Mo.-Ill. quadrangel map. The storage volume was also obtained from the hydraulic computation.

A 5 min. interval unit-graph was developed for the watershed which resulted in a peak inflow of 2789 c.f.s. and a time to peak of 15 min. Application of the probable maximum rainfall, minus losses, resulted in a flood hydrograph peak inflow of 12,302 c.f.s. Rainfall distribution for the 24 hour storm was according to EM 1110-2-1411.

Considering all factors, the combination of dam, spillway and storage is not sufficient to pass the PMF without overtopping the embankment. The crest elevation of 801.0 ft would be overtopped by 2.24 ft at flood pool elevation 803.24 ft.

Fifty percent of the PMF was routed through the spillway. The resultant maximum pool elevation was 801.41 ft, which is 0.41 ft above the crest. The portion of the PMF that will just reach the top of dam is about 45 percent, which is greater than the 100 year flood event. For additional information, see the "Summary of Dam Analyses" on Sheets 3 and 4.

OVERTOPPING ANALYSIS FOR BOWLING GREEN

INPUT PARAMETERS

1. Unit Hydrograph - SCS Dimensionless - Flood Hydrograph Package (HEC-1); Dam Safety Version Was Used. Hydraulic Inputs Are As Follows:

   a. Twenty-four Hour Rainfall of 25 Inches For 200 Square Miles - All Season Envelope

   b. Drainage Area = 900 Acres; = 1.40 Sq. Miles

   c. Travel Time of Runoff 0.33 Hrs.; Lag Time 0.2 Hrs.

   d. Soil Conservation Service Runoff Curve No. 80 (AMC III)

   e. Proportion of Drainage Basin Impervious 0.05

2. Spillways

   a. Primary Spillway: Concrete Weir Trapezoidal Section

      (Crest Elev. 795.0) Length = 40 ft. Side Slope 1:1 C = 3.1

   b. Emergency Spillway: None

      Length -- Ft.; Side Slopes --; C = --

   c. Dam Overflow

      Length 645 Ft.; Side Slopes Vert; C = 3.0

   Note: Spillway Rating Curve Computed by Hanson Engineers. Data Provided to Computer on Y4 and Y5 Cards.

SUMMARY OF DAM SAFETY ANALYSIS

1. Unit Hydrograph

   a. Peak - 2789 c.f.s.

   b. Time to Peak 15 Min.

2. Flood Routings Were Computed by the Modified Puls Method

   a. Peak Inflow (see Sheet 6)

      50% PMF 6,151 c.f.s.; 100% PMF 12,302 c.f.s.

b. Maximum Reservoir Elevation

50% PMF 801.41 100% PMF 803.24

c. Portion of PMF That Will Reach Top of Dam

45 %; Top of Dam Elev. 801.0 Ft.

3. Computer Input and Output Data Sheets 5 and 6

BOWLING GREEN DAM (PMF)

```
1**********************************
 FLOOD HYDROGRAPH PACKAGE (HEC-1)
 DAM SAFETY VERSION      JULY 1978
   LAST MODIFICATION  3 AUG 78
 **********************************
     1              A       OVERTOPPING ANALYSIS FOR BOWLING GREEN DAM (#4)
     2              A       CO CODE 163 CO NAME PIKE STATE ID #10262 OWNER CITY OF
     3              A       HANSON ENGINEERS INC  DAM SAFETY INSPECTION JOB #03779
     4              B     300       0       5       0       0       0       0
     5              B1      5
     6              J       1       8       1
     7              J1    0.2     0.3     0.4     0.5     0.6     0.7     0.8
     8              K       0       1                       0       0       1
     9              K1      INFLOW HYDROGRAPH COMPUTATION
    10              M       1       2     1.4             1.4               1
    11              P       0      25     102     120     130
    12              T                                                      -1      -8
    13              W2  0.334    0.20
    14              X       0     -.1       2
    15              K       1       2
    16              K1      RESERVOIR ROUTINE BY MODIFIED PULS AT BOWLING GREEN DAM
    17              Y                               1       1
    18              Y1      1                                            1.10      -1
    19              Y4    795     796     797     798     799     800     801     803
    20              Y5      0     127     368     693    1091    1560    2096    3367
    21              $S      0    1410    1638    1902    2179
    22              $E    725     795     800     805     810
    23              $$    795
    24              $D    801     3.0     1.5     645
    25              K      99
```

EN DAM (#4
J262 OWNER ... OF BOWLING GREEN
PECTION JOB #03779

0		0	0	0
0 7	C	1		
0				
			0 05	

T BOWLING GREEN DAM

	[illegible]	-1
800	[illegible]	803
1560	2[illegible]	3367

Sheet 5, Appendix C

2

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

BOWLING GREEN DAM (PMF)

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

OPERATION	STATION	AREA	PLAN	RATIO 1 0.20	RATIO 2 0.30	RATIO 3 0.40	RATIO 4 0.50
				RATIOS APPLIED TO FLO			
HYDROGRAPH AT	1	1.40	1	2460.	3691.	4921.	6151.
	(	3.63)	(	69.67)(	104.50)(	139.34)(	174.17)(
ROUTED TO	2	1.40	1	789.	1330.	1873.	2913.
	(	3.63)	(	22.34)(	37.66)(	53.05)(	82.50)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1		INITIAL VALUE	SPILLWAY CREST
	ELEVATION	795.00	795.00
	STORAGE	1410.	1410.
	OUTFLOW	0.	0.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURAT OVER HOUR
0.20	798.24	0.00	1558.	789.	0.0
0.30	799.51	0.00	1616.	1330.	0.0
0.40	800.58	0.00	1669.	1873.	0.0
0.50	801.41	0.41	1712.	2913.	0.5
0.60	801.92	0.92	1740.	4440.	0.9
0.70	802.35	1.35	1762.	6008.	1.2
0.80	802.69	1.69	1780.	7440.	1.6
1.00	803.24	2.24	1809.	9990.	2.9

ULTIPLE P[illegible] RATIO ECONOMIC COMPUTATIONS
(CUBIC ME[illegible] PER SECOND)
UARE KILO[illegible]ERS)

TIOS APPL[illegible] TO FLOWS

TIO [illegible]	[illegible]	RATIO 5	RATIO 6	RATIO 7	RATIO 8
0.40	[illegible]	0.60	0.70	0.80	1.00
4921	[illegible]	7381	8611	9841	12302
39.34)(	1[illegible])(	209.01)(	243.84)(	278.68)(	348.35)
1873	[illegible]	4440	6008	7440	9930
53.05)(	[illegible] 50)(	125.72)(	170.12)(	210.67)(	232.87)

AM SAFETY ANALYSIS

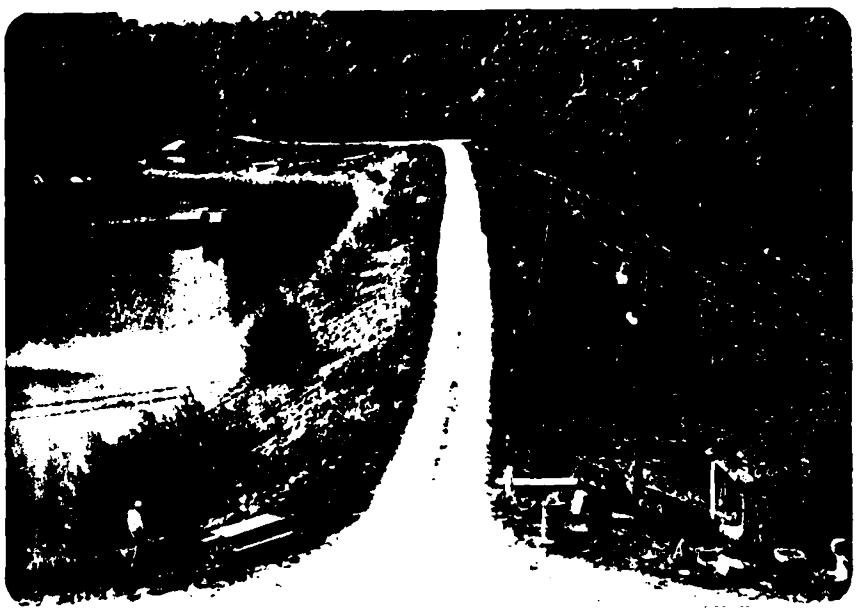
	SPILLWAY CREST	TOP OF DAM
	795.00	801.00
	1410	1691.
	0	2525.

MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
789	0.00	16.17	0.00
1330	0.00	16.17	0.00
1873	0.00	16.17	0.00
2913	0.58	16.08	0.00
4440	0.92	16.00	0.00
[illegible]	1.25	15.92	0.00
[illegible]	1.67	15.92	0.00
[illegible]	2.92	15.83	0.00

2

APPENDIX D

Crest of Dam - Looking East



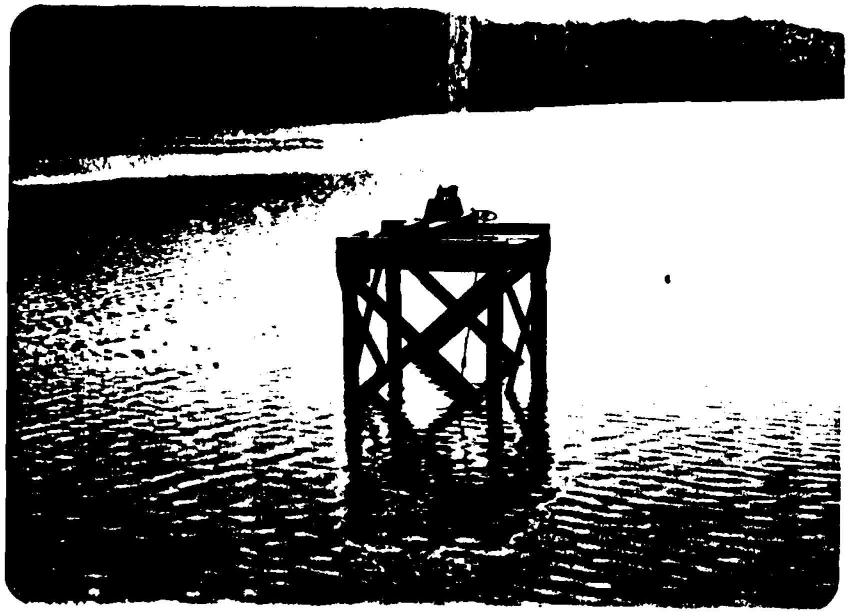
View of Dam - Looking West

Upstream Face of Dam - Looking East

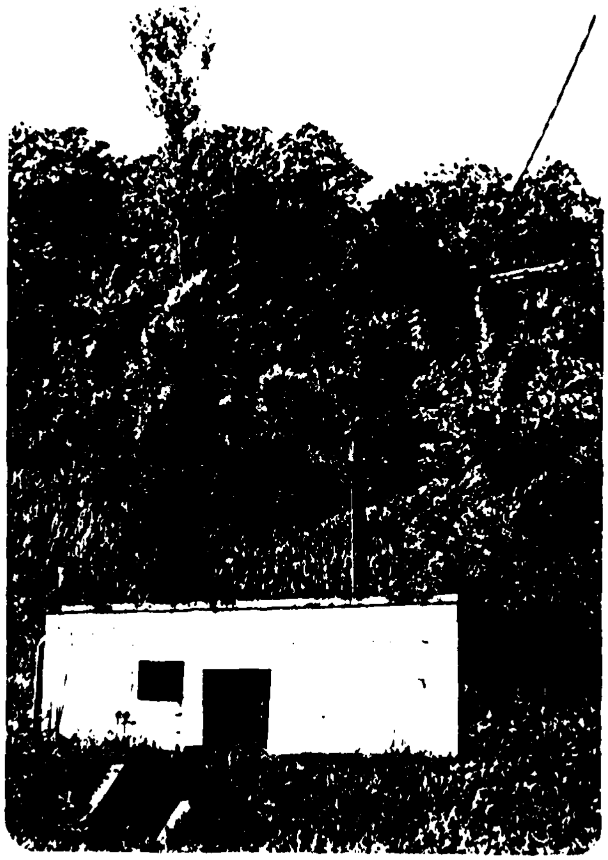
Downstream Face of Dam - Looking West

Grouted Area - West Abutment (Upstream)

Close-Up of Grouted Area



Intake Tower



Pumping Station

Area of Seepage from West Abutment

Apparent Seepage in Channel Below Pumping Station

Spillway - Looking Upstream

Spillway - Looking Downstream

Spillway and Plunge Pool

Outlet Channel Below Spillway

END

DATE
FILMED
10-81

DTIC