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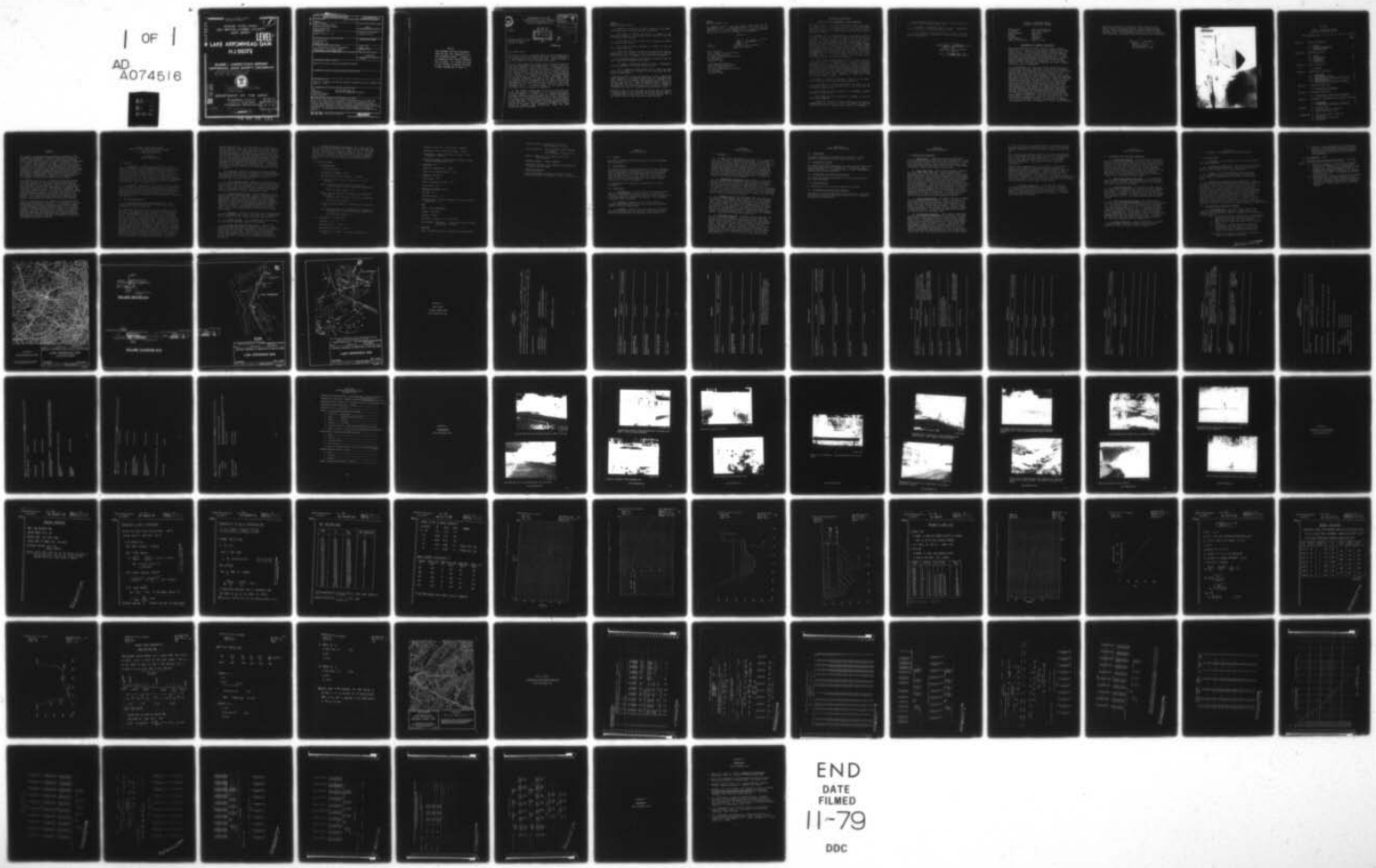

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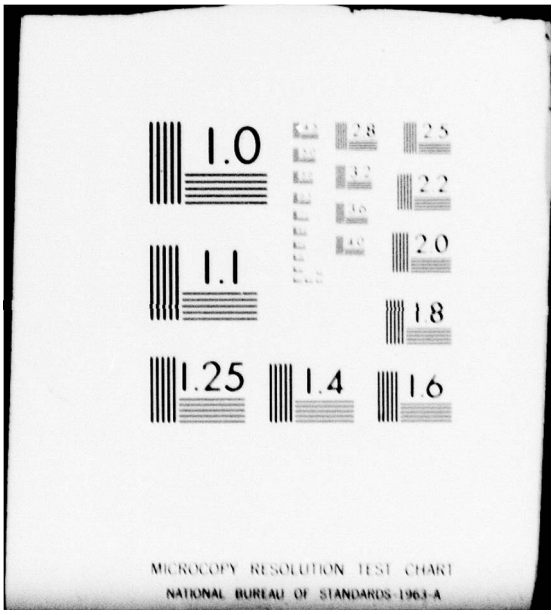
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PASSAIC RIVER BASIN
DEN BROOK, MORRIS COUNTY
NEW JERSEY

LEVEL II

LAKE ARROWHEAD DAM

NJ 00172

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

Lake Arrowhead Dam (NJ-00172). Passaic River Basin, Den Brook, Morris County, New Jersey. Phase 1 Inspection Report.

(9) Final rept.,

(10) Warren A. /Guinan

(15) DACW61-79-C-0011

DEPARTMENT OF THE ARMY
Philadelphia District
Corps of Engineers
Philadelphia, Pennsylvania

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dams
Embankments
Structural Analysis
Visual inspection
Lake Arrowhead Dam, NJ
National Dam Inspection Act Report

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report cites results of a technical investigation as to the dam's adequacy. The inspection and evaluation of the dam is as prescribed by the National Dam Inspection Act, Public Law 92-367. The technical investigation includes visual inspection, review of available design and construction records, and preliminary structural and hydraulic and hydrologic calculations, as applicable. An assessment of the dam's general condition is included in the report.

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Honorable Brendan T. Byrne
Governor of New Jersey
Trenton, NJ 08621

20 SEP 1979

Dear Governor Byrne:

Inclosed is the Phase I Inspection Report for Lake Arrowhead Dam in Morris County, New Jersey which has been prepared under authorization of the Dam Inspection Act, Public Law 92-367. A brief assessment of the dam's condition is given in the front of the report.

Based on visual inspection, available records, calculations and past operational performance, Lake Arrowhead Dam, initially listed as a high hazard potential structure, but reduced to a significant hazard potential structure as a result of this inspection, is judged to be in fair overall condition. The dam's spillway is considered inadequate since 7 percent of the Spillway Design Flood--SDF - would overtop the dam. (The SDF, in this instance, is one half of the Probable Maximum Flood.) The decision to consider the spillway, "inadequate" instead of "seriously inadequate" is based on the dam's reduced hazard classification and the determination that dam failure resulting from overtopping would not signficantly increase the hazard to loss of life downstream from the dam from that which would exist just before overtopping failure. To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. The spillway's adequacy and the need for a larger low level outlet pipe should be determined by a qualified professional consultant engaged by the owner using more sophisticated methods, procedures, and studies within six months from the date of approval of this report. Any remedial measures necessary to insure the adequacy of the spillway and to prevent overtopping should be initiated within calendar year 1980. In the interim, a detailed emergency operation plan and warning system should be promptly developed. Also, during periods of unusually heavy precipitation, around the clock surveillance should be provided.

b. Within six months from the date of approval of this report, engineering studies and analyses should be performed to:

(1) Design and oversee construction of repairs to the deteriorated concrete in the spillway structure and in the deck and piers near the right abutment.

(2) Design and oversee construction of replacement stoplogs and repair of stoplog slots.

(3) Design and oversee procedures for removal of trees and brush from the embankment.

c. Within three months of the date of approval of this report, a program should be initiated to check the condition of the dam periodically to watch for seepage or any indications of instability.

d. The following remedial actions should be completed within one year from the date of approval of this report:

(1) Engage a professional engineer to make a comprehensive technical inspection of the dam once every two years.

(2) If hydraulic studies indicate that a larger low level outlet is not required the existing low level outlet pipe and valve should be rehabilitated.

A copy of the report is being furnished to Mr. Dirk C. Hofman, New Jersey Department of Environmental Protection, the designated State Office contact for this program. Within five days of the date of this letter, a copy will also be sent to Congressman James A. Courter of the Thirteenth District. Under the provision of the Freedom of Information Act, the inspection report will be subject to release by this office, upon request, five days after the date of this letter.

Additional copies of this report may be obtained from the National Technical Information Services (NTIS), Springfield, Virginia 22161 at a reasonable cost. Please allow four to six weeks from the date of this letter for NTIS to have copies of the report available.

NAPEN-D
Honorable Brendan T. Byrne

An important aspect of the Dam Safety Program will be the implementation of the recommendations made as a result of the inspection. We accordingly request that we be advised of proposed actions taken by the State to implement our recommendations.

Sincerely,

JAMES G. TON
Colonel, Corps of Engineers
District Engineer

1 Incl
As stated

Copies furnished:
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LAKE ARROWHEAD DAM (NJ00172)

CORPS OF ENGINEERS ASSESSMENT OF GENERAL CONDITIONS

This dam was inspected on 16 May 1979 by Anderson-Nichols and Company, Inc. under contract to the State of New Jersey. The State, under agreement with the U.S. Army Engineer District, Philadelphia, had this inspection performed in accordance with the National Dam Inspection Act, Public Law 92-367.

Lake Arrowhead Dam, initially listed as a high hazard potential structure, but reduced to a significant hazard potential structure as a result of this inspection, is judged to be in fair overall condition. The dam's spillway is considered inadequate since 7 percent of the Spillway Design Flood--SDF - would overtop the dam. (The SDF, in this instance, is one half of the Probable Maximum Flood.) The decision to consider the spillway, "inadequate" instead of "seriously inadequate" is based on the dam's reduced hazard classification and the determination that dam failure resulting from overtopping would not signficantly increase the hazard to loss of life downstream from the dam from that which would exist just before overtopping failure. To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. The spillway's adequacy and the need for a larger low level outlet pipe should be determined by a qualified professional consultant engaged by the owner using more sophisticated methods, procedures, and studies within six months from the date of approval of this report. Any remedial measures necessary to insure the adequacy of the spillway and to prevent overtopping should be initiated within calendar year 1980. In the interim, a detailed emergency operation plan and warning system should be promptly developed. Also, during periods of unusually heavy precipitation, around the clock surveillance should be provided.

b. Within six months from the date of approval of this report, engineering studies and analyses should be performed to:

(1) Design and oversee construction of repairs to the deteriorated concrete in the spillway structure and in the deck and piers near the right abutment.

(2) Design and oversee construction of replacement stoplogs and repair of stoplog slots.

(3) Design and oversee procedures for removal of trees and brush from the embankment.

c. Within three months of the date of approval of this report, a program should be initiated to check the condition of the dam periodically to watch for seepage or any indications of instability.

d. The following remedial actions should be completed within one year from the date of approval of this report:

(1) Engage a professional engineer to make a comprehensive technical inspection of the dam once every two years.

(2) If hydraulic studies indicate that a larger low level outlet is not required the existing low level outlet pipe and valve should be rehabilitated.

APPROVED: for James G. Ton

JAMES G. TON
Colonel, Corps of Engineers
District Engineer

DATE: 19 September 1979

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam:	Lake Arrowhead Dam
ID Number:	Fed ID No. NJ00172
State Located:	New Jersey
County:	Morris
Stream:	Den Brook
River Basin:	Passaic
Date of Inspection:	May 16, 1979

ASSESSMENT OF GENERAL CONDITIONS

Lake Arrowhead Dam is 54 years old and in fair overall condition. It is small in size and is classified as significant hazard. The concrete spillway structure shows evidence of deterioration. Severe spalling of the concrete is evident on the underside of the spillway deck. Trees and brush are growing along the downstream toe. The downstream conduit system which carries the discharge from Lake Arrowhead's spillway is inadequate in its carrying capacity. The spillway itself can pass less than 3 percent of the PMF and is inadequate.

It is recommended that the owner retain the services of a professional engineer, qualified in the design and inspection of dams, to accomplish the following in the near future: oversee the design and construction of repairs to the deteriorated concrete in the spillway structure and in the deck and piers near the right abutment; replace the stoplogs and repair the stoplog slots; investigate, through additional hydraulic evaluation, the necessity for a larger low level outlet pipe and either install a new one or rehabilitate the existing low-level outlet pipe and valve; remove the trees and their root systems, and brush growing at the downstream toe of the structure; conduct detailed hydrologic and hydraulic analyses of the watershed, reservoir and dam, and design and implement appropriate mitigating measures to provide for safe passage of high discharges. It is further recommended: that starting immediately the owner check the condition of the dam periodically to watch for changes in seepage or stability; and that in the future, a professional engineer, qualified in the design and inspection of dams, be engaged to conduct a comprehensive

technical inspection of the dam at least once every two years. Also, in the near future, a surveillance program for use during and immediately following periods of heavy rainfall, and a warning program to follow in case of flood-flow conditions or imminent dam failure should be established.

Warren A. Guinan

Warren A. Guinan, P.E.
Project Manager
New Jersey No. 16848

16 MAY 1979

OVERVIEW
LAKE ARROWHEAD DAM

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY REPORT

LAKE ARROWHEAD DAM N.J. NO. 25-53 FED ID NO. NJ00172

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PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test Flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. The test flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY INSPECTION PROGRAM
LAKE ARROWHEAD DAM
U.S. #NJ00172 NJ #25-53

SECTION 1
PROJECT INFORMATION

1.1 General

a. Authority. Authority to perform the Phase I Safety Inspection of Lake Arrowhead Dam was received from the State of New Jersey, Department of Environmental Protection, Division of Water Resources by letter dated 4 April 1979 under Contract FPM No. 39 dated 28 June 1978. This authority was given pursuant to the National Dam Inspection Act, Public Law 92-367 and by agreement between the State and the U.S. Army Engineers District, Philadelphia. The inspection discussed herein was performed by Anderson-Nichols & Co., Inc. on 16 May 1979.

b. Purpose. The purpose of the Phase I Investigation is to develop an assessment of the general conditions with respect to the safety of Lake Arrowhead Dam and appurtenances based upon available data and visual inspection, and, determine any need for emergency measures and conclude if additional studies, investigations, and analyses are necessary and warranted.

1.2 Project Description

a. Description of Dam and Appurtenances. Lake Arrowhead Dam is an 8-foot high, 375-foot long earth embankment dam, built around 1925.

The downstream face of the dam is of stone masonry and is vertical. The upstream side of the dam is occupied by the Lake Arrowhead Clubhouse, dock facilities, and a bathing beach. The clubhouse occupies the area of the northwest (right) abutment. A concrete slab and wooden plank deck extends from behind the clubhouse to a point approximately one third of the way across the dam. Southeast of the deck the beach begins and extends to the southeast abutment of the dam. The slope of the beach is about 30H:1V. A wooden fence extends from the clubhouse to the southeast abutment on the downstream edge of the dam crest. Near the southeast abutment is a gate in the stone masonry wall that provides vehicle access to the beach from Mosswood Trail. The spillway exits the dam beneath the concrete deck through the concrete core wall. It has a lower opening, 2 feet wide by 2.4 feet high, controlled with stoplogs. The upper

uncontrolled opening is 10 feet wide by 1.1 feet high. A 6-inch diameter, cast iron, low level outlet pipe passes through the toe of the dam about one foot to the right of the stoplog section. Mosswood Trail, a paved street, is located immediately below the dam and parallels the crest. Two 24-inch concrete pipes are provided to carry spillway and low level outlet discharge beneath Mosswood Trail and into the stormwater drainage system for the area. The conduit system eventually discharges into Den Brook just upstream of its mouth on the Rockaway River. (Essential features of the dam are given in Figure 2). A sketch of the conduit system, based on field observations, is given in Figure 3.

b. Location. The dam is located in Morris County, New Jersey on Den Brook, a tributary to the Rockaway River, approximately one mile east of Denville. It is at north latitude 40°, 53.4' and west longitude 74° 28.1'. A location map is given in Figure 1.

c. Size Classification. Based on its storage of 114 acre-feet, which is less than 1000 acre-feet, but more than 50 acre-feet, and its height of 8 feet, which is less than 40 feet, Lake Arrowhead Dam is classified as small in size, in accordance with the criteria given in the Recommended Guidelines for Safety Inspection of Dams.

d. Hazard Classification. Visual inspection of the downstream area, and the breach analysis contained herein, shows that a breach of Lake Arrowhead Dam could cause appreciable, but not excessive, damage to the restaurant immediately downstream of the dam, the automobile dealership on U.S. Route 46 and additional commercial properties along U.S. Route 46. No permanent residences are downstream of the dam. There would probably be no loss of life. Thus, Lake Arrowhead Dam is classified as Significant Hazard.

e. Ownership. The dam is owned by Lake Arrowhead Club, Denville Township, New Jersey. Mr. John Losh, 24 Basswood Drive, Denville is the current president of the club.

f. Purpose of Dam. Lake Arrowhead Dam was originally designed and is currently used for recreation.

g. Design and Construction History. The dam was originally built by Arthur D. Crane Co. in 1925. Little information was disclosed regarding the design and construction of the original dam. The current club president stated that a small pond of about 5 acres existed prior to the construction of the dam. The dam increased the size of the pond to about 19 acres and made it usable for recreation.

h. Normal Operational Procedures. The current president of the Lake Arrowhead Club, John Losh, stated that the lake is lowered in the fall, by removal of two of the flashboards, to eliminate ice damage around the shore. In the spring, after the peak runoff has passed, the flashboards are replaced to raise the lake up to its summer recreation level. No formal written operating procedures were disclosed.

1.3 Pertinent Data

a. Drainage Area

0.22 square miles

b. Discharge at Damsite (cfs)

Maximum known flood at damsite - unknown

Low level outlet at pool elevation - 1.5 (if operable)

Gated spillway capacity at pool elevation -
with stoplogs in place (as during inspection) - 0
with stoplogs removed - 20

Gated spillway capacity at maximum pool elevation (top dam) -
with stoplogs in place (as during inspection) - 0
with stoplogs removed - 27

Ungated spillway capacity at maximum pool elevation - 16

Total spillway capacity at maximum pool elevation -
with stoplogs in place (as during inspection) - 16
with stoplogs removed - 43

c. Elevation (ft. above MSL)

Top dam - 519.9

Recreation pool - 519.0

Maximum pool (½ PMF) - 521.0

Spillway crest (gated) - at time of inspection - 519.2

Upstream invert low level outlet - unknown

Downstream invert low level outlet - 514.3

Streambed at centerline of dam (invert of 24" culverts) - 511.7

Maximum tailwater - 519.0 (from tailwater rating curve over Mosswood Trail)

d. Reservoir (ft.)

Length of maximum pool - 1600

Length of recreation pool - 1500

e. Storage (acre-feet)

Normal pool - 96

Design surcharge (½ PMF) - 137

Top of dam - 114

f. Reservoir Surface (acres)

Top dam - 20

Recreation pool - 19

Spillway crest - (with stoplogs in place as during inspection) - 19

g. Dam

Type - earth embankment

Length - 375± feet

Height - 8 feet

Top Width - varies - 10 to 50+ feet

Side Slopes - Upstream: Varies to 30H:1V at beach
Downstream: Vertical

h. Spillway

Type - Combination free overflow and stoplog gated

Length of weir - stoplogs - 1.95 feet
free overflow - 10 feet

Crest elevation - 519.2 feet MSL (with stoplogs in place)
516.9 feet MSL (stoplog sill)

Gates - rough cut 2 x 6 inch by 1.95 foot long stoplogs

Upstream channel - Lake Arrowhead

Downstream channel - 24" concrete pipe which discharges into Den Brook

i. Regulating Outlets

Six-inch diameter cast iron low level outlet. Valving mechanism at unknown location in reservoir.

SECTION 2
ENGINEERING DATA

2.1 Design

No plans or hydraulic/hydrologic data for Lake Arrowhead were disclosed.

2.2 Construction

No recorded data concerning construction of Lake Arrowhead Dam were disclosed. Reference data on file with the New Jersey Department of Environmental Protection indicates that the dam was built in 1925 by Arthur D. Crane Co., that the dam is 488 feet long, that two 8-inch cast iron outlet pipes were provided and that the outlet channel culvert is 30 inches in diameter.

2.3 Operation. No engineering operational data were disclosed.

2.4 Evaluation

a. Availability. A search of the New Jersey Department of Environmental Protection files, contact with community officials and contact with the owner revealed only a limited amount of recorded information. All disclosed information was retrieved.

b. Adequacy. Because of the limited amount of recorded data available evaluation of this dam was based solely on visual observations.

c. Validity. Parts of the recorded data retrieved were found to be incorrect based on visual observations. Specific discrepancies are discussed in Section 5.1 a.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. Dam. Trees and brush are growing at the downstream toe. No evidence of seepage was observed. No evidence of bulging or other signs of slope instability were observed. Two drain pipes which appear to lie parallel to the downstream toe of the dam have outlets on either side of the channel downstream of the stoplog spillway. No water was discharging from the pipes at the time of the inspection. Owner's representatives indicated that one of the pipes is a drain for the cellar of Lake Arrowhead's clubhouse at the right abutment and that the other pipe is a drain for house cellars on the left abutment.

b. Appurtenant Structures. The stoplogs in the spillway are weathered and the metal stoplog slots are rusted. Surface spalling and erosion of the concrete in the spillway structure has occurred to a maximum depth of 2" in isolated areas. The location of the low level outlet mechanism is unknown. Minor deterioration and spalling of the underside of the concrete deck and concrete piers of the deck structure on the crest of the dam near the right abutment were observed. Some reinforcing steel was exposed.

c. Reservoir Area. The watershed above the reservoir is gently sloping and partially wooded. No defined streams are present. Two smaller ponds discharge into Lake Arrowhead. Many houses are built on the shore of the reservoir. No visible evidence of significant sedimentation was noted. At the time of the inspection no visible evidence of extensive growth of vegetation in the reservoir was observed. However, it should be noted that an inspection report dated August 1959 includes mention of "a large growth of vegetable matter, reportedly heavy enough to walk on."

d. Downstream Channel. The water that discharges over the spillway flows about 15' in an open channel and then enters two 24-inch diameter concrete pipes and flows underground about 1220 feet to a small tributary of the Rockaway River. One of the 24-inch lines was almost completely blocked with debris and it is unclear whether it can function as intended. Only one 24-inch line was visible in a catch basin below the dam. This indicates that the second, blocked line may have no downstream outlet. The 24-inch line connects with a 54-inch line at a location along the 1220-foot run.

SECTION 4
OPERATIONAL PROCEDURES

4.1 Procedures

No formal operating procedures were disclosed. Normal operating procedures are described in Section 1.2 h.

4.2 Maintenance of Dam

No formal maintenance procedures for the operating facilities were disclosed. From the condition of the dam and appurtenant structures it is apparent that a regular maintenance program has not been followed.

4.3 Maintenance of Operating Facilities

No formal maintenance procedures for the operating facilities were disclosed.

4.4 Warning System

No description of any warning system was disclosed.

4.5 Evaluation of Operational Adequacy

Because of the lack of operation and maintenance procedures, the remedial measures described in Section 7.2 c. should be implemented as prescribed.

SECTION 5
HYDROLOGIC/HYDRAULIC

5.1 Evaluation of Features

a. Design Data. Because no original design data were disclosed, an evaluation could not be performed. State of New Jersey inventory data from 1925 indicates two 8-inch cast iron outlet pipes. One 6-inch pipe was found. The inventory data also indicates a 30-inch culvert downstream of the dam. Two 24-inch culverts were found.

b. Experience Data. Data received through conversation with John Losh, President, Lake Arrowhead Club, indicated that in the 25 years he has lived on Lake Arrowhead he has never seen the dam overtopped or the low level outlet operated. During periods of high water the Rockaway River creates a backwater on Den Brook forcing water back into the culvert system which carries Lake Arrowhead's spillway discharge. Under such conditions discharge from Lake Arrowhead has in the past been forced out of the culvert in the restaurant parking lot just downstream of the dam. Experience also indicates that local flooding is more related to drainage problems in the surrounding area than to discharges from Lake Arrowhead Dam. This was the case in January of 1979 when U.S. Route 46 was inundated by 3 feet of water while the dam discharge was minimal.

c. Visual Observations. No visual evidence of damage due to overtopping was observed. Debris, consisting of rocks and silt, partially obstruct one of the two 24" CP which leads from the spillway toe, under Mosswood Trail, under U.S. Route 46 and into Den Brook. This may cause serious reduction in the conduit system's capacity during a flood occurrence. At the time of inspection no water was passing over the spillway crest.

d. Overtopping Potential. The hydraulic/hydrologic evaluation for Lake Arrowhead Dam is based on a spillway design flood (SDF) equal to half of the probable maximum flood (PMF) in accordance with the range of test floods given in the evaluation guidelines for dams classified as significant hazard and small in size. The PMF has been determined by application of the SCS dimensionless unit hydrograph procedure to the 24-hour PMP storm of 22.5 inches. Hydrologic computations are given in Appendix C. The routed half PMF peak discharge for the subject watershed is 621 cfs. The minimum elevation of the dam allows

0.7 foot of depth in the spillway before overtopping occurs, assuming the stoplogs remain in place. Under this head the spillway capacity is 18 cfs which is less than the required SDF.

Flood routing calculations indicate that Lake Arrowhead Dam will be overtopped for more than 7 hours to a maximum depth of 1.1 feet under half PMF conditions. It is estimated that the dam can pass less than 3 percent of the PMF without overtopping. The spillway is thus considered inadequate.

Because Lake Arrowhead Dam was classified as high hazard, based on the number of structures and the intensity of commercial activity downstream, a breach analysis using the HEC-1DB program was performed. A cross section (a plan of which is shown on Figure 3) was chosen to represent the downstream hazard area. The results of the breach analysis, contained in Appendix 3, indicate that breaching of the dam does not significantly increase the hazard downstream over the non-breach condition at the chosen cross section.

e. Drawdown Capability. If the low level outlet currently in place can be restored to operable condition, it is estimated that the pond can be drained in approximately 31 days, assuming no significant inflow. This time period is considered inadequate for draining the reservoir in an emergency situation.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations. The only visual evidence of potential stability problems was the growth of trees and brush on the downstream slope and at the downstream toe of the dam. If the trees blow over and their roots pull out or if a tree dies and its roots rot, serious seepage problems could result. Based on the visual inspection alone it is not possible to determine the character of the dam foundation or the interior of the cross section. Therefore, it is not possible to evaluate the factor of safety of the dam against slope failure.

b. Design and Construction Data. A reference-data sheet dated 16 December 1925 indicates that the dam has a concrete core wall and is founded on clay, with footings that are 9 feet below streambed.

c. Operating Records. An inspection report dated 22 August 1972, indicates that "the dam has minor seepage." No evidence of seepage was observed during the present inspection. An undated sketch refers to a "break in dam," near the left abutment. No details concerning this break are contained in any of the other records that were disclosed.

d. Post-Construction Changes. The undated sketch referred to in the paragraph immediately above mentions that: (1) the "break in dam" is to be repaired with concrete," (2) the upstream face of the dam is to be covered with "clay over plastic membrane," (3) a "possible additional standpipe" spillway is to be added in the future, and (4) a "leaching pit" (French drain) was to be installed at the downstream toe of the entire length of the dam. The standpipe spillway was apparently not built. It cannot be determined from the visual evidence alone whether or not the other proposed work was carried out.

e. Seismic Stability. Lake Arrowhead Dam is located in Seismic Zone 1 and in accordance with the Phase I guidelines does not warrant seismic analysis.

SECTION 7
ASSESSMENT, RECOMMENDATIONS/REMEDIAL MEASURES

7.1 Dam Assessment

a. Condition. Lake Arrowhead Dam is 54 years old and is in fair condition.

b. Adequacy of Information. The information available is such that the assessment of the dam must be based primarily on the results of the visual inspection.

c. Urgency. The recommendations made in Section 7.2 a. and the operating and maintenance procedures in 7.2 c. should be implemented by the owner as prescribed below.

d. Necessity for Additional Data/Evaluation. The information available from the visual inspection is adequate to identify the potential problems that are listed in Sections 5 and 6. These problems require the attention of a professional engineer experienced in the design and construction of dams to design or specify remedial measures. If left unattended, the problems could lead to instability of the structure. Although unrelated to the stability of the structure, of special concern is the location and capacity of the outlet conduit system. A study should be made and remedial measures implemented to insure that the capacity provided by this system is adequate to carry maximum spillway discharge in addition to normal stormwater along the road

7.2 Recommendations/Remedial Measures

a. Recommendations. The owner should retain the services of a professional engineer, experienced in the design and construction of dams, to accomplish the following in the future:

(1) Design and construct repairs to the deteriorated concrete in the spillway structure and in the deck and piers near the right abutment.
(2) Replace the stoplogs and repair metal stoplog slots.
(3) Investigate, through additional hydraulic evaluation, the necessity of a larger low level outlet pipe or rehabilitation of the existing low level outlet pipe and valve.
(4) Design and oversee procedures for removal of trees, root systems, and brush.

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(5) Conduct a detailed hydrologic and hydraulic analysis of the watershed, reservoir and dam, and design and implement appropriate mitigating measures to provide for safe passage of high discharges.

b. Alternatives. None

c. Operating and Maintenance Procedures. The owner should:

(1) Check the condition of the dam periodically to watch for seepage or any indications of instability. This should be started very soon.
(2) Engage a professional engineer to make a comprehensive technical inspection of the dam once every two years. This should be started in the future.
(3) Establish a surveillance program for use during and immediately following periods of heavy rainfall, and also a warning program to follow in case of floodflow conditions or imminent dam failure. This should be done in the near future.

DAM LOCATION
Newfoundland
Oak Ridge
Macopin
Midvale
Wanaque
Oakland
Franklin Lakes
Waldwick
Wyckoff
Midland Park
Ridgewood
Glen Rock
Sparta
Lake Mohawk
New Bussia
Milton
Petersburg
Green Pond
Bloomingdale
Pompton Lakes
Butler
Riverdale
Pompton Plains
North Haledon
Hawthorne
Haledon
Paterson
Wayne
Prospect Park
Lincoln Park
Pequannock
Jacksonville
Hibernia
Taylortown
Jefferson
Woodport
Glasser
Hurdtown
Woodstock
Marcella
Kinnelon
Berkshire Valley
Mt. Hope
Mt. Arlington
Middletown
Rockaway
Denville
Boonton
Montville
Towaco
Wharton
Dover
Kenvil
Mine Hill
Victory Garden
Mountain Lakes
Parsippany
Troy Hills
Littleton
Mill Brook
Shongum Lake
Morris Plains
Cedar Knolls
Morris
Hanover
East Hanover
Whippany
Randolph
Morristown
Florham Park
Madison
Convent Station
Chatham
New Vernon
Harding
Green Village
Summit
Millburn
Short Hills
Maplewood
Irvington
NEWARK
Springfield
Union
Hillside
Bernardsville
Basking Ridge
Peapack
Far Hills
Passaic
New Providence
Mountainside
Scotch Plains
Berkeley Heights
Murray Hill
Gillette
Stirling
Millington
Lyons
Myersville
Liberty Corners
Bernards
Pluckemin
Westfield
Kenilworth
Cranford
Roselle
Roselle Park
Elizabeth
Linden
Watchung
Mt. Bethel
Warren
North Plainfield
Plainfield
Fanwood
Garwood
Winfield
Clark
Lyons V.A. Hospital
Great Swamp Nat'l Wildlife Refuge
Greystone Park State Hospital
Rabbinical Coll. of America
Brookside
Ford Mansion
Villa Walsh
Fort Nonsense
Morristown Nat'l Historical Park
Assumption Coll. for Sisters
Coll. of St. Elizabeth
Drew Univ.
Seton Hall Univ.
Kean College
Union Coll.
Caldwell
West Caldwell
North Caldwell
Cedar Grove
Verona
West Orange
Montclair
Bloomfield
Nutley
Belleville
Glen Ridge
Orange
East Orange
South Orange
Newark
Harrison
Kearny
Lincoln Tunnel
Passaic
Clifton
Little Falls
Great Notch
Singac
West Paterson
Totowa
Lambert Castle
Packanack Lake
Pine Brook
Essex Fells
Roseland
Livingston
Whippany
Northfield
Jersey City
Bayonne
Newark Bay
Arthur Kill
Staten Island
Raritan Bay
Sandy Hook Bay
Lake Arrowhead
Lake Denmark
Picatinny Arsenal
Lake Hopatcong
Lake Valhalla
White Meadow Lake
Durham Pond
Sticklers Pond
Splitrock Pond
Butler Res.
Point View Res.
Packanack Lake
Susquehanna
Norvin Green State Forest
Morris Lake
Green Pond
Lake Shongum
Cedar Knolls
Mt. Freedom
Ironia
Oxbury
Ralston
Mendham
Gladstone
Peapack
Far Hills
Liberty Corners
Pluckemin
Bernards
Watchung
Mt. Bethel
Warren
North Plainfield
Plainfield
Clark
Linden
Roselle
Roselle Park
Kenilworth
Cranford
Westfield
Scotch Plains
Berkeley Heights
Murray Hill
Mountainside
New Providence
Passaic
Springfield
Union
Hillside
Newark
Millburn
Short Hills
Maplewood
Irvington
South Orange
East Orange
Orange
Glen Ridge
Montclair
Bloomfield
Nutley
Belleville
Verona
West Orange
Caldwell
West Caldwell
North Caldwell
Cedar Grove
Clifton
Passaic
Little Falls
Great Notch
Singac
West Paterson
Totowa
Lambert Castle
Paterson
Prospect Park
Wayne
Packanack Lake
Pine Brook
Essex Fells
Roseland
Livingston
Whippany
Northfield
Florham Park
Madison
Convent Station
Chatham
New Providence
Summit
Millburn
Short Hills
Maplewood
Irvington
Newark
Springfield
Union
Hillside
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Linden
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Roselle Park
Kenilworth
Cranford
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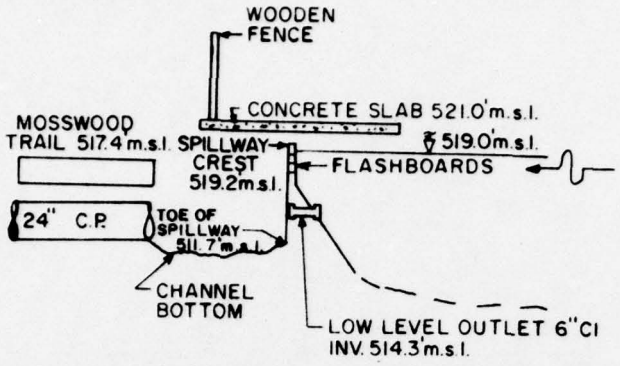
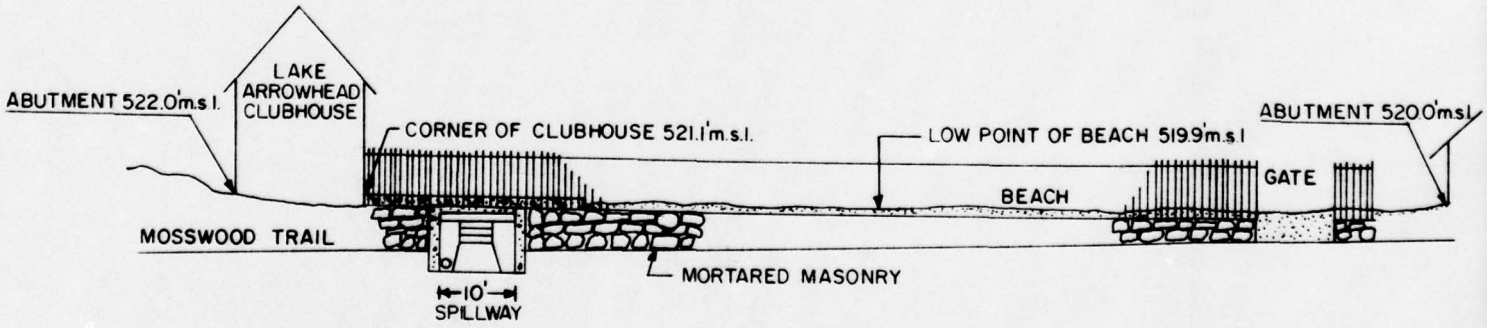
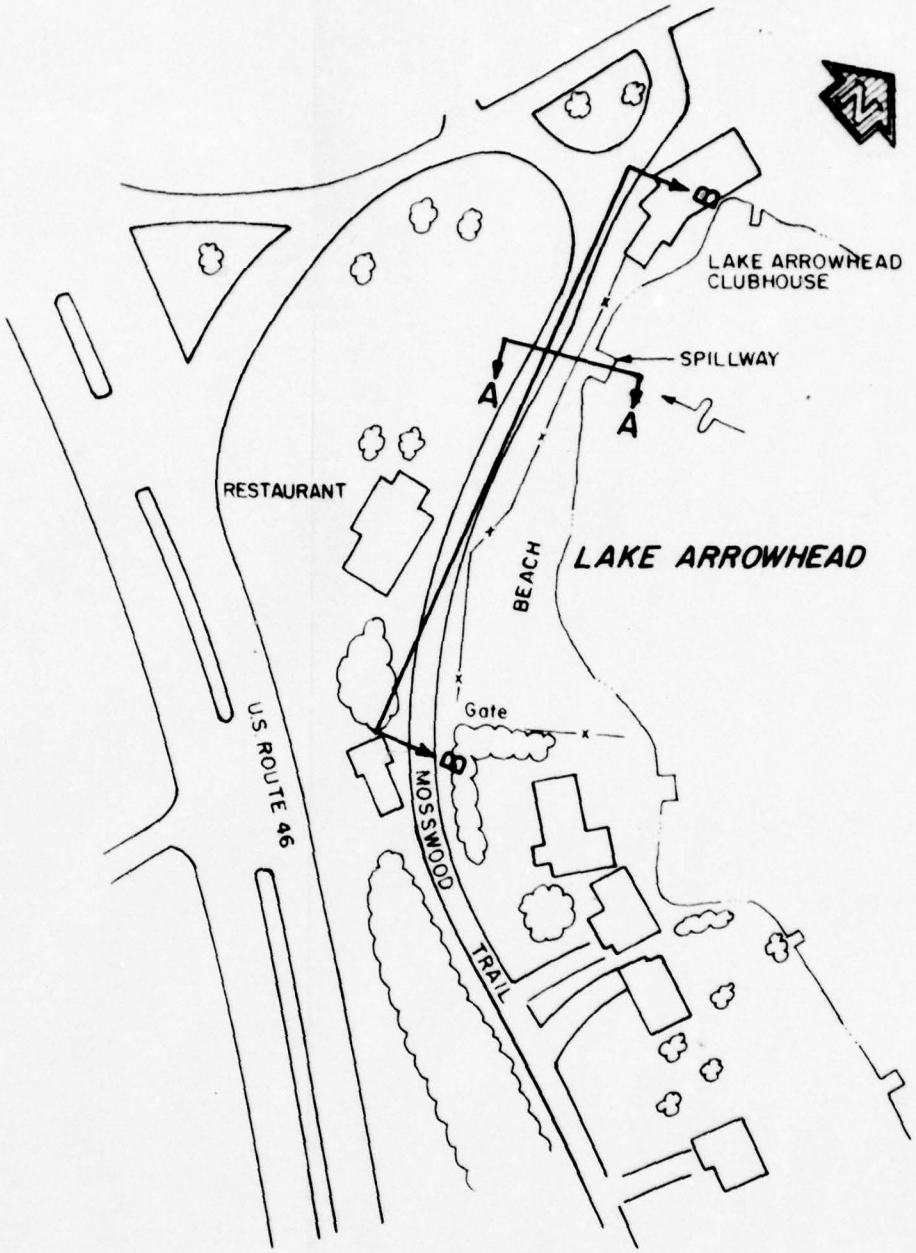
Essex Fells
Roseland
Livingston
Whippany
Northfield
Florham Park
Madison
Convent Station
Chatham

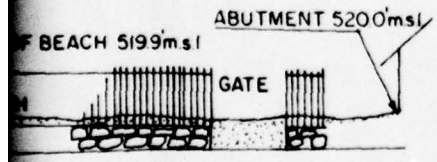


SPILLWAY SECTION A-A



SPILLWAY ELEVATION B-B





PLAN 2

DATA FROM FIELD INSPECTION MAY 16, 1979

Anderson - Nichols & Co., Inc BOSTON MASSACHUSETTS	U.S. ARMY ENGINEER DIST. PHILADELPHIA CORPS OF ENGINEERS PHILADELPHIA, PA

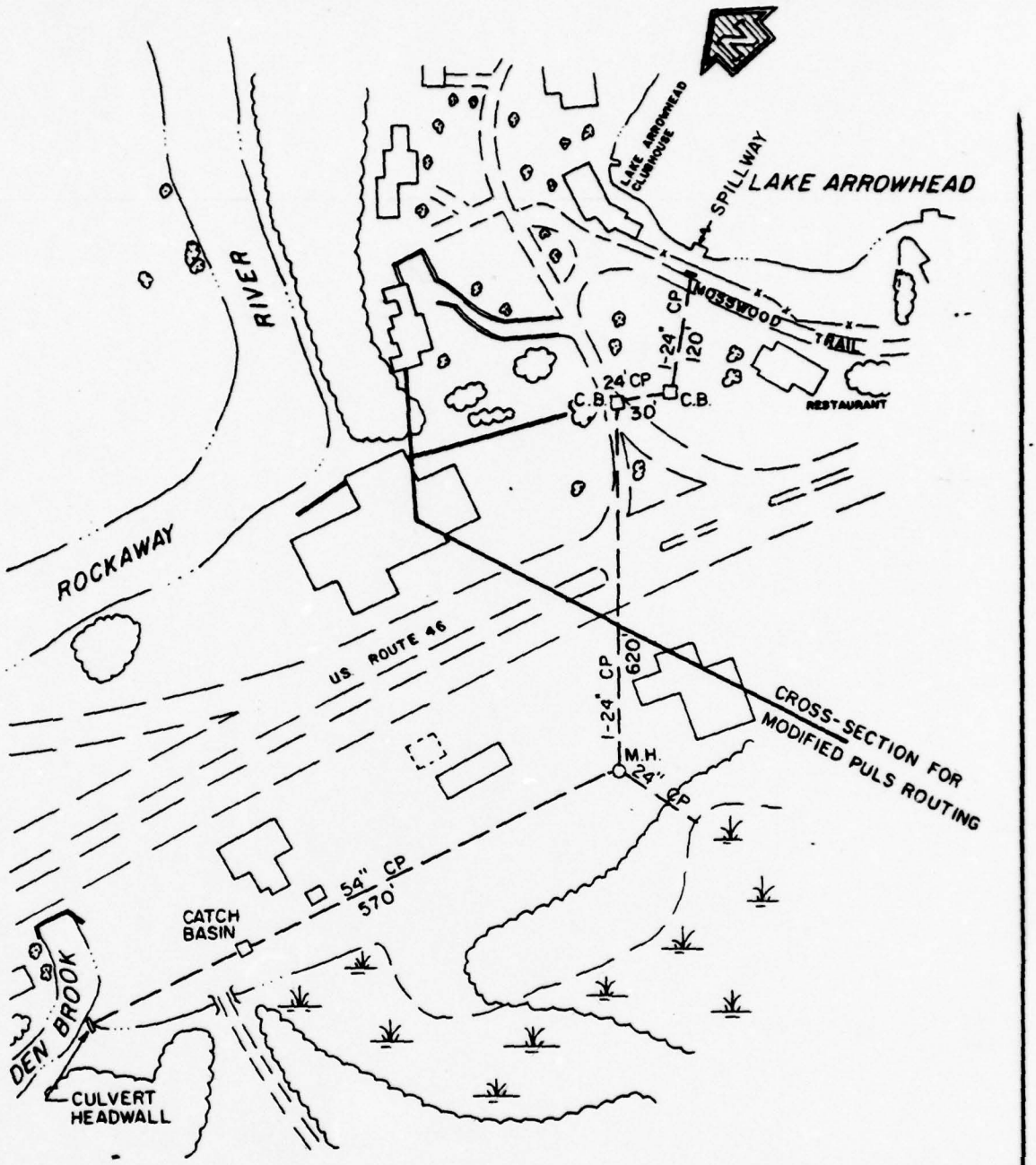
NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

LAKE ARROWHEAD DAM

DEN BROOK NEW JERSEY

SCALE: NOT TO SCALE
DATE: JULY, 1979

FIGURE 2



DATA FROM: MAP BY ROBINSON AERIAL SURVEY, PHOTOGRAMMETRIC MAPPING, NEWTON, NJ AND FIELD INSPECTION MAY 16, 1979

Anderson - Nichols & Co., Inc. BOSTON MASSACHUETTS	U.S. ARMY ENGINEER DIST. PHILADELPHIA CORPS OF ENGINEERS PHILADELPHIA, PA.

NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

LAKE ARROWHEAD DAM

DEN BROOK NEW JERSEY

			SCALE: NOT TO SCALE
			DATE: JULY, 1979

FIGURE 3

APPENDIX 1

CHECK LIST

VISUAL INSPECTION

LAKE ARROWHEAD DAM

Check List
Visual Inspection
Phase 1

Name Dam Lake Arrowhead County Morris State New Jersey Coordinators NJDEP

Date(s) Inspection May 16, 1979 Weather Sunny Temperature 65°

Pool Elevation at Time of Inspection 519.0 MSL Tailwater at Time of Inspection None MSL

Inspection Personnel:

Warren Guinan — Ronald Hirschfeld

Stephen Gilman — John Losh, President, Lake Arrowhead Club

David Deane

Hirschfeld & Guinan Recorder

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS	None apparent.	
UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE	None apparent.	
SLOUGHING OR EROSION OF EMBANKMENT AND ABUTMENT SLOPES	None apparent.	
VERTICAL AND HORIZONTAL ALIGNMENT OF THE CREST	Good.	
RIPRAP FAILURES	No riprap.	

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
RAILINGS		
JUNCTION OF EMBANKMENT AND ABUTMENT, SPILLWAY AND DAM	No apparent problems.	
ANY NOTICEABLE SEEPAGE	None.	
STAFF GAGE AND RECORDER	None apparent.	
DRAINS	None apparent. Two drain pipes discharge parallel to axis of dam into channel below spillway. One is reported to be a drain for clubhouse cellar at right end of dam. Second is reported to possibly be a drain for house cellars at left end of dam.	

UNGATED SPILLWAY

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE WEIR	Fair condition, some spalling and erosion on surface to a maximum depth of 2".	Free overflow is notched for gated-stoplog spillway
APPROACH CHANNEL	concrete deck overhangs spillway for 15' upstream of weir.	
DISCHARGE CHANNEL	See gated spillway.	
BRIDGE AND PIERS OVER SPILLWAY	None observed.	See approach channel.

GATED SPILLWAY

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE SILL	Concrete spillway and training walls -	fair condition, some spalling and erosion on surface, maximum depth 2".
	Steel stoplog slots -	Badly rusted.
	Concrete deck -	Top side good condition, surface erosion only underside, numerous spalled areas 6" depth, some steel visible.
APPROACH CHANNEL	Wide and unobstructed.	
DISCHARGE CHANNEL	Discharges from stoplog spillway via open channel into two concrete pipes about 15 feet downstream and then underground to Den Brook.	
BRIDGE AND PIERS	Concrete deck - see above.	
	Piers -	Eroded and spalled - 1" maximum depth; coarse aggregate visible; minor hairline cracks visible
GATES AND OPERATION EQUIPMENT	Double stoplog slots.	

INSTRUMENTATION

VISUAL EXAMINATION	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
MONUMENTATION/SURVEYS	None apparent.	
OBSERVATION WELLS	None apparent.	
WEIRS	None apparent.	
PIEZOMETERS	None apparent.	
OTHER	None apparent.	

RESERVOIR

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	Rolling, forested. Many houses on shoreline.	
SEDIMENTATION	No visible evidence of significant sedimentation.	

DOWNSTREAM CHANNEL

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONDITION (OBSTRUCTIONS, DEBRIS, ETC.)	Discharge is carried through 2 - 24" underground pipes. One nearly completely obstructed with debris. Discharge lines from dam tie into storm drain system for general area.	Outlet for debris blocked, pipe could not be located in downstream conduit system.
SLOPES	Not applicable.	
APPROXIMATE NO. OF HOMES AND POPULATION	6 commercial properties along heavily traveled U.S. Route 46. One restaurant immediately downstream of dam. No permanent population.	Substantial downstream storage compared to volume of water.

CHECK LIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION

ITEM	REMARKS
PLAN OF DAM	No original plans were disclosed. Plans for this report were developed from visual inspection May 16, 1979.
REGIONAL VICINITY MAP	Prepared for this report.
CONSTRUCTION HISTORY	No records of construction history were disclosed.
TYPICAL SECTIONS OF DAM	Prepared for this report from visual inspection.
HYDROLOGIC/HYDRAULIC DATA	No original data were disclosed.
OUTLETS - PLAN	None disclosed.
- DETAILS	None disclosed.
- CONSTRAINTS	None disclosed.
- DISCHARGE RATINGS	None disclosed.
RAINFALL/RESERVOIR RECORDS	None disclosed.

ITEM	REMARKS
MONITORING SERVICES	Unknown
MODIFICATIONS	None disclosed.
HIGH POOL RECORDS	None disclosed.
POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS	The only available records discuss proposed changes to the spillway. These changes were never incorporated.
PRIOR ACCIDENTS OR FAILURE OF DAM DESCRIPTION REPORTS	None disclosed.
MAINTENANCE OPERATION RECORDS	None disclosed.

ITEM	REMARKS
DESIGN REPORTS	None disclosed.
GEOLOGY REPORTS	None disclosed.
DESIGN COMPUTATIONS HYDROLOGY & HYDRAULICS DAM STABILITY SEEPAGE STUDIES	None disclosed.
MATERIALS INVESTIGATIONS BORING RECORDS LABORATORY FIELD	None disclosed.
POST-CONSTRUCTION SURVEYS OF DAM	None disclosed.
BORROW SOURCES	Unknown.

ITEM	REMARKS
SPILLWAY PLAN	No original plans were disclosed.
SECTIONS	Typical section of spillway was developed for this report from visual inspection May 16, 1979.
DETAILS	None disclosed.
OPERATING EQUIPMENT	None disclosed.
PLANS & DETAILS	None disclosed.

CHECK LIST
HYDROLOGIC AND HYDRAULIC DATA
ENGINEERING DATA

DRAINAGE AREA CHARACTERISTICS: 0.22 square miles, gently sloping and partially wooded.

ELEVATION TOP NORMAL POOL (STORAGE CAPACITY): 519.0 MSL (96 acre-feet)

ELEVATION TOP FLOOD CONTROL POOL (STORAGE CAPACITY): 519.9 (116 acre-feet)

ELEVATION MAXIMUM DESIGN POOL: 521 MSL

ELEVATION TOP DAM: 519.9 msl

CREST: free overflow stoplog gated spillway

a. Elevation 519.9 MSL

b. Type stoplog and concrete weir

c. Width 10 feet

d. Length 1.5 feet

e. Location Spillover right center perpendicular to flow

f. Number and Type of Gates one gate consisting of four stoplogs

OUTLET WORKS: Emergency draindown, pipe only

a. Type

b. Location

c. Entrance Inverts

d. Exit Inverts

e. Emergency Draindown Facilities 6" C.I. not operated in 25 years

HYDROMETEORLOGICAL GAGES: none

a. Type

b. Location

c. Records

MAXIMUM NON-DAMAGING DISCHARGE: 18 cfs

APPENDIX 2

PHOTOGRAPHS

LAKE ARROWHEAD DAM

16 MAY 1979

VIEW FROM EAST END OF DAM LOOKING ALONG THE CREST OF THE DAM

16 MAY 1979

VIEW FROM EAST END OF DAM LOOKING EAST ALONG THE SHORE

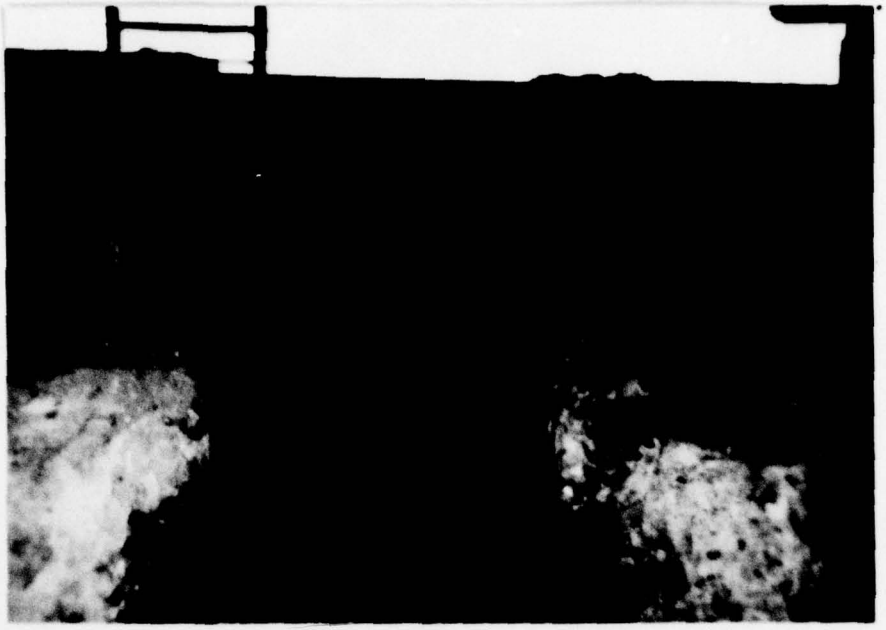
LAKE ARROWHEAD DAM

16 MAY 1979

CONCRETE SLAB BUILT OUT FROM UPSTREAM FACE OF DAM NEAR CLUB-HOUSE. VIEW IS LOOKING NORTHWEST.

16 MAY 1979

SPILLWAY STRUCTURE OF LAKE ARROWHEAD DAM



16 MAY 1979

STOPLOGS IN SPILLWAY STRUCTURE

16 MAY 1979

SPILLWAY STRUCTURE SHOWING DRAWDOWN PIPE

16 MAY 1979

OUTLET OF LAKE ARROWHEAD. VIEW FROM MOSSWOOD TRAIL LOOKING NORTH.

16 MAY 1979

DOWNSTREAM FACE OF DAM VIEW IS LOOKING NORTHWEST ALONG MOSSWOOD TRAIL. NOTE GUARDRAIL INDICATING OUTLET.

16 MAY 1979

DOWNSTREAM FACE OF DAM VIEW IS FROM CENTER OF DAM LOOKING TOWARD LEFT ABUTMENT.

16 MAY 1979

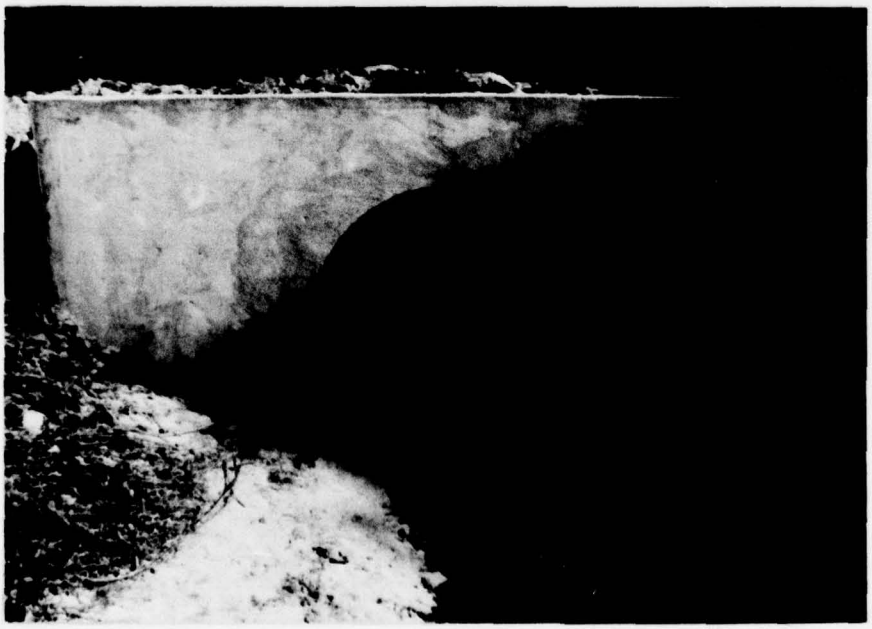
VIEW SHOWING DOWNSTREAM FACE OF DAM AND RESTAURANT DOWNSTREAM ON MOSSWOOD TRAIL. VIEW IS LOOKING NORTHWEST TOWARD SPILLWAY OUTLET.

16 MAY 1979

VIEW OF TWO 24" PIPES FOR FLOW UNDER MOSSWOOD TRAIL IMMEDIATELY DOWNSTREAM OF OUTLET STRUCTURE. NOTE RIGHT PIPE BLOCKED WITH DEBRIS.

16 MAY 1979

VIEW DOWNSTREAM FROM SPILLWAY VIEW IS LOOKING SOUTHWEST



16 MAY 1979

OUTLET OF PRINICPAL SPILLWAY CONDUIT

LAKE ARROWHEAD DAM

16 MAY 1979

HIGH WATER MARK ON FENCE DOWNSTREAM FROM JANUARY 1979
(UNRELATED TO DAM DISCHARGE).

16 MAY 1979

OUTLET CHANNEL FROM PRINCIPAL SPILLWAY CONDUIT TO DEN BROOK

APPENDIX 3

HYDROLOGIC COMPUTATIONS

LAKE ARROWHEAD DAM

Anderson-Nichols & Company, Inc.

JOB NO. 3290-02

Subject H&H

LAKE ARROWHEAD DAM

Sheet No. 1 of 18
Date 1/79
Computed KJS
Checked ELJ

SQUARES 1/4 " SCALE

HYDROLOGIC COMPUTATIONS

NAME: LAKE ARROWHEAD DAM

LOCATION: MORRIS COUNTY, NJ

DRAINAGE AREA: 0.22 SQUARE MILES

SURFACE AREA AT NORMAL POOL: 19.2 ACRES

EVALUATION CRITERIA: SIZE: SMALL
HAZARD: SIGNIFICANT

SPILLWAY DESIGN FLOOD: BASED ON SIZE AND HAZARD CLASSIFICATION THE SPILLWAY DESIGN FLOOD WILL BE ½ THE PMF (PROBABLE MAXIMUM FLOOD) WITH A PEAK INFLOW OF 808 CFS.

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Anderson-Nichols & Company, Inc.

Subject H&H

JOB NO. 3290-02

LAKE ARROWHEAD DAM

Sheet No. 2 of 18
Date 10/19
Computed KVS
Checked FDD

SQUARES 1/4 IN. SCALE 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

DETERMINATION OF TIME OF CONCENTRATION

OVERLAND FLOW : FARTHEST POINT TO END RESERVOIR : 1900 FT.

ELEVATION DIFFERENCE : 593.0 - 519.0 : 74.0 = Δ

T_C FOR OVERLAND FLOW

① BY KIRPICH NOMOGRAPH = 9.0 MINUTES

② BY IZZARD'S FORMULA

$$T_C = \frac{(L)^{1.115}\,ft}{7700\,H^{.38}} = \frac{1900^{1.115}}{7700\,(74)^{.38}} = 0.115 \text{ HRS.} = 6.9 \text{ MINUTES}$$

WHERE L = LENGTH OF OVERLAND FLOW
H = ELEV. DIFFERENCE

③ BY EQUATION - CALIFORNIA CULVERT ⑥

$$T_C = \left(\frac{11.9\,L^3\,mi}{H\,FT}\right)^{.385} = \left(\frac{(11.9)(.360)^3}{74}\right)^{.385} = 0.152 = 9.12 \text{ MINUTES}$$

④ BY WESTON FORMULA ⑦

SLOPE = $\frac{74}{1900}$ = 3.8% ∴ BY TEXAS HIGHWAY AVG. VEL = 3.0

$$T_C = \frac{L}{3600\,V} = \frac{1900}{3600(3)} = 5.6 \text{ min}$$

⑥ DESIGN OF SMALL DAMS P.71 ⑦ DESIGN OF SMALL DAMS P70 TEXAS HIGHWAY

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SQUARES 1/4 IN. SCALE

DETERMINATION OF THE TIME OF CONCENTRATION (CONT)

T_c = AVG. OF ABOVE = 7.7 MINUTES = 0.13 HRS

DETERMINE TIME OF PEAK

$$T_p = \frac{D}{2} + 0.6\,T_c$$

WHERE D = 5 MIN = 0.08HR

$$\therefore T_p = \frac{.08}{2} + 0.6\,(0.13) = 0.12 \text{ HR.}$$

USE: T_p = 0.17 HR

UNIT HYDROGRAPH

TAKE q_p FROM SCS FORMULA

$$q_p = \frac{256\,A}{T_p} = \frac{256\,(0.22)}{0.17} = 331 \text{ cfs}$$

A CURVILINEAR HYDROGRAPH MAY BE CONSTRUCTED FOR THE VALUES OF q_p & T_p BY USING SCS RATIO'S

(8) FROM MEMO 29 MAY 79 FROM L. LIPSKI, CHIEF, HYDROLOGY - HYDRAULICS BR. NCD

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SQUARES 1/4 IN. SCALE

UNIT HYDROGRAPH (CONT.)

HOURS T	T/T_P	q/q_P	UNIT HYDROGRAPH q
0	0	0	0
0.08	0.47	0.470	156
0.17	1.00	1.000	331
0.25	1.47	0.935	310
0.33	1.94	0.780	258
0.42	2.47	0.565	187
0.50	2.94	0.390	129
0.58	3.41	0.280	93
0.67	3.94	0.195	65
0.75	4.41	0.142	47
0.83	4.88	0.102	34
0.92	5.41	0.083	28
1.00	5.88	0.053	18
1.08	6.35	0.039	13
1.17	6.88	0.028	9
1.25	7.35	0.020	7
1.33	7.82	0.017	6
1.42	8.35	0.012	4
1.50	8.82	0.009	3
1.58	9.29	0.005	2
1.67	9.82	0.002	1
1.75	10.29	0.001	0
1.83	10.76	0.0	0

$$(q_T)(\text{DURATION})(3600)\left(\frac{1}{(\text{SQ MI})^2(DA)}\right)(12) = \text{INCHES UNDER HYDROGRAPH}$$

$$(1683)(0.0833)(3600)\left(\frac{1}{(5.29)^2(.22)}\right)(12) = .987"$$

Anderson-Nichols & Company, Inc. Subject H&H

JOB NO. 3290-02 LAKE ARROWHEAD DAM

Sheet No. 5 of 18
Date 6/79
Computed KJS
Checked

SQUARES 1/4 IN. SCALE 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

ACREAGE OF LAKE AT VARIOUS ELEVATIONS ①

ELEVATION	P_R	SQ IN	ACRES	COMMENTS
M.S. 519	41.74	83.48	19.2	
520	43.65	87.30	20.0	
522	48.00	96.00	22.0	
524	55.44	110.88	25.5	INCLUDES COOPER LAKE
526	72.17	144.34	33.2	INCLUDES COOPER LAKE

STORAGE ELEVATION DETERMINATIONS ①

ELEVATION FT.	SURFACE AREA ACRES	DEPTH FT	AVG. SEC. AREA ACRES	INCREM. STORAGE ACRE-FT	CUMULATIVE STOR ACRE FT
519	19.2	5	19.2	96	96
520	20.0	6	19.6	20	116
522	22.0	8	21.0	42	158
524	25.5	10	23.8	48	206
526	33.2	12	29.4	59	265

① MAP FROM ROBINSON AERIAL SURVEYS, 1"=100', C.I.=2', NEWTON, NJ

ANDERSON-NICHOLS & COMPANY

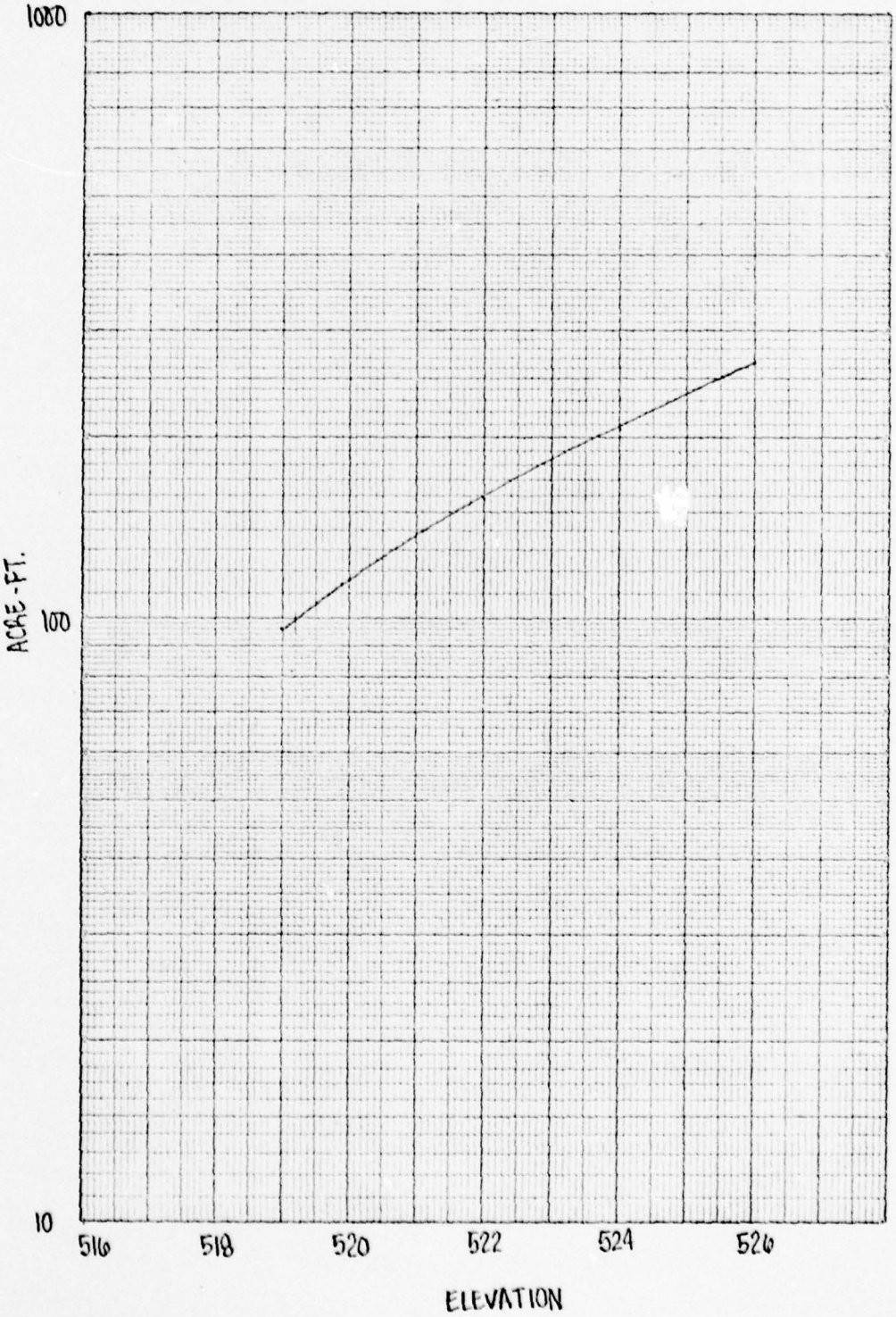
COMPUTED KJS

CHECKED FDD

LAKE ARROWHEAD DAM 6/18

STORAGE-ELEVATION CURVE

JOB NO. 3290-02



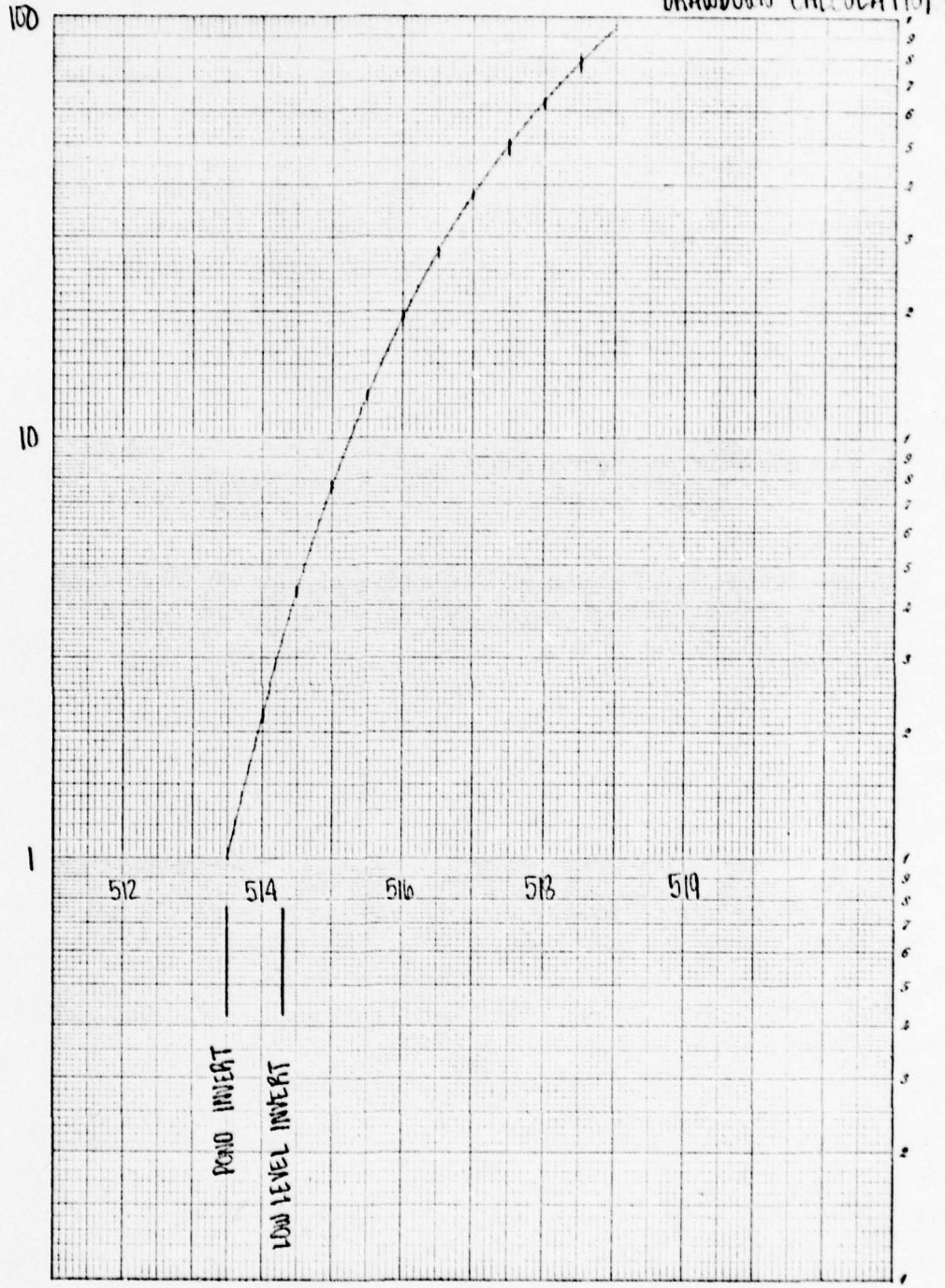
NO. 31.193-R 20 DIVISIONS PER INCH (120 DIVISIONS) BY TWO 4½-INCH CYCLES RATIO RULING. IN STOCK DIRECT FROM CODES BOOK CO., NORWOOD, MASS. 02062
PRINTED IN U.S.A.
CODES GRAPH PAPER

ANDERSON-NICHOLS & COMPANY

COMPUTED MJS
CHECKED FDD

LAKE ARROWHEAD DAM
STORAGE-ELEVATION CURVE EXTENSION FOR DRAWDOWN CALCULATION

7/18



NO. 3115-R. 20 DIVISIONS PER INCH (120 DIVISIONS) BY 2-INCH CYCLES RATIO RULING. IN STOCK DIRECT FROM CODEX BOOK CO. NORWOOD, MASS. 02062
GRAPH PAPER
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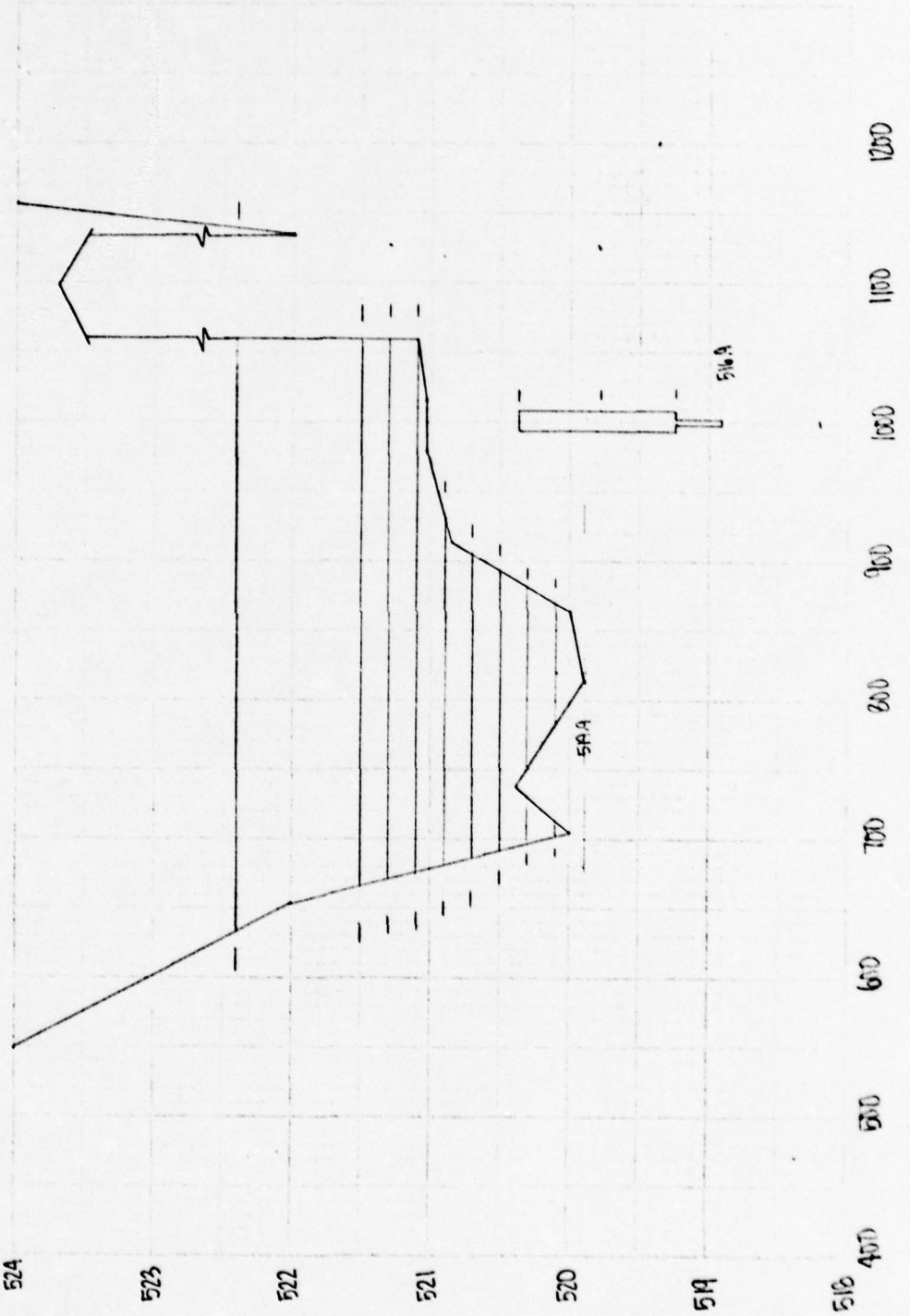
ANDERSON-NICHOLS & COMPANY

COMPUTED: WJS

CHECKED: FDD

LAKE ARROWHEAD DAM
OUTLET WIER
JOB NO. 3290-02

8/18



ANDERSON-NICHOLS & COMPANY
COMPUTED KJS
CHECKED FDD

LAKE ARROWHEAD DAM
OUTLET STRUCTURE
JOB NO. 2210-02

7.3

Anderson-Nichols & Company, Inc.

JOB NO. 3290-02

Subject H&H

LAKE ARROWHEAD

Sheet No. 10 of 18
Date 6/13
Computed KVS
Checked EDR

SQUARES 1/4 IN. SCALE 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

DEVELOPMENT OF RATING CURVE

① SPILLWAY CURVE

A. COMPUTE Q USING WEIR EQUATION ($Q = CLH^{3/2}$) TO CONCRETE SLAB THEN PRESSURE FLOW EQUATION ($Q = CA\sqrt{2gH}$).

B. "C" VALUES FOR WEIR = 3.0 , ORIFICE = 0.88

② TOP OF DAM

A. COMPUTE Q USING WEIR EQUATION ($Q = CLH^{3/2}$)

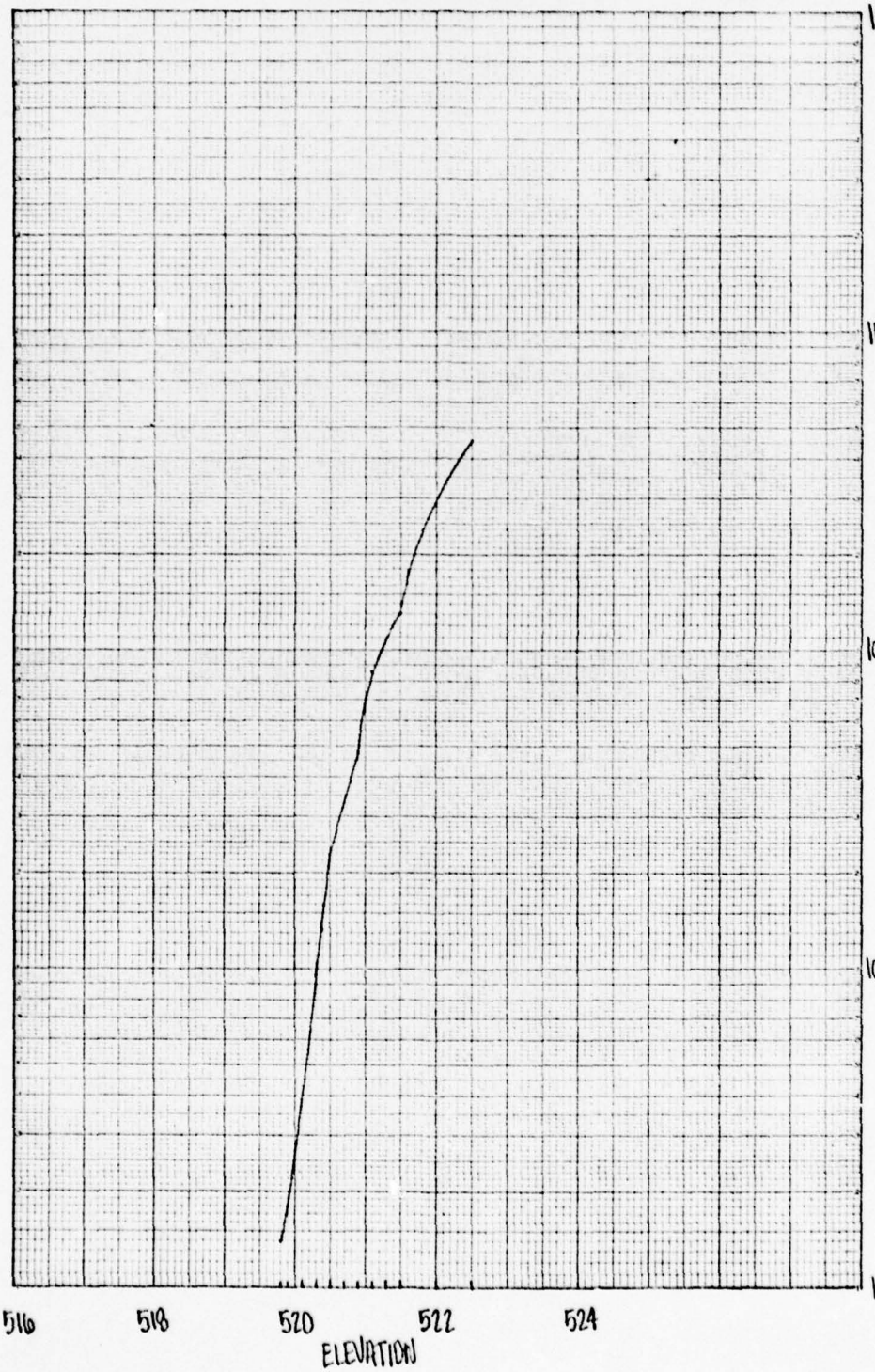
B. LENGTH OF WEIR VARIES WITH ELEVATION

ELEVATION (FT)	SPILLWAY		TOP OF DAM			TOTAL Q (CFS)
	H	Q	H	L	Q	
519.2	0	–				0
519.8	.6	14				14
519.9	.7	18				18
520.1	.9	26	.2	47.5	13	39
520.3	1.1	35	.4	80	61	96
520.5	.7*	65	.6	100	139	204
520.7	.9	74	.8	110	236	310
520.9	1.1	81	1.0	125	375	456
521.1	1.3	89	1.2	190	749	838
521.3	1.5	95	1.4	195	969	1064
521.5	1.7	101	1.6	195	1183	1284
522.0	2.2	115	2.1	300	2739	2854
522.5	2.7	128	2.6	300	4402	4530

*Orifice flow begins A = 11.59 ft²

COMPUTED: KJS
CHECKED: FDD

LAKE AFTERBAY HEAD 11/18
RATING CURVE
JOB NO. 3290-02

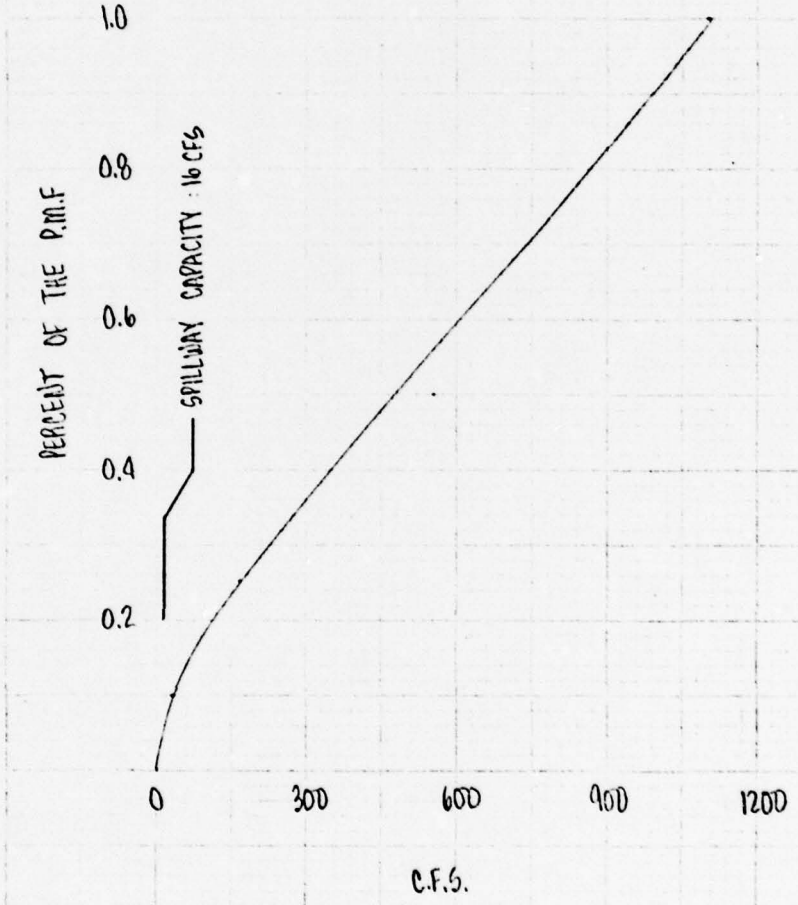


NO. 31.226. 20 DIVISIONS PER INCH (120 DIVISIONS) BY FOUR CYCLES RATIO RULING. KEUFFEL & ESSER CO. IN STOCK DIRECT FROM CODES BOOK CO., NORWOOD, MASS. 02062 GRAPH PAPER MADE IN U.S.A.

ANDERSON-NICHOLS & COMPANY

COMPUTED: HJS
CHECKED: FOD

LAKE ARROWHEAD DAM
OVERTOPPING POTENTIAL 12/3
JOB NO. 3270-02



SQUARES 1/4 "" SCALE

DETERMINATION OF "C" FOR BLOW-OFF PIPE

$D = 0.5'$ C.I. $D_1 = 6"$ C.I.

$N = 0.015$ ("SOIL & WATER CONSERVATION ENGINEERING" p 632)

$A_p = 28.3$ SQ. IN. (AREA OF PIPE OPENING) $= 0.20$ SQ. FT.

$L_p = 30$ FT.

K_F = FRICTION LOSS THROUGH PIPE

K_L = ENTRANCE LOSS OF PIPE = 0.8 (IBID p. 639)

C_p = COEFFICIENT OF DISCHARGE (INCORPORATES A_p & $2g$)

C = COEFFICIENT OF DISCHARGE

$$K_F = \frac{5087\, n^2}{D_1^{4/3}} = \frac{5087\,(.015)^2}{6^{1.333}} = \frac{1.14}{10.90} = 0.10$$

$$C_p = A_p \sqrt{\frac{2g}{1 + K_L + K_F L_p}}$$

$$= .20 \sqrt{\frac{64.4}{1 + .8 + (0.1)(30)}}$$

$C_p = 0.73$

$$\therefore C = \frac{.73}{.20} / \sqrt{64.4} \qquad C = 0.45$$

Anderson-Nichols & Company, Inc.

JOB NO. 3290-02

Subject H&H

LAKE ARROWHEAD DAM

Sheet No. 14 of 18
Date 7/74
Computed KJC
Checked EDS

SQUARES 1/4 "" SCALE 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

DRAWDOWN CALCULATIONS

CALCULATIONS ASSUME ① NO SIGNIFICANT INFLOW ② 6" CI LOW LEVEL OUTLET BE FULLY OPERABLE ③ ALL FLASHBOARDS REMOVED ④ $Q_p = C_p(H)^{1/2} = 0.73(H)^{1/2}$

⑤ AC./FT./DAY = 1.9835 · (AVG. Q) ⑥ DAYS = Δ STORAGE / AC. FT. DAY

ELEV. FT.	STORAGE AC./FT.	Δ STORAGE AC./FT.	H FT.	Q_p CFS	AVG. Q CFS	AC/FT. PER DAY	DAYS Δ STOR./AC.FT.DAY
516.9	36		2.6	1.18			
		8			1.13	2.24	3.57
516.5	28		2.2	1.08			
		9			1.02	2.02	4.46
516.0	19		1.7	0.95			
		6			0.88	1.75	3.43
515.5	13		1.2	0.80			
		5			0.71	1.41	3.55
515.0	8		0.7	0.61			
		4			0.47	0.93	4.30
514.5	4		0.2	0.33			
		2			0.17	0.34	11.76
514.3	0		0	0			

31.07 DAYS

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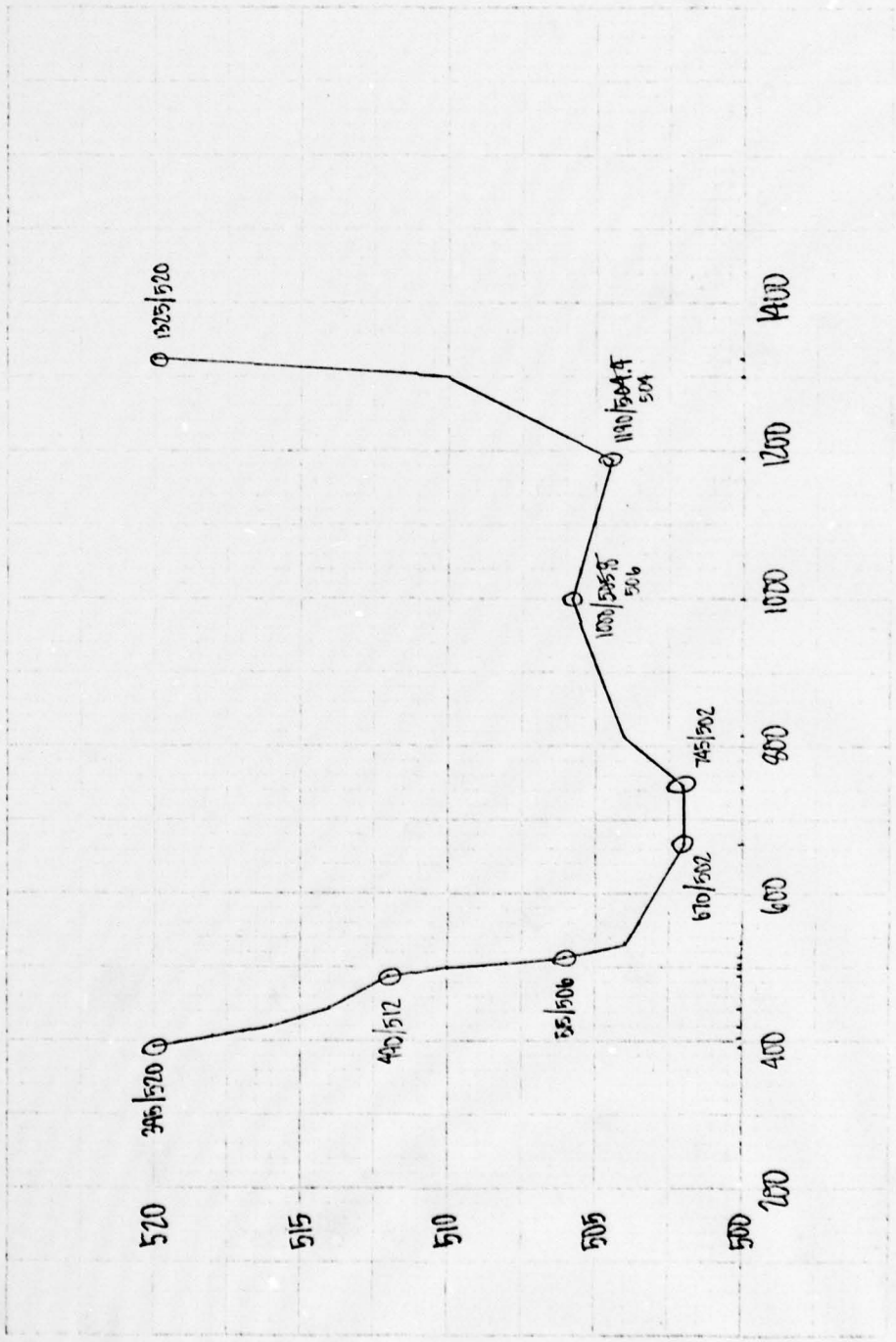
LAKE ARROWHEAD DAM 5/18
DOWNSTREAM CROSS-SECTION
JOB NO. 3220-02



ANDERSON-NICHOLS & COMPANY

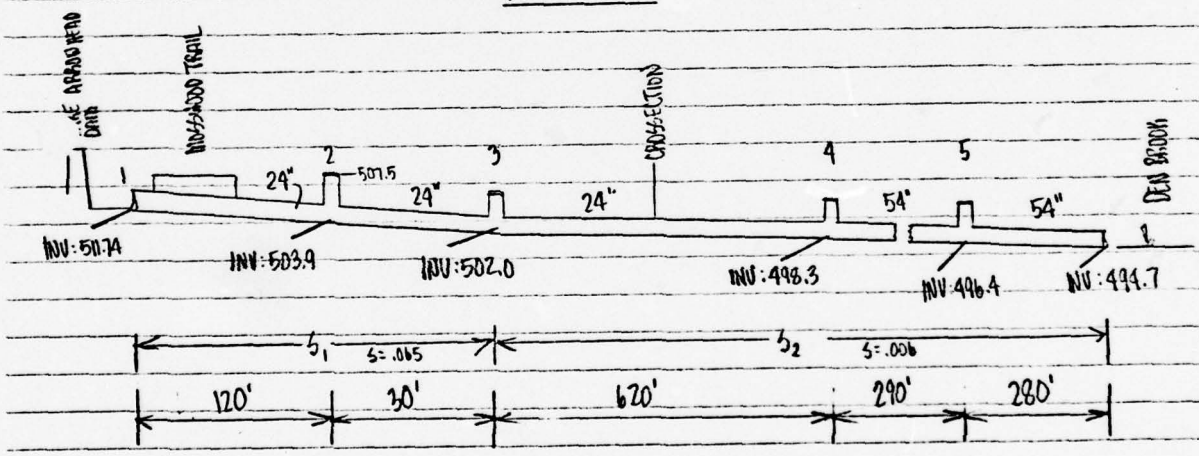
COMPUTED: KJS
CHECKED: FDD

LAKE ARROWHEAD DAM
JOB NO. 3270-02 Id/E
7/79

CULVERT SYSTEM DOWNSTREAM OF LAKE ARROWHEAD DAM

LAKE ARROWHEAD SPILLWAY DISCHARGES INTO A CULVERT SYSTEM WHICH CONSISTS OF VARIOUS LENGTHS OF CULVERT AND THREE CATCH BASINS. A PLAN VIEW OF THE SYSTEM IS SHOWN IN FIGURE 3. PIPE CAPACITIES WILL BE DETERMINED FOR THE SYSTEM UNDER ½ PMF CONDITIONS.

PIPE PROFILE



$L_1 = 120$ $L_2 = 30$ $L_3 = 620$ $L_4 = 570$

UNDER ½ PMF CONDITIONS

HW DEPTH FROM WIER SECTION ON MOSSWOOD TRAIL.

WIER LENGTH = 180' CREST = 518.0 C = 3.0

$Q = CLH^{3/2}$ $567 = (3)(180)(H)^{3/2}$ $\therefore H^{3/2} = \frac{567}{(3)(180)} = 1.05 \Rightarrow H = 1.01$ EL. = 519.01

ANDERSON-NICHOLS & COMPANY

COMPUTED: RJS
CHECKED: FCD

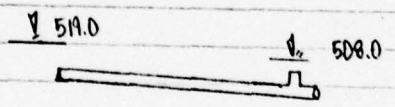
LAKE ARROWHEAD
JOB NO. 3230-02
7/79

UNDER ½ PMF CONDITIONS (CONT.)

HW	INLET HW	CB2 HW	CB3 HW	CB4 HW	OUTLET (DEN BROOK) HW
519.01	519.0	508.0	504.0	501.0	500.0

1) CAPACITY OF L_1

$L_1 = 120'$



$H = 519.0 - 508.0 = 11.0'$ $D = 24"$

CHART 7 HYDRAULIC CHARTS $Q = 29$ cfs

2) CAPACITY OF L_2

$L_2 = 30'$

$H = 508.0 - 504.0 = 4.0'$ $D = 24"$

$Q = 21$ cfs

3) CAPACITY OF L_3

H = 504.0 - 501.0 = 3.0' D = 24"

L_3 = 620'

Q = 20 cfs

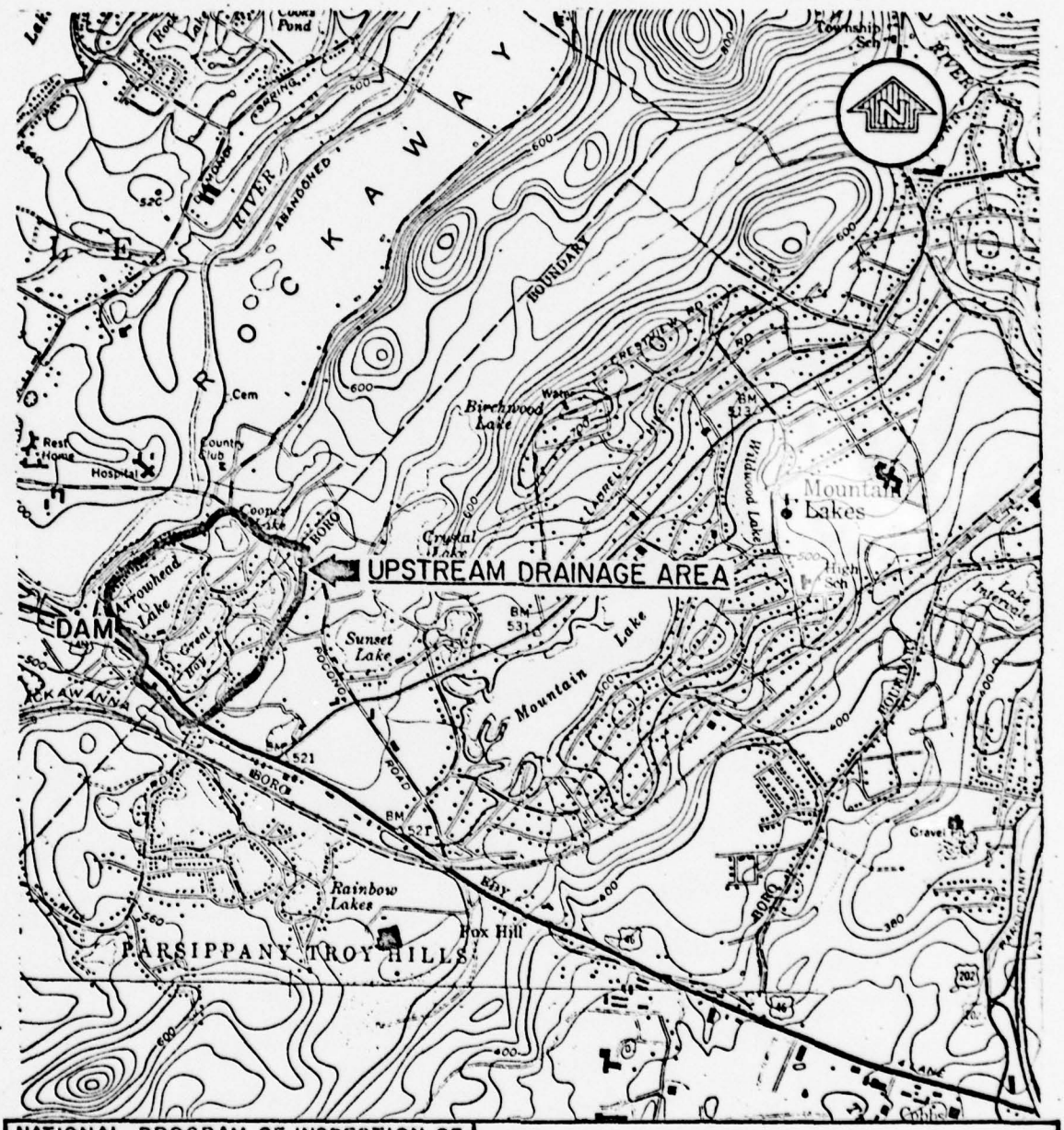
4) CAPACITY OF L_4

H = 501.0 - 500.0 = 1.0' D = 54"

L_4 = 570

Q = 122 cfs

CONCLUSION: UNDER ½ PMF CONDITIONS THE TOTAL OUTFLOW OF THE DAM IS 621 CFS OF WHICH THE 1ST CULVERT (L_1) CAN CARRY 29 CFS. THIS IS INADEQUATE AS THE CULVERT CAPACITY IS 5% OF THE PMF.



NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

LAKE ARROWHEAD DAM
DENVILLE TOWNSHIP, NEW JERSEY

REGIONAL VICINITY MAP

DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
PHILADELPHIA, PENNSYLVANIA

ANDERSON-NICHOLS & CO., INC. BOSTON, MA

SCALE IN MILES

0 1/2

MAP BASED ON U.S.G.S. 7.5 MINUTE QUADRANGLE SHEETS. BOONTON, N.J., 1954, UPDATED 1970. MORRISTOWN, N.J., 1954, UPDATED 1970.

HEC-1 OUTPUT

OVERTOPPING AND BREACH ANALYSIS

LAKE ARROWHEAD DAM

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HEC-1 FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION  JULY 1978
 LAST MODIFICATION  26 FEB 79
```

```
    1                A1 ARROWHEAD LAKE DAM BREACH ANALYSIS ****K.STUART****  ANDERSON-NICHOLS****
    2                A2 NEW JERSEY DAM NUMBER 25-53
    3                A3 0.2, 0.5, AND 1.0 MULTIPLES OF PMF FROM 6-HOUR 25.5 INCH PMP
    4                R    120       0       5       0       0       0       0       0       0       0
    5                P1     5
    6                J      2       3       1
    7                J1   0.1    0.25     0.5
    8                K      0       A1                              1
    9                K1 DEVELOP INFLOW HYDROGRAPH
   10                M             -1     .22                     .8                      1
   11                O     72                                                             1
   12                O1  .213    .213    .213    .213    .213    .213    .213    .213    .213    .213
   13                O1  .213    .213    .255    .255    .255    .255    .255    .255    .255    .255
   14                O1  .255    .255    .255    .255    .319    .319    .319    .319    .319    .319
   15                O1  .319    .319    .319    .319    .319    .319    .194    .388    .388    .581
   16                O1  .678   1.647   2.713   1.066    .678    .581    .388    .388    .298    .298
   17                O1  .298    .298    .298    .298    .298    .298    .298    .298    .298    .298
   18                O1  .234    .234    .234    .234    .234    .234    .234    .234    .234    .234
   19                O1  .234    .234
   20                T                                                      1      .1
   21                U     20
   22                U1  156.    331.    310.    258.    187.    129.     93.     65.     47.     34.
   23                U1   28.     18.     13.      9.      7.      6.      4.      3.      2.      1.
   24                X   -3.
   25                K      1       A2                              1
   26                K1 ROUTE HYDROGRAPH THROUGH IMPOUNDMENT
   27                Y                              1       1
   28                Y1     1                                               96      -1
   29                Y4 519.2    519.8   519.9   520.1   520.3   520.5   520.7   520.9   521.1   521.3
   30                Y4 521.5    522.0   522.5
   31                Y5    0.      14.     18.     39.     96.    204.    310.    456.    838.   1064.
   32                Y5 1284.    2854.   4530.
   33                $S    0.      96.    116.    158.    206.    265.
   34                $E 514.2    519.    520.    522.    524.    526.
   35                $$ 519.2
   36                $D 519.9
   37                $B    20       1     515      .5     519   519.9
   38                $B    10       1     515       1     519     525
   39                K      1       A3                              1       1
   40                K1 DAM BREACH ANALYSIS *MOD PULS METHOD*
   41                Y                              1       1
   42                Y1     1
   43                Y6   .04     .04     .04     502     520     580    .026
   44                Y7   395     520     400     512     515     506     670     502     745     502
   45                Y7  1000     506    1190     504    1325     520
   46                K     99
```

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PREVIEW OF SEQUENCE OF STREAM NETWORK CALCULATIONS

RUNOFF HYDROGRAPH A1	A1
ROUTE HYDROGRAPH TO	A2
ROUTE HYDROGRAPH TO	A3
END OF NETWORK	

ARROWHEAD LAKE DAM BREACH ANALYSIS ****K.STUART**** ANDERSON-NICHOLS****
NEW JERSEY DAM NUMBER 25-53
0.2, 0.5, AND 1.0 MULTIPLES OF PMF FROM 6-HOUR 25.5 INCH PPF

JOB SPECIFICATION

NQ	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
120	0	5	0	0	0	0	0	0	0

JOPER	NWT	LROPT	TRACE
5	0	0	0

MULTI-PLAN ANALYSES TO BE PERFORMED
NPLAN= 2 NRTIO= 3 LRTIO= 1

RTIOS= .10 .25 .50

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

SUB-AREA RUNOFF COMPUTATION

DEVELOP INFLOW HYDROGRAPH

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
A1	0	0	0	0	010000000		0	0

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
0	-1	.22	0.00	.22	.80	0.000		010000000	0

PRECIP DATA

NP	STORM	DAJ	DAK
72	0.00	0.00	0.00

PRECIP PATTERN

.21	.21	.21	.21	.21	.21	.21	.21	.21	.21
.21	.21	.26	.26	.26	.26	.26	.26	.26	.26
.26	.26	.26	.26	.32	.32	.32	.32	.32	.32
.32	.32	.32	.32	.32	.32	.19	.39	.39	.58
.68	1.65	2.71	1.07	.68	.58	.39	.39	.30	.30
.30	.30	.30	.30	.30	.30	.30	.30	.30	.30
.23	.23	.23	.23	.23	.23	.23	.23	.23	.23
.23	.23								

LOSS DATA

IPROPT	STRKP	DLTKP	RTIOL	ERAIN	STRKS	RTIOK	STRTL	CNSTL	ALSPX	RTIMP
0	0.00	0.00	1.00	0.00	0.00	1.00	1.00	.10	0.00	0.00

GIVEN UNIT GRAPH, NUHGG= 20

156.	331.	319.	258.	187.	132.	93.	65.	47.	34.

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2P. 1P. 13. 9. 7. 6. 4. 3. 2. 1.

UNIT GRAPH TOTALS 1701. CFS OR 1.00 INCHES OVER THE AREA

RECESSION DATA

STRTQ= -3.00 QRCSN= 0.00 RTIOR= 1.00

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	END-OF-PERIOD FLOW COMP Q	MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.05	1	.17	0.00	.17	1.	1.01	5.05	61	.19	.18	.01	395.
1.01	.10	2	.17	0.00	.17	1.	1.01	5.10	62	.19	.18	.01	373.
1.01	.15	3	.17	0.00	.17	1.	1.01	5.15	63	.19	.18	.01	354.
1.01	.20	4	.17	0.00	.17	1.	1.01	5.20	64	.19	.18	.01	339.
1.01	.25	5	.17	0.00	.17	1.	1.01	5.25	65	.19	.18	.01	329.
1.01	.30	6	.17	.02	.15	4.	1.01	5.30	66	.19	.18	.01	322.
1.01	.35	7	.17	.16	.01	33.	1.01	5.35	67	.19	.18	.01	317.
1.01	.40	8	.17	.16	.01	86.	1.01	5.40	68	.19	.18	.01	314.
1.01	.45	9	.17	.16	.01	135.	1.01	5.45	69	.19	.18	.01	311.
1.01	.50	10	.17	.16	.01	176.	1.01	5.50	70	.19	.18	.01	310.
1.01	.55	11	.17	.16	.01	205.	1.01	5.55	71	.19	.18	.01	308.
1.01	1.00	12	.17	.16	.01	225.	1.01	6.00	72	.19	.18	.01	307.
1.01	1.05	13	.20	.20	.01	245.	1.01	6.05	73	0.00	0.00	0.00	279.
1.01	1.10	14	.20	.20	.01	266.	1.01	6.10	74	0.00	0.00	0.00	219.
1.01	1.15	15	.20	.20	.01	284.	1.01	6.15	75	0.00	0.00	0.00	163.
1.01	1.20	16	.20	.20	.01	298.	1.01	6.20	76	0.00	0.00	0.00	117.
1.01	1.25	17	.20	.20	.01	308.	1.01	6.25	77	0.00	0.00	0.00	83.
1.01	1.30	18	.20	.20	.01	315.	1.01	6.30	78	0.00	0.00	0.00	60.
1.01	1.35	19	.20	.20	.01	321.	1.01	6.35	79	0.00	0.00	0.00	43.
1.01	1.40	20	.20	.20	.01	324.	1.01	6.40	80	0.00	0.00	0.00	31.
1.01	1.45	21	.20	.20	.01	327.	1.01	6.45	81	0.00	0.00	0.00	23.
1.01	1.50	22	.20	.20	.01	329.	1.01	6.50	82	0.00	0.00	0.00	17.
1.01	1.55	23	.20	.20	.01	330.	1.01	6.55	83	0.00	0.00	0.00	12.
1.01	2.00	24	.20	.20	.01	332.	1.01	7.00	84	0.00	0.00	0.00	9.
1.01	2.05	25	.26	.25	.01	340.	1.01	7.05	85	0.00	0.00	0.00	6.
1.01	2.10	26	.26	.25	.01	358.	1.01	7.10	86	0.00	0.00	0.00	5.
1.01	2.15	27	.26	.25	.01	374.	1.01	7.15	87	0.00	0.00	0.00	4.
1.01	2.20	28	.26	.25	.01	387.	1.01	7.20	88	0.00	0.00	0.00	2.
1.01	2.25	29	.26	.25	.01	397.	1.01	7.25	89	0.00	0.00	0.00	2.
1.01	2.30	30	.26	.25	.01	404.	1.01	7.30	90	0.00	0.00	0.00	1.
1.01	2.35	31	.26	.25	.01	408.	1.01	7.35	91	0.00	0.00	0.00	1.
1.01	2.40	32	.26	.25	.01	412.	1.01	7.40	92	0.00	0.00	0.00	1.
1.01	2.45	33	.26	.25	.01	414.	1.01	7.45	93	0.00	0.00	0.00	1.
1.01	2.50	34	.26	.25	.01	416.	1.01	7.50	94	0.00	0.00	0.00	1.
1.01	2.55	35	.26	.25	.01	417.	1.01	7.55	95	0.00	0.00	0.00	1.
1.01	3.00	36	.26	.25	.01	418.	1.01	8.00	96	0.00	0.00	0.00	1.
1.01	3.05	37	.16	.15	.01	403.	1.01	8.05	97	0.00	0.00	0.00	1.
1.01	3.10	38	.31	.30	.01	395.	1.01	8.10	98	0.00	0.00	0.00	1.
1.01	3.15	39	.31	.30	.01	416.	1.01	8.15	99	0.00	0.00	0.00	1.
1.01	3.20	40	.46	.46	.01	462.	1.01	8.20	100	0.00	0.00	0.00	1.
1.01	3.25	41	.54	.53	.01	547.	1.01	8.25	101	0.00	0.00	0.00	1.
1.01	3.30	42	1.32	1.31	.01	750.	1.01	8.30	102	0.00	0.00	0.00	1.
1.01	3.35	43	2.17	2.16	.01	1222.	1.01	8.35	103	0.00	0.00	0.00	1.
1.01	3.40	44	.85	.84	.01	1596.	1.01	8.40	104	0.00	0.00	0.00	1.
1.01	3.45	45	.54	.53	.01	1616.	1.01	8.45	105	0.00	0.00	0.00	1.
1.01	3.50	46	.46	.46	.01	1496.	1.01	8.50	106	0.00	0.00	0.00	1.
1.01	3.55	47	.31	.30	.01	1279.	1.01	8.55	107	0.00	0.00	0.00	1.
1.01	4.00	48	.31	.30	.01	1074.	1.01	9.00	108	0.00	0.00	0.00	1.
1.01	4.05	49	.24	.23	.01	907.	1.01	9.05	109	0.00	0.00	0.00	1.
1.01	4.10	50	.24	.23	.01	766.	1.01	9.10	110	0.00	0.00	0.00	1.
1.01	4.15	51	.24	.23	.01	647.	1.01	9.15	111	0.00	0.00	0.00	1.

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1.01	4.20	52	.24	.23	.01	590.	1.01	9.20	112	0.00	0.00	0.00		1.
1.01	4.25	53	.24	.23	.01	538.	1.01	9.25	113	0.00	0.00	0.00		1.
1.01	4.30	54	.24	.23	.01	495.	1.01	9.30	114	0.00	0.00	0.00		1.
1.01	4.35	55	.24	.23	.01	466.	1.01	9.35	115	0.00	0.00	0.00		1.
1.01	4.40	56	.24	.23	.01	446.	1.01	9.40	116	0.00	0.00	0.00		1.
1.01	4.45	57	.24	.23	.01	432.	1.01	9.45	117	0.00	0.00	0.00		1.
1.01	4.50	58	.24	.23	.01	423.	1.01	9.50	118	0.00	0.00	0.00		1.
1.01	4.55	59	.24	.23	.01	414.	1.01	9.55	119	0.00	0.00	0.00		1.
1.01	5.00	60	.24	.23	.01	408.	1.01	10.00	120	0.00	0.00	0.00		1.
									SUM	20.41	18.86	1.55		32180.
										(519.)(	479.)(	39.)(		911.24)

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	1616.	444.	268.	268.	32165.
CMS	46.	13.	8.	8.	911.
INCHES		18.79	18.89	18.89	18.89
MM		477.16	479.79	479.79	479.79
AC-FT		220.	222.	222.	222.
THOUS CU M		272.	273.	273.	273.

HYDROGRAPH AT STA A1 FOR PLAN 1, RTIO 3

0.	0.	0.	0.	0.	2.	16.	43.	68.	88.
102.	112.	122.	133.	142.	149.	154.	158.	160.	162.
163.	164.	165.	166.	170.	179.	187.	194.	198.	202.
204.	206.	207.	208.	209.	209.	202.	197.	208.	231.
274.	379.	611.	790.	808.	743.	639.	537.	454.	383.
331.	295.	269.	248.	233.	223.	216.	211.	207.	204.
197.	186.	177.	170.	164.	161.	159.	157.	156.	155.
154.	154.	139.	109.	82.	58.	42.	30.	22.	16.
12.	8.	6.	4.	3.	2.	2.	1.	1.	1.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	808.	222.	134.	134.	16083.
CMS	23.	6.	4.	4.	455.
INCHES		9.39	9.44	9.44	9.44
MM		238.58	239.90	239.90	239.90
AC-FT		110.	111.	111.	111.
THOUS CU M		136.	137.	137.	137.

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HYDROGRAPH ROUTING

ROUTE HYDROGRAPH THROUGH IMPOUNDMENT

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
A2	1	0	0	0	010000000	0	0	

ALL PLANS HAVE SAME ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP	LSTR
0.0	0.000	0.00	1	1	0	0	0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	0.000	0.000	0.000	96.	-1

STAGE	519.20	519.80	519.90	520.10	520.30	520.50	520.70	520.90	521.10	521.30
	521.50	522.00	522.50							
FLOW	0.00	14.00	18.00	39.00	96.00	204.00	310.00	456.00	838.00	1064.00
	1204.00	2054.00	4530.00							

CAPACITY=	0.	96.	116.	158.	204.	265.
ELEVATION=	514.	519.	520.	522.	524.	526.

CREL	SPWID	COOW	EXPW	FLEVL	COOL	CAREA	EXPL
519.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DAM DATA

TOPEL	COOD	EXPD	DAMWID
519.9	0.0	0.0	0.

DAM BREACH DATA

BRWID	Z	ELBM	TFAIL	WSEL	FAILEL
20.	1.00	515.00	.50	519.00	519.90

•OVN•

STATION A2, PLAN 1, RATIO 3

BEGIN DAM FAILURE AT 2.33 HOURS

END-OF-PERIOD HYDROGRAPH ORDINATES

OUTFLOW

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	1.	3.	4.	5.	6.	7.
9.	10.	11.	12.	14.	16.	18.	24.	85.	185.
308.	445.	594.	752.	702.	658.	618.	585.	555.	530.
502.	476.	496.	511.	533.	551.	562.	564.	559.	548.
534.	517.	500.	482.	465.	448.	432.	417.	403.	390.
378.	366.	354.	342.	331.	321.	311.	302.	293.	285.
276.	271.	263.	256.	247.	237.	227.	217.	207.	197.
188.	179.	171.	163.	156.	149.	142.	136.	130.	124.
119.	114.	110.	105.	101.	97.	93.	90.	87.	83.
80.	77.	75.	72.	70.	67.	65.	63.	61.	59.
57.	55.	53.	52.	50.	49.	47.	46.	44.	43.

STORAGE

96.	96.	96.	96.	96.	96.	96.	96.	96.	97.	97.
98.	99.	99.	100.	101.	102.	103.	104.	105.	106.	106.
107.	109.	110.	111.	112.	113.	114.	115.	116.	117.	117.
116.	115.	113.	110.	106.	103.	100.	97.	95.	92.	92.
91.	89.	89.	91.	93.	94.	95.	95.	95.	94.	94.
93.	91.	90.	88.	87.	85.	83.	82.	81.	79.	79.
78.	77.	76.	74.	73.	72.	71.	70.	69.	68.	68.
67.	66.	66.	65.	64.	62.	61.	60.	59.	58.	57.
56.	55.	54.	53.	51.	50.	49.	49.	48.	47.	47.
46.	45.	44.	44.	43.	42.	42.	41.	40.	40.	40.
39.	39.	38.	38.	37.	37.	36.	36.	35.	35.	35.
35.	34.	34.	33.	33.	33.	32.	32.	32.	31.	31.

STAGE

519.0	519.0	519.0	519.0	519.0	519.0	519.0	519.0	519.0	519.0	519.1
519.1	519.1	519.2	519.2	519.3	519.3	519.4	519.4	519.5	519.5	519.5
519.6	519.6	519.7	519.7	519.8	519.8	519.9	520.0	520.0	520.0	520.0
520.0	520.0	519.8	519.7	519.6	519.3	519.2	519.1	518.9	518.8	518.8
518.7	518.7	518.7	518.7	518.8	518.9	519.0	519.0	518.9	518.9	518.9
518.8	518.8	518.7	518.6	518.5	518.4	518.4	518.3	518.2	518.2	518.2
518.1	518.0	518.0	517.9	517.9	517.8	517.7	517.7	517.6	517.6	517.6
517.6	517.5	517.5	517.3	517.4	517.3	517.3	517.2	517.1	517.1	517.1
517.0	516.9	516.9	516.8	516.8	516.7	516.7	516.6	516.6	516.5	516.5
516.5	516.5	516.4	516.4	516.3	516.3	516.3	516.2	516.2	516.2	516.2
516.2	516.1	516.1	516.1	516.1	516.0	516.0	516.0	516.0	515.9	515.9
515.9	515.9	515.9	515.9	515.9	515.8	515.8	515.8	515.8	515.8	515.8

PEAK OUTFLOW IS 752. AT TIME 2.83 HOURS

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	752.	735.	212.	212.	25460.
CMS	21.	21.	6.	6.	721.
INCHES		9.	14.99	14.99	14.99
MM		14.10	379.77	379.77	379.77
AC-FT		360.28	175.	175.	175.
THOUS CU M		166.	216.	216.	216.
		205.			

THE DAM BREACH HYDROGRAPH WAS DEVELOPED USING A TIME INTERVAL OF .010 HOURS DURING BREACH FORMATION. DOWNSTREAM CALCULATIONS WILL USE A TIME INTERVAL OF .083 HOURS. THIS TABLE COMPARES THE HYDROGRAPH FOR DOWNSTREAM CALCULATIONS WITH THE COMPUTED BREACH HYDROGRAPH. INTERMEDIATE FLOWS ARE INTERPOLATED FROM END-OF-PERIOD VALUES.

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TIME (HOURS)	TIME FROM BEGINNING OF BREACH (HOURS)	INTERPOLATED BREACH HYDROGRAPH (CFS)	-	COMPUTED BREACH HYDROGRAPH (CFS)	=	ERROR (CFS)	ACCUMULATED ERROR (CFS)	ACCUMULATED ERROR (AC-FT)
2.333	0.000	24.		24.		0.	0.	0.
2.344	.010	32.		28.		4.	4.	0.
2.354	.021	40.		34.		6.	9.	0.
2.365	.031	47.		41.		7.	16.	0.
2.375	.042	55.		48.		7.	23.	0.
2.385	.052	62.		56.		6.	29.	0.
2.396	.063	70.		65.		5.	33.	0.
2.406	.073	78.		75.		3.	36.	0.
2.417	.083	85.		85.		0.	36.	0.
2.427	.094	90.		96.		2.	38.	0.
2.438	.104	110.		107.		3.	41.	0.
2.448	.115	123.		119.		3.	44.	0.
2.458	.125	135.		131.		4.	48.	0.
2.469	.135	148.		144.		3.	51.	0.
2.479	.146	160.		157.		3.	53.	0.
2.490	.156	172.		171.		1.	55.	0.
2.500	.167	185.		185.		0.	55.	0.
2.510	.177	200.		199.		1.	56.	0.
2.521	.188	216.		214.		2.	58.	0.
2.531	.198	231.		229.		2.	60.	0.
2.542	.208	246.		244.		2.	62.	0.
2.552	.219	262.		260.		2.	65.	0.
2.563	.229	277.		276.		2.	66.	0.
2.573	.240	293.		292.		1.	67.	0.
2.583	.250	308.		308.		0.	67.	0.
2.594	.260	325.		325.		1.	68.	0.
2.604	.271	342.		341.		1.	69.	0.
2.615	.281	360.		358.		1.	70.	0.
2.625	.292	377.		375.		1.	71.	0.
2.635	.302	394.		393.		1.	72.	0.
2.646	.313	411.		410.		1.	73.	0.
2.656	.323	428.		428.		1.	74.	0.
2.667	.333	445.		445.		0.	74.	0.
2.677	.344	464.		463.		1.	75.	0.
2.688	.354	483.		481.		1.	76.	0.
2.698	.365	501.		499.		2.	78.	0.
2.708	.375	520.		517.		2.	80.	0.
2.719	.385	538.		536.		2.	82.	0.
2.729	.396	557.		555.		2.	84.	0.
2.740	.406	575.		574.		1.	85.	0.
2.750	.417	594.		594.		-0.	85.	0.
2.760	.427	614.		613.		0.	85.	0.
2.771	.437	633.		633.		1.	86.	0.
2.781	.448	653.		652.		1.	87.	0.
2.792	.458	673.		672.		1.	87.	0.
2.802	.469	693.		692.		1.	88.	0.
2.813	.479	713.		712.		0.	88.	0.
2.823	.490	733.		732.		0.	89.	0.
2.833	.500	752.		752.		0.	89.	0.

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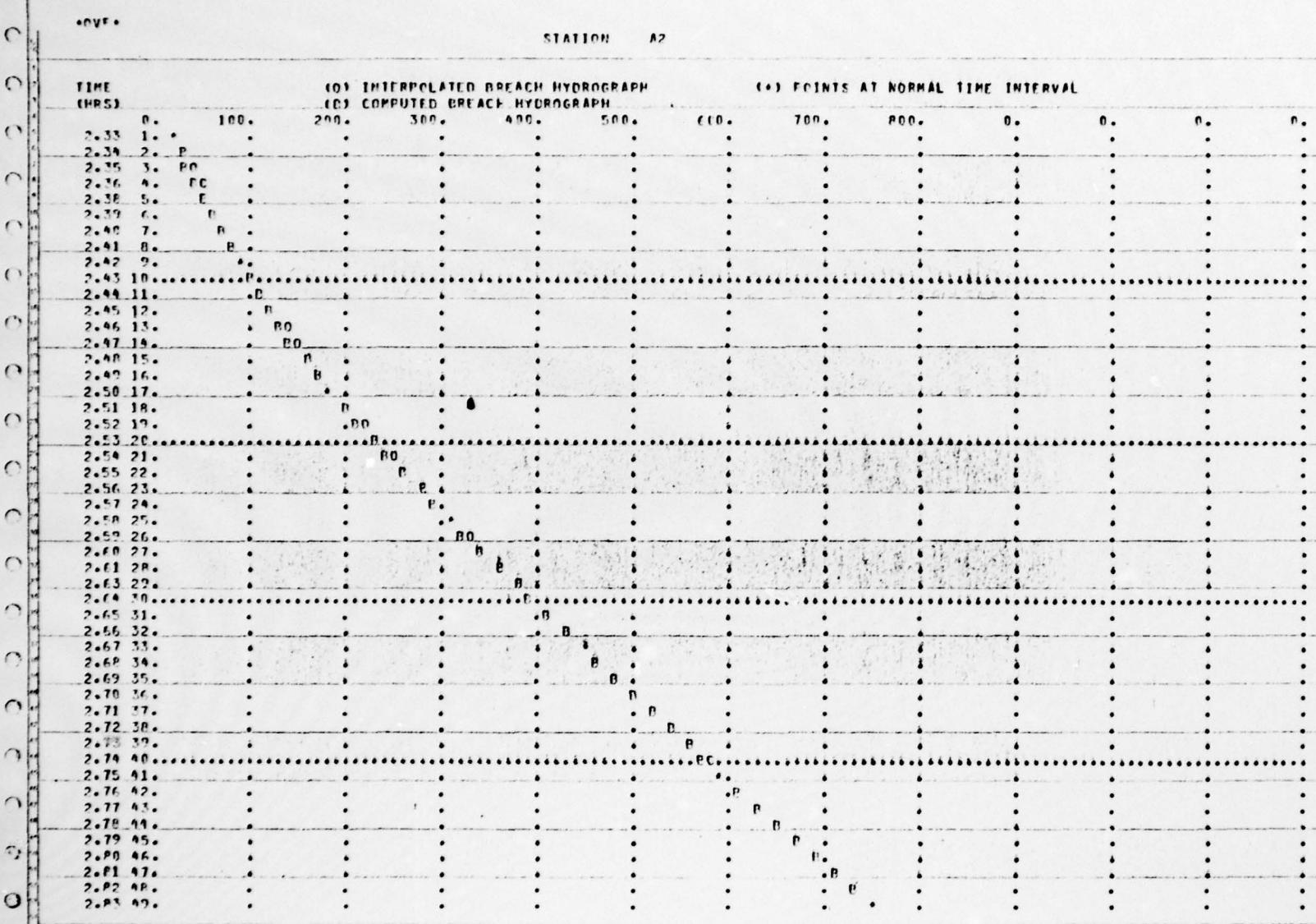
STATION A2



DAM BREACH DATA

PRVID	Z	ELDP	TFAIL	WSEL	FAILEL
10.	1.00	515.00	1.00	519.00	525.00

STATION A2, PLAN 2, RATIO 3

END-OF-PERIOD HYDROGRAPH ORDINATES

OUTFLOW

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	1.	3.	4.	5.	6.	7.
9.	10.	11.	12.	14.	16.	18.	24.	30.	35.
44.	59.	72.	84.	95.	112.	127.	139.	149.	161.
176.	200.	247.	324.	426.	556.	621.	605.	553.	499.
443.	415.	387.	360.	335.	312.	297.	284.	272.	262.
252.	242.	233.	223.	214.	206.	199.	192.	186.	181.
177.	173.	169.	162.	151.	139.	124.	109.	96.	89.
82.	76.	70.	64.	59.	54.	49.	45.	41.	38.
37.	36.	35.	34.	32.	31.	30.	29.	28.	27.
26.	26.	25.	24.	23.	22.	21.	21.	20.	19.
19.	18.	18.	18.	17.	17.	17.	17.	16.	16.

STORAGE

96.	96.	96.	96.	96.	96.	96.	96.	97.	97.
98.	99.	99.	100.	101.	102.	103.	104.	105.	106.
107.	109.	110.	111.	112.	113.	114.	115.	116.	117.
118.	120.	121.	121.	122.	123.	124.	124.	124.	125.
125.	126.	128.	131.	134.	136.	137.	137.	136.	135.
135.	134.	133.	132.	131.	131.	130.	130.	129.	129.
128.	128.	128.	127.	127.	127.	126.	126.	126.	126.
125.	125.	125.	125.	124.	124.	123.	123.	122.	122.
121.	121.	120.	120.	120.	119.	119.	119.	118.	118.
118.	117.	117.	117.	117.	117.	116.	116.	116.	116.
116.	115.	115.	115.	115.	115.	115.	115.	114.	114.
114.	114.	114.	114.	114.	114.	113.	113.	113.	113.

STAGE

519.0	519.0	519.0	519.0	519.0	519.0	519.0	519.0	519.0	519.1
519.1	519.1	519.2	519.2	519.3	519.3	519.4	519.4	519.5	519.5
519.6	519.6	519.7	519.7	519.8	519.8	519.9	520.0	520.0	520.1
520.1	520.2	520.2	520.3	520.3	520.3	520.4	520.4	520.4	520.4
520.4	520.5	520.6	520.7	520.9	521.0	521.0	521.0	521.0	520.9
520.9	520.8	520.8	520.8	520.7	520.7	520.7	520.7	520.6	520.6
520.6	520.6	520.6	520.5	520.5	520.5	520.5	520.5	520.5	520.5
520.4	520.4	520.4	520.4	520.4	520.4	520.4	520.3	520.3	520.3
520.3	520.2	520.2	520.2	520.2	520.2	520.1	520.1	520.1	520.1
520.1	520.1	520.1	520.0	520.0	520.0	520.0	520.0	520.0	520.0
520.0	520.0	520.0	520.0	519.9	519.9	519.9	519.9	519.9	519.9
519.9	519.9	519.9	519.9	519.9	519.9	519.9	519.9	519.9	519.9

PEAK OUTFLOW IS 621. AT TIME 3.92 HOURS

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	621.	182.	117.	117.	17617.
CMS	18.	5.	3.	3.	499.
INCHES		7.68	8.00	8.00	8.00
MM		195.12	203.12	203.12	203.12
AC-FT		90.	58.	58.	58.
THOUS CU M		111.	110.	110.	110.

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HYDROGRAPH ROUTING

DAM BREACH ANALYSIS •MOD PULS METHOD•

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
A3	1	0	0	0	1	1	0	0

ALL PLANS HAVE SAME ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP	LSTR
0.0	0.000	0.00	1	1	0	0	0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	0.000	0.000	0.000	0.	0

NORMAL DEPTH CHANNEL ROUTING

QN(1)	QN(2)	QN(3)	ELNVT	ELMAX	RLNTH	SEL
.0400	.0400	.0400	5020.0	520.0	3804.	.02603

STATION A3, PLAN 1, RTIO 3

OUTFLOW

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	1.	2.	3.	5.	6.	7.
8.	10.	11.	12.	13.	15.	17.	22.	64.	156.
273.	407.	554.	735.	723.	657.	628.	588.	561.	535.
515.	499.	495.	506.	527.	547.	561.	564.	560.	550.
537.	522.	504.	487.	470.	453.	437.	421.	407.	394.
381.	369.	357.	345.	339.	324.	314.	305.	296.	287.
280.	272.	265.	258.	249.	240.	230.	220.	210.	200.
191.	182.	177.	165.	158.	151.	144.	138.	132.	126.
121.	116.	111.	106.	102.	98.	94.	91.	87.	84.
81.	78.	75.	73.	70.	68.	66.	63.	61.	59.
57.	56.	54.	52.	51.	49.	48.	46.	45.	44.

STOR

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

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STAGE

502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0
502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0
502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.1	502.3
502.5	502.7	503.0	503.1	503.0	503.0	503.0	503.0	503.0	502.9
502.9	502.9	502.9	502.9	502.9	502.9	503.0	503.0	503.0	503.0
502.9	502.9	502.9	502.8	502.8	502.8	502.8	502.7	502.7	502.7
502.7	502.6	502.6	502.6	502.6	502.6	502.5	502.5	502.5	502.5
502.5	502.5	502.5	502.4	502.4	502.4	502.4	502.4	502.4	502.3
502.3	502.3	502.3	502.3	502.3	502.3	502.3	502.2	502.2	502.2
502.2	502.2	502.2	502.2	502.2	502.2	502.2	502.2	502.2	502.1
502.1	502.1	502.1	502.1	502.1	502.1	502.1	502.1	502.1	502.1
502.1	502.1	502.1	502.1	502.1	502.1	502.1	502.1	502.1	502.1

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	735.	335.	212.	212.	25448.
CMS	21.	9.	6.	6.	721.
INCHES		14.18	14.94	14.94	14.94
MM		360.22	379.60	379.60	379.60
AC-FT		166.	175.	175.	175.
THOUS CU M		205.	216.	216.	216.

MAXIMUM STORAGE = 1.

MAXIMUM STAGE IS 503.1

STATION A3. PLAN 2. RTIO 3

OUTFLOW

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	1.	2.	3.	5.	6.	7.
8.	10.	11.	12.	13.	15.	17.	22.	28.	34.
42.	54.	68.	81.	92.	107.	124.	136.	147.	158.
171.	193.	233.	301.	397.	519.	620.	609.	563.	505.
454.	422.	395.	367.	341.	318.	301.	288.	275.	264.
255.	245.	236.	226.	217.	208.	201.	194.	188.	183.
178.	174.	170.	164.	154.	142.	128.	113.	100.	90.
84.	78.	72.	66.	60.	55.	50.	46.	42.	39.
37.	36.	35.	34.	33.	32.	31.	30.	29.	28.
27.	26.	25.	24.	23.	22.	22.	21.	20.	19.
19.	18.	18.	18.	17.	17.	17.	17.	16.	16.

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STOR

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

STAGE

502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0
502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0
502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.1
502.1	502.1	502.1	502.1	502.2	502.2	502.2	502.2	502.3	502.3
502.3	502.3	502.4	502.5	502.7	502.9	503.0	503.0	503.0	502.9
502.8	502.7	502.7	502.6	502.6	502.6	502.5	502.5	502.5	502.5
502.4	502.4	502.4	502.4	502.4	502.4	502.3	502.3	502.3	502.3
502.3	502.3	502.3	502.3	502.3	502.2	502.2	502.2	502.2	502.2
502.1	502.1	502.1	502.1	502.1	502.1	502.1	502.1	502.1	502.1
502.1	502.1	502.1	502.1	502.1	502.1	502.1	502.1	502.0	502.0
502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0
502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0	502.0

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	620.	182.	113.	113.	13613.
CMS	18.	5.	3.	3.	385.
INCHES		7.68	7.99	7.99	7.99
MM		195.19	203.06	203.06	203.06
AC-FT		90.	94.	94.	94.
THOUS CU M		111.	116.	116.	116.

MAXIMUM STORAGE = 1.

MAXIMUM STAGE IS 503.0

***

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

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS RATIO 1 .10	RATIO 2 .25	RATIO 3 .50
HYDROGRAPH AT	A1	.22	1	162.	404.	808.
		(.57)		(4.58)(	11.44)(	22.88)(
			2	162.	404.	808.
				(4.58)(	11.44)(	22.88)(
ROUTED TO	A2	.22	1	661.	799.	752.
		(.57)		(18.73)(	22.62)(	21.31)(
			2	19.	190.	621.
				(.55)(	5.39)(	17.57)(
ROUTED TO	A3	.22	1	637.	779.	735.
		(.57)		(18.02)(	22.06)(	20.81)(
			2	19.	190.	620.
				(.55)(	5.37)(	17.56)(

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SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ..... INITIAL VALUE SPILLWAY CREST TOP OF DAM

ELEVATION	519.00	519.20	519.90
STORAGE	96.	100.	114.
OUTFLOW	0.	0.	18.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.10	519.90	.00	114.	661.	.17	6.42	5.92
.25	520.03	.13	117.	739.	.55	3.92	3.42
.50	520.03	.13	117.	752.	.46	2.83	2.33

PLAN 2 ..... INITIAL VALUE SPILLWAY CREST TOP OF DAM

ELEVATION	519.00	519.20	519.90
STORAGE	96.	100.	114.
OUTFLOW	0.	0.	18.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.10	519.91	.01	114.	196.	.75	6.17	0.00
.25	520.47	.57	126.	190.	5.58	4.17	0.00
.50	520.99	1.09	137.	621.	7.00	3.92	0.00

PLAN 1 STATION A3

RATIO	MAXIMUM FLOW,CFS	MAXIMUM STAGE,FT	TIME HOURS
.10	637.	503.0	6.42
.25	779.	503.1	3.92
.50	735.	503.1	2.83

PLAN 2 STATION A3

RATIO	MAXIMUM FLOW,CFS	MAXIMUM STAGE,FT	TIME HOURS
.10	19.	502.0	6.25
.25	190.	502.3	4.17
.50	620.	503.0	3.92

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APPENDIX 4

REFERENCES

LAKE ARROWHEAD DAM

APPENDIX 4

REFERENCES

LAKE ARROWHEAD DAM

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