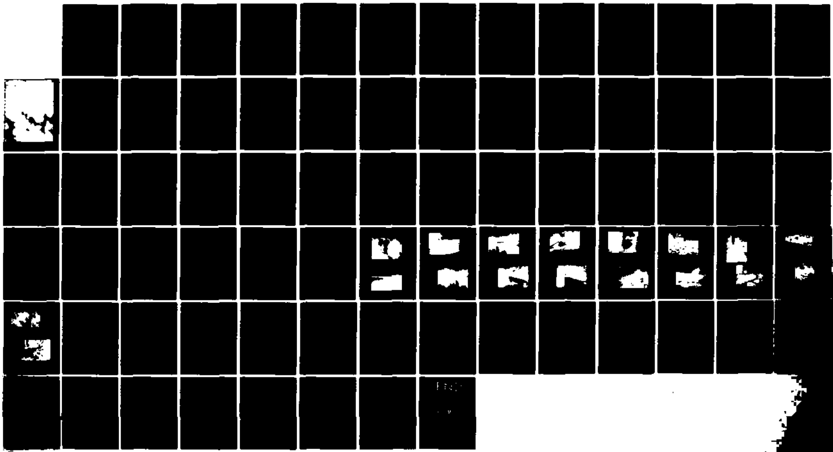
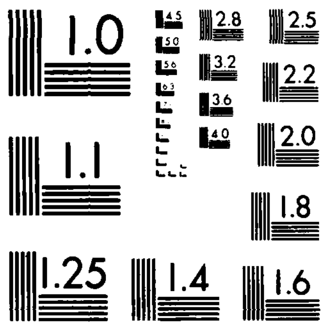
AD-A156 452 NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS CRYSTAL LAKE DAM (NH. (U) CORPS OF ENGINEERS WALTHAM MA NEW ENGLAND DIV NOV 78 1/1

UNCLASSIFIED F/G 13/13 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

CONNECTICUT RIVER BASIN

ENFIELD, NEW HAMPSHIRE

CRYSTAL LAKE DAM

NH 00269

NHWRB NO. 77.01

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS. 02154

NOVEMBER 1978

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NH 00269	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Crystal Lake Dam NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS		5. TYPE OF REPORT & PERIOD COVERED INSPECTION REPORT
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) U.S. ARMY CORPS OF ENGINEERS NEW ENGLAND DIVISION		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS DEPT. OF THE ARMY, CORPS OF ENGINEERS NEW ENGLAND DIVISION, NEDED 424 TRAPELO ROAD, WALTHAM, MA. 02254		12. REPORT DATE November 1978
		13. NUMBER OF PAGES 52
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)

APPROVAL FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

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

18. SUPPLEMENTARY NOTES

Cover program reads: Phase I Inspection Report, National Dam Inspection Program; however, the official title of the program is: National Program for Inspection of Non-Federal Dams; use cover date for date of report.

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

DAMS, INSPECTION, DAM SAFETY,

Connecticut River Basin
Enfield, New Hampshire
Crystal Lake Brook

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

The dam is a 170 ft. long, 22 ft. high dam consisting of stone, earth and concrete. THe inspection did not disclose any findings that indicate an immediate unsafe condition. The general condition of the dam is good. The dam's spillway will not pass the required test flood. Many overhanging trees and two debris dams were noted in the downstream channel.

DISCLAIMER NOTICE

CRYSTAL LAKE DAM

NH 00269

NHWRB 77.01

CONNECTICUT RIVER BASIN
ENFIELD, NEW HAMPSHIRE

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

LETTER OF TRANSMITTAL

FROM THE CORPS OF ENGINEERS TO THE STATE

TO BE SUPPLIED BY THE CORPS OF ENGINEERS

NATIONAL DAM INSPECTION PROGRAM
PHASE I - INSPECTION REPORT
BRIEF ASSESSMENT

Identification No.: 00269

Name of Dam: Crystal Lake Dam

Town: Enfield

County and State: Grafton, New Hampshire

Stream: Crystal Lake Brook

Date of Inspection: September 1, 1978

Crystal Lake Dam is a 170 foot long, 22 foot high dam consisting of stone, earth and concrete. Engineering data available consisted of two sets of plans dated 1918 and 1943 both showing plan and elevation of the dam and details of additions and improvements made at those times. No construction specifications or design calculations were available.

The visual inspection of Crystal Lake Dam did not disclose any findings that indicate an immediate unsafe condition. The genenal condition of the dam is good. The inspection revealed trees growing on the downstream face of the dam and two small cracks in the upper section of the dam's upstream reinforced concrete retaining wall. Also scoured concrete walls and an area of leakage at the outlet works discharge channel were observed. Many overhanging trees and two debris dams were noted in the downstream channel.

Crystal Lake Dam's spillway will not pass the required test flood. The dam's spillway capacity is approximately 36 percent of the test flood and consequently, the dam would be overtopped by approximately 2.7 feet under test flood conditions.

It is recommended that the owner engage a qualified engineer to evaluate further the potential for overtopping and the inadequacy of the spillway. Also, provisions should be made by the owner to repair the area of leakage at the interface of the spillway and the outlet works structure, to remove all trees growing on the downstream face of the dam and to remove all obstructions in the downstream channel.

The recommendations and remedial measures are described in Section 7 and should be accomplihsed by the owner within two years after receipt of this Phase I - Inspection Report.

Gordon H. Slaney, Jr., P.E.
Project Engineer

Howard, Needles, Tammen & Bergendoff
Boston, Massachusetts

This Phase I Inspection Report on   Dam has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the <u>Recommended Guidelines for Safety Inspection of Dams</u>, and with good engineering judgment and practice, and is hereby submitted for approval.

CHARLES G. TIERSCH, Chairman
Chief, Foundation and Materials Branch
Engineering Division

FRED J. RAVENS, Jr., Member
Chief, Design Branch
Engineering Division

SAUL COOPER, Member
Chief, Water Control Branch
Engineering Division

APPROVAL RECOMMENDED:

JOE B. FRYAR
Chief, Engineering Division

THIS SHEET TO BE FURNISHED BY THE CORPS OF ENGINEERS

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. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there by any chance that unsafe conditions be detected.

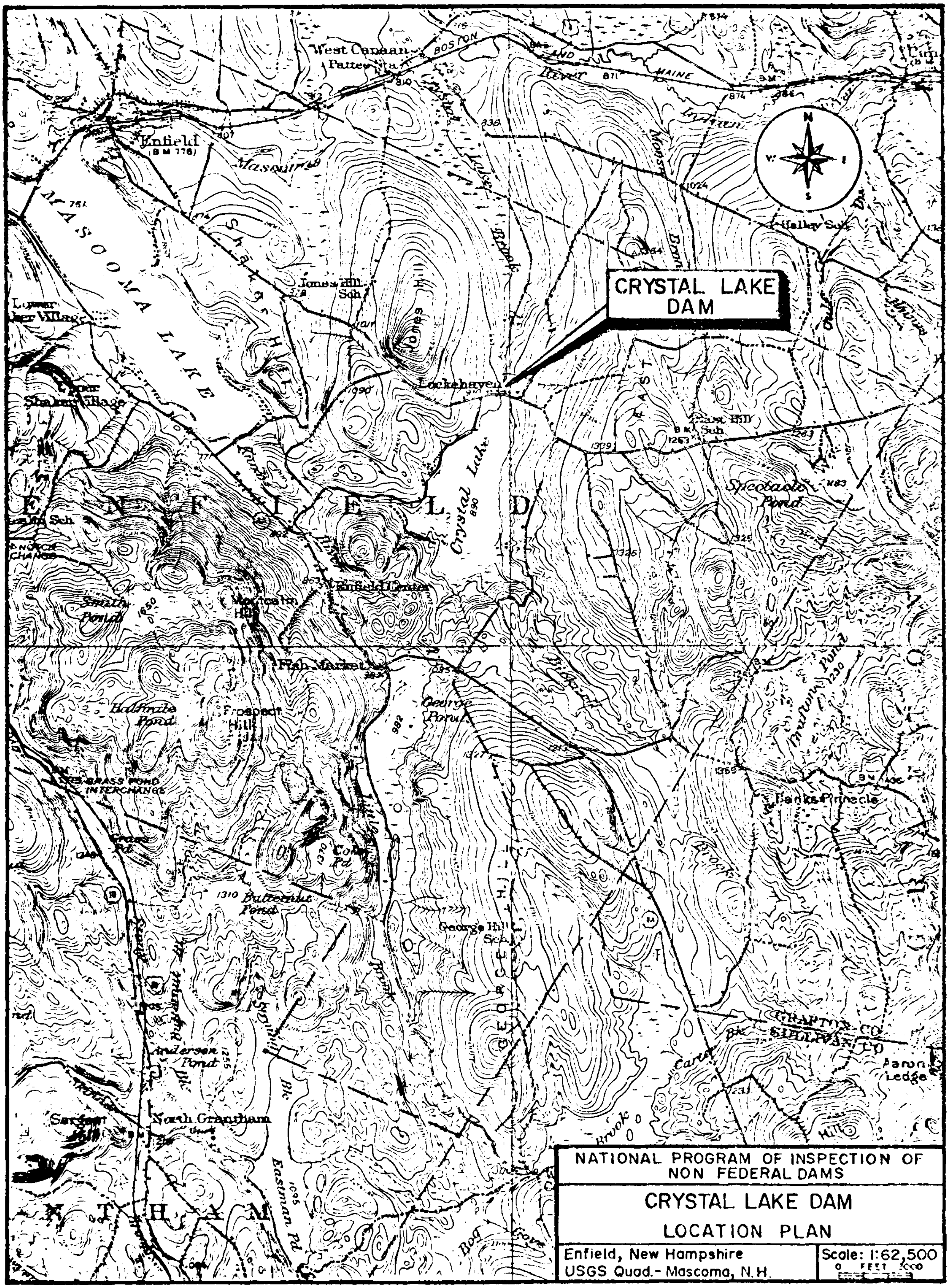
Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test Flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aide 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.

TABLE OF CONTENTS

REPORT

APPENDIXES

CRYSTAL LAKE DAM - Overview Looking Downstream



NATIONAL PROGRAM OF INSPECTION OF NON FEDERAL DAMS

CRYSTAL LAKE DAM

LOCATION PLAN

Enfield, New Hampshire
USGS Quad.- Mascoma, N.H.

Scale: 1:62,500

NATIONAL DAM INSPECTION PROGRAM
PHASE I INSPECTION REPORT
CRYSTAL LAKE DAM

SECTION 1
PROJECT INFORMATION

1.1 General

a. Authority. Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a National Program of Dam Inspection throughout the United States. Tne New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. Howard, Needles, Tammen & Bergendoff has been retained by the New England Division to inspect and report on selected dams in the State of New Hampshire. Authorization and notice to proceed were issued to Howard, Needles, Tammen & Bergendoff under a letter of July 12, 1978 from John P. Chandler, Colonel, Corps of Engineers. Contract No. DACW33-78-C-0356 has been assigned by the Corps of Engineers for this work.

b. Purpose

(1) To perform technical inspection and evaluation of non-Federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-Federal interests.

(2) To encourage and prepare the states to initiate quickly effective dam safety program for non-Federal dams.

(3) To update, verify and complete the National Inventory of Dams.

1.2 Description of Project

a. Location. Crystal Lake Dam is located in the Town of Enfield, New Hampshire, approximately 6 miles downstream from the headwaters of Bicknell Brook. Below Crystal Lake Dam, the brook known as Crystal Lake Brook, flows in a generally northerly direction for a distance of approximately 3 miles to its confluence with Mascoma River in Canaan, New Hampshire. The dam is shown on U.S.G.S. Quadrangle, Mascoma, New Hampshire-Vermont, with coordinates approximately

N 43°36'40", W 72°05'00", Grafton County, New Hampshire. Crystal Lake Dam's location is shown on the Location Map immediately preceding page 1-1.

b. Description of Dam and Appurtenant Structures. Crystal Lake Dam is a composite structure consisting of earth fill, stone and concrete. The structure is approximately 170 feet in length. The maximum structural height of the dam, according to existing plans, is about 22 feet from the base to the top of the concrete wall. The original dam consisted of an upstream and downstream rock wall, approximately 21 feet apart, with cobble and earth fill placed between the walls. In approximately 1919 the upstream rock wall was replaced with a reinforced concrete retaining wall which, in 1943, was increased in height to its present elevation.

The appurtenant structures consist of a stone masonry spillway section approximately 50 feet wide and 5.5 feet high, a spillway channel and outlet works consisting of a mechanically operated 4 foot by 4 foot wooden gate and an outlet channel made of large cut rock slabs.

Figure 1, located in Appendix B, shows the plan of the dam, spillway and outlet works. Photographs of each structure are shown in Appendix C.

c. Size Classification. Intermediate (hydraulic height - 22 feet, storage - 4,840 acre-feet) based on storage (≥1,000 to 50,000 acre-feet) as given in Recommended Guidelines for Safety Inspection of Dams.

d. Hazard Classification. The dam's potential for damage rates it as a significant hazard classification. A major breach could result in damage to several homes in the West Canaan and Enfield areas and the loss of a few lives.

e. Ownership. This dam is owned by the State of New Hampshire Water Resources Board.

f. Operator. This dam is maintained and operated by the State of New Hampshire Water Resources Board, 37 Pleasant Street, Concord, New Hampshire 03301. Chairman of the Water Resources Board is Mr. George M. McGee, Sr.; Mr. Vernon Knowlton is Chief Engineer. Telephone No. (603)271-1110.

g. Purpose of Dam. The purpose of this dam is primarily to provide a recreational lake with some flood control benefits which are described in Section 4, Operational Procedures.

h. Design and Construction History. Little information is available regarding the original design and construction of

Crystal Lake Dam. Two sets of drawings (2 sheets each) were prepared by the Mascoma River Improvement Co., one in 1918, the second in 1943. The 1918 plans were prepared for the replacement of the upstream rock wall with a reinforced concrete retaining wall. The 1943 drawings were prepared for raising the upstream retaining wall to its present elevation.

The drawings for this dam are available at the New Hampshire Water Resources Board. No in-depth design or construction data were disclosed for this dam.

i. Normal Operational Procedure. Crystal Lake Dam is used primarily for the retention of Crystal Lake which is used for recreational purposes. A secondary purpose of the dam and its resulting reservoir area is for control of winter and early spring runoff. The normal operational procedure for this dam is to lower the reservoir level in the month of October or November of each year. The resultant available storage is used to control snow melt and heavy runoff during the winter and spring months. In May of each year, the reservoir is returned to its summertime recreational level.

1.3 Pertinent Data

a. Drainage Area. The drainage area above the Crystal Lake Dam consists of approximately 13 square miles of rolling, heavily wooded hills. The periphery of Crystal Lake is comprised of wooded area with some residences located near the reservoir.

The reservoir area itself contains no islands and is devoid of dead trees protruding through the surface or other visible impediments to navigation. There were some private docks or piers noted along the area inspected.

The watershed supporting Crystal Lake is forested rolling terrain with few flat areas. All areas in the basin are well vegetated with manmade imperviousness being limited to a few paved roads and housing. Topographic elevation in the watershed ranges from about 2,020 to 890 feet MSL.

The major tributary draining into Crystal Lake is Bicknell Brook which is approximately 5 miles long with a vertical drop over its length of about 500 feet.

b. Discharge at Dam Site

(1) The outlet works for Crystal Lake consist of a spillway section and an outlet structure consisting of a mechanically

operated, 4 foot by 4 foot wooden gate and an outlet channel constructed of large cut rock slabs. The reservoir behind the dam can be lowered approximately 8 feet from the spillway crest elevation (892.0) by opening the outlet gate. This lowers the reservoir to within approximately 3 feet of the original river bed elevation of 880.5.

(2) The maximum discharge at this dam site is unknown.

(3) The spillway capacity with a water surface at the top of the dam (elevation 897.5) is approximately 1,950 cfs.

(4) The spillway capacity with the water surface at the test flood elevation is approximately 3,500 cfs at an elevation of approximately 900.2.

(5) The total project discharge at the test flood elevation of 900.2 is estimated to be 5,400 cfs.

c. <u>Elevation</u> (feet above MSL) based on elevation of 892 for the spillway crest as obtained from existing data.

(1) Streambed at centerline of dam - 880.5.

(2) Maximum tailwater - unknown.

(3) Upstream portal invert diversion tunnel - none.

(4) Recreation pool - 892.0.

(5) Full flood control pool - 884 (see Section 1.2.i).

(6) Spillway crest - 892.0.

(7) Design surcharge - unknown.

(8) Top dam - 897.5.

(9) Test flood surcharge - 900.2.

d. <u>Reservoir</u> (miles)

(1) Length of maximum pool - 1.50.

(2) Length of recreational pool - 1.50.

(3) Length of flood control pool - 1.45.

e. <u>Storage</u> (Acre-Feet)

(1) Recreation pool - 2,720.

(2) Flood control pool - 1,300.

(3) Spillway crest pool - 2,720.

(4) Top of dam - 4,840.

f. Reservoir Surface (acres)

(1) Recreation pool - 378.

(2) Flood control pool - 340.

(3) Spillway crest - 372.

(4) Test flood pool - 388. Note: Vertical sides assumed.

(5) Top dam - 388.

g. Dam

(1) Type - stone, earth, concrete.

(2) Length - 170 feet, overall.

(3) Height - 22 feet (maximum).

(4) Top width - 10" wall, 21 foot earth fill section.

(5) Side slopes - US = vertical; DS = variable.

(6) Zoning - unknown.

(7) Impervious core - concrete retaining wall.

(8) Cutoff - concrete wall.

(9) Grout curtain - none.

(10) Other - none.

h. Diversion and Regulating Tunnel

See Section j below.

i. Spillway

(1) Type - broad crested - vertical drop spillway.

(2) Length of weir - 50 feet.

(3) Crest elevation - 892.0.

(4) Gates - none.

(5) Upstream channel - none.

(6) Downstream channel - the downstream channel is a boulder strewn stream bed with many small diameter trees on each bank. Approximately 300 feet downstream from the dam, the channel has a debris dam consisting of washed down trees and branches.

j. Regulatory Outlets. The regulating outlet consists of a wooden, mechanically operated, control gate having an effective opening of 4.0 feet by 4.0 feet. The invert of the gate opening (884.0) is such that the water level of Crystal Lake may be lowered 8 feet from its spillway crest elevation (892.0) which is about 3 feet above the original channel bed.

SECTION 2
ENGINEERING DATA

2.1 Design

No original design data were disclosed for Crystal Lake. Two sets of drawings (2 sheets each) dated 1919 and 1943 showing additions and improvements made to the existing dam were the only design information found. Both sets of plans were prepared by the Mascoma River Improvement Company.

2.2 Construction

No construction records were available for use in evaluating the dam.

2.3 Operation

No engineering operational data were disclosed.

2.4 Evaluation

a. Availability. Engineering data available for Crystal Lake Dam is limited to the two sets of plans mentioned above. These plans are on file at the New Hampshire Water Resources Board.

b. Adequacy. Available engineering data, which when combined with visual inspection are considered adequate for a Phase I investigation.

c. Validity. The field investigation indicated that the external features of Crystal Lake Dam substantially agree with those shown on the available plans.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. General. The field inspection of Crystal Lake Dam was made on September 1, 1978. The inspection team consisted of personnel from Howard, Needles, Tammen & Bergendoff and Geotechnical Engineers, Inc. Inspection checklists, completed during the visual inspection are included in Appendix A. At the time of the inspection, the water level was approximately 2 inches below the spillway crest elevation. The upstream face of the dam could only be inspected above this water level.

b. Dam. Visual inspection of the embankment revealed no signs of distress.

Upstream Slope

The upstream slope of the dam is formed by a reinforced concrete retaining wall which was constructed in 1919 to replace the original rock wall. This wall is in good condition and exhibits no signs of distress that would indicate there has been significant movement of the wall.

Crest

The crest has no pavement. No evidence of cracking or misalignment was observed.

Downstream Slope

The face of the downstream slope was traversed (1) along the crest, (2) along the downstream toe and (3) at approximately mid-height.

The original downstream rock wall is visible over portions of the dam length. Photo 10 shows remnants of the original downstream wall near the right abutment. The rock wall protrudes about 3 feet above the ground surface in the area of the photograph.

Photos 7 and 9 show the trees that have been allowed to grow on the slope of the dam.

No seepage or damp areas were observed along the toe of the dam.

Visual inspection of the concrete retaining wall indicated two surface cracks located in the center section of the wall length. The cracked wall section is through the top and sides of the wall and appear to be related to thermal forces. Overall, it appears that the wall is in good condition.

c. Appurtenant Structures. The spillway structure is constructed of selected and/or shaped stones with the top surface being reinforced with a 5-inch thick concrete slab. The upstream rock face of the spillway has been covered with a concrete wall. All portions of the spillway, Photos 8, 11 and 12, appeared to be in good condition.

The downstream face of the spillway, which is between the left abutment and the embankment, is constructed of rock masonry. This rock wall, shown in Photo 12, is in good condition.

The outlet works consists of a wooden, mechanically operated control gate and a stone and concrete sluiceway discharge channel. The gate has a maximum effective opening of 4.0 feet wide by 4.0 feet high. The wooden plank gate appears to be in good condition. As no representative from the New Hampshire Water Resources Board was present, the gate (Photo 14) was not operated but visual inspection indicated that it was in good condition, and it has been reported to be operational. Alignment of the sluiceway channel (Photo 13) was good and the channel was clean. Inspection of the concrete portion of the channel walls revealed a horizontal crack 18"± above the invert along the left wall of the channel. The concrete on the right wall was eroded to a height of about 2 feet above the channel floor. All stone portions of the channel were in good condition. Visual inspection of the outlet works also showed a leak at the interface of the dam's spillway section and the left wall of the outlet works sluiceway discharge channel.

Visual inspection of the spillway/outlet works discharge channel showed it to be a boulder strewn stream bed with many small diameter trees on each bank.

b. Reservoir Area. The reservoir slopes are generally covered with trees and brush. A more detailed description of the drainage area is included in Section 1.3 of this report. Cottages are scattered along the shoreline several of which appear to be in a flood zone.

e. Downstream Channel. The downstream channel between the dam and the swampy area about 3,000 feet downstream is a boulder strewn stream bed with many trees overhanging from the banks (Photo 16). Approximately 300 feet downstream from the dam, the channel has a debris dam consisting of washed down trees and branches as shown in Photo 18. Approximately 500 feet downstream the channel is again covered with fallen trees. Except for the swampy area located about 3,000 feet downstream of the dam, the downstream channel is relatively narrow and steep, providing for little storage between the dam and the downstream Town of Enfield.

3.2 EVALUATION

Visual examination indicates no immediate safety problems. The general condition of this dam is good. However, trees which have been permitted to grow on the embankment should be removed. The visual inspection revealed the following:

(a) Trees growing in the downstream face of the dam.

(b) Two small cracks in the upper section of the dam's upstream reinforced concrete retaining wall.

(c) Leakage at the interface of the dam's spillway section and outlet works sluiceway discharge channel.

(d) Scoured concrete walls at the outlet works sluiceway discharge channel.

(e) Many overhanging trees and two debris dams in the downstream channel.

SECTION 4
OPERATIONAL PROCEDURES

4.1 Procedure

The Crystal Lake Dam is used primarily for the retention of Crystal Lake which is used for recreational purposes. A secondard purpose of the dam and its resulting reservoir area is for control of winter and early spring runoff. The normal operational procedure for this dam is to lower the reservoir level sometime in the month of October or November of each year. The resultant available storage is used to control snow melt and heavy runoff during the winter and spring months. In May of each year, the reservoir is returned to its summertime recreational level.

4.2 Maintenance of Dam

This dam is visited by one of the State of New Hampshire Water Resources Board's dam operators approximately once per week. During these visits water levels are recorded, grass is cut as necessary, painting is done as necessary and any major deficiencies that may be noted are reported to the Water Resources Board. Occasional clearing of the brush on the embankment is also scheduled on a need basis.

In 1919, a new reinforced concrete retaining wall was constructed to replace the original rock wall which formed the original upstream face of the dam. In 1944, this retaining wall was increased in height to its present elevation.

4.3 Maintenance of Operating Facilities

Maintenance on the outlet works facilities is done on an as needed basis.

4.4 Description of Warning Systems

There are no warning systems in effect at this facility.

4.5 Evaluation

The current operation and maintenance procedures for Crystal Lake Dam are inadequate to insure that all problems encountered can be remedied within a reasonable period of time. The owner should establish a written operation and maintenance procedure as well as establishing a warning system to follow in event of flood flow conditions or imminent dam failure.

SECTION 5
HYDROLOGY AND HYDRAULIC ANALYSIS

5.1 Evaluation of Features

a. General. Crystal Lake Dam is a composite structure consisting of stone, earth and concrete with a total length of approximately 170 feet and a maximum structural height of 22 feet. The appurtenant works consist of a spillway section and an outlet works structure. The spillway has a maximum opening of 50 feet wide by 5.5 feet high. The outlet works structure consists of a mechanically operated 4 foot by 4 foot wooden gate and an outlet channel made of large cut rock slabs.

The dam is located on Crystal Lake Brook and creates an impoundment of water primarily used for recreational purposes. By lowering the reservoir level during the winter, the storage created behind the dam is also used to provide some control over snow melt and stormwater runoff during the winter months. Crystal Lake Dam is classified as being intermediate in size having a maximum storage of 4,840 acre-feet.

b. Design Data. No hydrologic or hydraulic design data were disclosed for Crystal Lake.

c. Experience Data. Maximum discharge at this dam site is unknown.

d. Visual Observations. No evidence of damage to any portion of the project from overtopping was visible at the time of the inspection.

e. Overtopping Potential. As no detailed design and operational information are available, hydrologic evaluation was performed using dam information gathered by field inspection, watershed size and an estimated test flood equal to one-half the Probable Maximum Flood (PMF) as determined by guide curves issued by the Corps of Engineers. Based on a drainage area of 13 square miles, it was estimated that the test flood inflow at Crystal Lake Dam would be 10,300 cfs. Following the guidance for Estimating Effect of Surcharge Storage on Maximum Probable Discharge results in a test flood discharge of 5,400 cfs. As the maximum spillway capacity at the top of the dam is only 1,970 cfs (approximately 36 percent of the test flood discharge flow), the test flood will result in the dam being overtopped by approximately 2.7 feet.

f. Dam Failure Analysis. The impact of failure of the dam at maximum pool (top of dam) was assessed using the "Rule of Thumb" Guidance for Estimating Downstream Dam Failure Hydrographs issued by the Corps of Engineers. [illegible] covered the reach extending from the dam [illegible]. Failure of Crystal Lake Dam at maximum [illegible] result in a downstream channel depth of a[illegible] feet for a reach extending about 3,000 fe[illegible] the dam. At this point, the channel depth wo[illegible]ise due to the swampy characteristics of the [illegible]de section available through this reach. Be[illegible] area, up to and including the reach passing thro[illegible] and the Town of Enfield, the channel depth woul[illegible] from 9 feet to 12 feet. An increase in wate[illegible] of thi[illegible] magnitude would probably result in the loss of a few lives, damage several downstream roadways and could possibly destroy several homes.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations. The visual observation did not disclose any immediate stability problems. Portions of the original downstream rock wall have deteriorated, but the downstream slope formed by natural erosion appears stable.

b. Design and Construction Data. Existing drawings, dated 1918 and 1919, indicate that the original dam consisted of an upstream and downstream rock wall with "cobbles and earth fill" between the walls which were about 21 feet apart.

c. Operating Records. No operating records were made available.

d. Post-Construction Changes. Since the original construction, a reinforced concrete retaining wall was constructed in about 1919 to replace the upstream rock wall. According to existing drawings, the wall was constructed after removing the upstream rock wall except in the spillway area where a concrete facing was placed on the existing rock wall. In 1944, the reinforced concrete retaining wall constructed in 1919, was increased in height by about three feet to its present elevation.

Seismic Stability

The dam is located in Seismic Zone 2, and in accordance with recommended Phase I guidelines does not warrant seismic analysis.

SECTION 7
ASSESSMENT, RECOMMENDATIONS AND REMEDIAL MEASURES

7.1 Dam Assessment

a. Condition. The visual inspection of Crystal Lake Dam did not disclose any findings that indicate an immediate unsafe condition. The observed condition of the dam is generally good. The inspection revealed the following:

(1) Trees growing on the downstream face of the dam.

(2) Two small cracks in the upper section of the dam's upstream reinforced concrete retaining wall.

(3) Leakage at the interface of the dam's spillway section and outlet works sluiceway discharge channel.

(4) Scoured concrete walls at the outlet works sluiceway discharge channel.

(5) Many overhanging trees and two debris dams in the downstream channel.

The hydraulic analysis reveals the inadequacy of the spillway to pass the test flood without overtopping the dam.

b. Adequacy of Information. Existing drawings provide information which when combined with the visual inspection permit an adequate Phase I level evaluation.

c. Urgency. This dam is in generally good condition. The recommendations and remedial measures presented in Sections 7.2 and 7.3 should be implemented by the owner within two years of this Phase I Inspection Report.

d. Need of Additional Investigation. The findings of the visual inspection do not warrant additional investigation.

7.2 Recommendations

It is recommended that the owner engage a qualified engineer to evaluate further the potential for overtopping and the inadequacy of the spillway.

7.3 Remedial Measures

(a) All trees growing on the downstream face of the dam must be removed.

(b) The joint between the spillway and the sluiceway channel wall should be repaired.

(c) The scoured concrete walls of the sluiceway discharge channel should be repaired.

(d) The debris dams and the tree and brush growth in the downstream channel should be removed and kept clean in the future.

(e) A written operational procedure to follow in the event of flood flow conditions or imminent dam failure should be developed.

(f) The technical inspection program should be continued on an annual basis.

7.4 Alternatives

There are no practical alternatives to the recommendations of Section 7.2 and 7.3 except that on an interim basis the owner may consider operating the reservoir at a lower level throughout the year so as to provide more storage for extreme flood events.

APPENDIX A

VISUAL CHECK LIST WITH COMMENTS

VISUAL INSPECTION CHECK LIST
PARTY ORGANIZATION

PROJECT Crystal Lake
Enfield, New Hampshire

DATE September 1, 1978

TIME 9 a.m.

WEATHER 65° Cloudy

W.S. ELEV. 891.83 U.S. 881.0± DN.S

PARTY:

1. Gordon Slaney, HNTB
2. Stan Masur, HNTB
3. D. P. LaGatta, GEI
4.
5.
6.
7.
8.
9.
10.

	PROJECT FEATURE	INSPECTED BY	REMARKS
1.	Dam	Dan LaGatta	
2.	Spillway, Sluiceway	Stan Mazur	
3.	Outlet Works/Downstream Channel	Gordon Slaney	
4.			
5.			
6.			
7.			
8.			
9.			
10.			

PERIODIC INSPECTION CHECK LIST

PROJECT Crystal Lake - Enfield, New Hampshire   DATE September 1, 1978

PROJECT FEATURE Dam   NAME

DISCIPLINE Geotechnical Engineer   NAME D. P. LaGatta

AREA EVALUATED	CONDITION
DAM EMBANKMENT	
Crest Elevation	897.5
Current Pool Elevation	891.83
Maximum Impoundment to Date	Unknown
Surface Cracks	None observed.
Pavement Condition	No pavement
Movement or Settlement of Crest	None observed.
Lateral Movement	None observed on U.S. face.
Vertical Alignment	No misalignment observed.
Horizontal Alignment	No misalignment observed.
Condition at Abutment and at Concrete Structures	Concrete walls have been added to raise dam, and walls extend into abutments. Both walls in good condition.
Indications of Movement of Structural Items on Slopes	Minor cracking of U.S. wall above earth section.
Trespassing on Slopes	No trespassing on slopes, but crest has a path and dam is used for fishing.
Sloughing or Erosion of Slopes or Abutments	
Rock Slope Protection - Riprap Failures	No rock slope protection.
Unusual Movement or Cracking at or near Toes	None.
Unusual Embankment or Downstream Seepage	None observed.
Piping or Boils	None observed.
Foundation Drainage Features	None.
Toe Drains	None.
Instrumentation System	None.
Vegetation	Trees growing on d.s. slope

PERIODIC INSPECTION CHECK LIST

PROJECT Crystal Lake - Enfield, N.H. DATE September 1, 1978

PROJECT FEATURE Intake Channel/Structure NAME D.P. LaGatta

DISCIPLINE Structural Hydraulic/Geotechnical Engineers NAME S. Mazur, G. Slaney

AREA EVALUATED	CONDITION
OUTLET WORKS - INTAKE CHANNEL AND INTAKE STRUCTURE	
a. Approach Channel	None.
Slope Conditions	
Bottom Conditions	
Rock Slides or Falls	
Log Boom	
Debris	
Condition of Concrete Lining	
Drains or Weep Holes	
b. Intake Structure	
Condition of Concrete	Good.
Stop Logs and Slots	See Gate.

PERIODIC INSPECTION CHECK LIST

PROJECT Crystal Lake - Enfield, N.H. DATE September 1, 1978

PROJECT FEATURE Control Tower NAME S. Mazur

DISCIPLINE Structural/Hydraulics Engineers NAME G. Slaney

AREA EVALUATED	CONDITION
OUTLET WORKS - CONTROL TOWER	
a. Concrete and Structural	Control tower and intake structure are one and the same. The inlet structure gate is not housed.
General Condition	
Condition of Joints	
Spalling	
Visible Reinforcing	
Rusting or Staining of Concrete	
Any Seepage or Efflorescence	
Joint Alignment	
Unusual Seepage or Leaks in Gate Chamber	
Cracks	
Rusting or Corrosion of Steel	
b. Mechanical and Electrical	Outlet works gate is hand operated. Reported to be operational although not opened as no owner's representative was present. All portions of the gate structure appeared to be in good condition.
Air Vents	
Float Wells	
Crane Hoist	
Elevator	
Hydraulic System	
Service Gates	
Emergency Gates	
Lightning Protection System	
Emergency Power System	
Wiring and Lighting System	

PERIODIC INSPECTION CHECK LIST

PROJECT Crystal Lake, Enfield, N.H. DATE September 1, 1978

PROJECT FEATURE Transition Conduit NAME S. Mazur

DISCIPLINE Structural/Hydraulic Engineers NAME G. Slaney

AREA EVALUATED	CONDITION
OUTLET WORKS - TRANSITION AND CONDUIT	
General Condition of Concrete	None.
Rust or Staining on Concrete	
Spalling	
Erosion or Cavitation	
Cracking	
Alignment of Monoliths	
Alignment of Joints	
Numbering of Monoliths	

PERIODIC INSPECTION CHECK LIST

PROJECT Crystal Lake, Enfield, New Hampshire	DATE September 1, 1978
PROJECT FEATURE Outlet Structure/Channel	NAME S. Mazur, C. Slaney
DISCIPLINE Structural/Hydraulic/Geotechnical Engineers	NAME D.P. LaGatta

AREA EVALUATED	CONDITION
OUTLET WORKS - OUTLET STRUCTURE AND OUTLET CHANNEL	
General Condition of Concrete	Fair.
Rust or Staining	None noted.
Spalling	Bottom 2 feet of right wall was scoured, horizontal crack 18" above invert noted in left wall.
Erosion or Cavitation	
Visible Reinforcing	None observed.
Any Seepage or Efflorescence	Some seepage between spillway and outlet structure.
Condition at Joints	Good.
Drain Holes	None.
Channel	The outlet channel floor is lined with large cut rock slabs.
Loose Rock or Trees Overhanging Channel	None.
Condition of Discharge Channel	Good.

PERIODIC INSPECTION CHECK LIST

PROJECT Crystal Lake, Enfield, New Hampshire

DATE September 1, 1978

PROJECT FEATURE Spillway and Channels

NAME S. Mazur, G. Slaney

DISCIPLINE Structural/Hydraulic/Geotechnical Engineers

NAME D.P. LaGatta

AREA EVALUATED	CONDITION
OUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS	
a. Approach Channel	None.
General Condition	
Loose Rock Overhanding Channel	
Trees Overhanging Channel	
Floor of Approach Channel	
b. Weir and Training Walls	
General Condition of Concrete	Good.
Rust or Staining	None observed.
Spalling	None observed.
Any Visible Reinforcing	None.
Any Seepage or Efflorescence	None.
Drain Holes	
c. Discharge Channel	Boulder strewn stream bed with many small diameter trees on bank. The channel has a debris dam consisting of washed down trees and branches.
General Channel	
Loose Rock Overhanging Channel	
Trees Overhanging Channel	
Floor of Channel	
Other Obstructions	

PERIODIC INSPECTION CHECK LIST

PROJECT______________________________ DATE____________________

PROJECT FEATURE______________________ NAME____________________

DISCIPLINE___________________________ NAME____________________

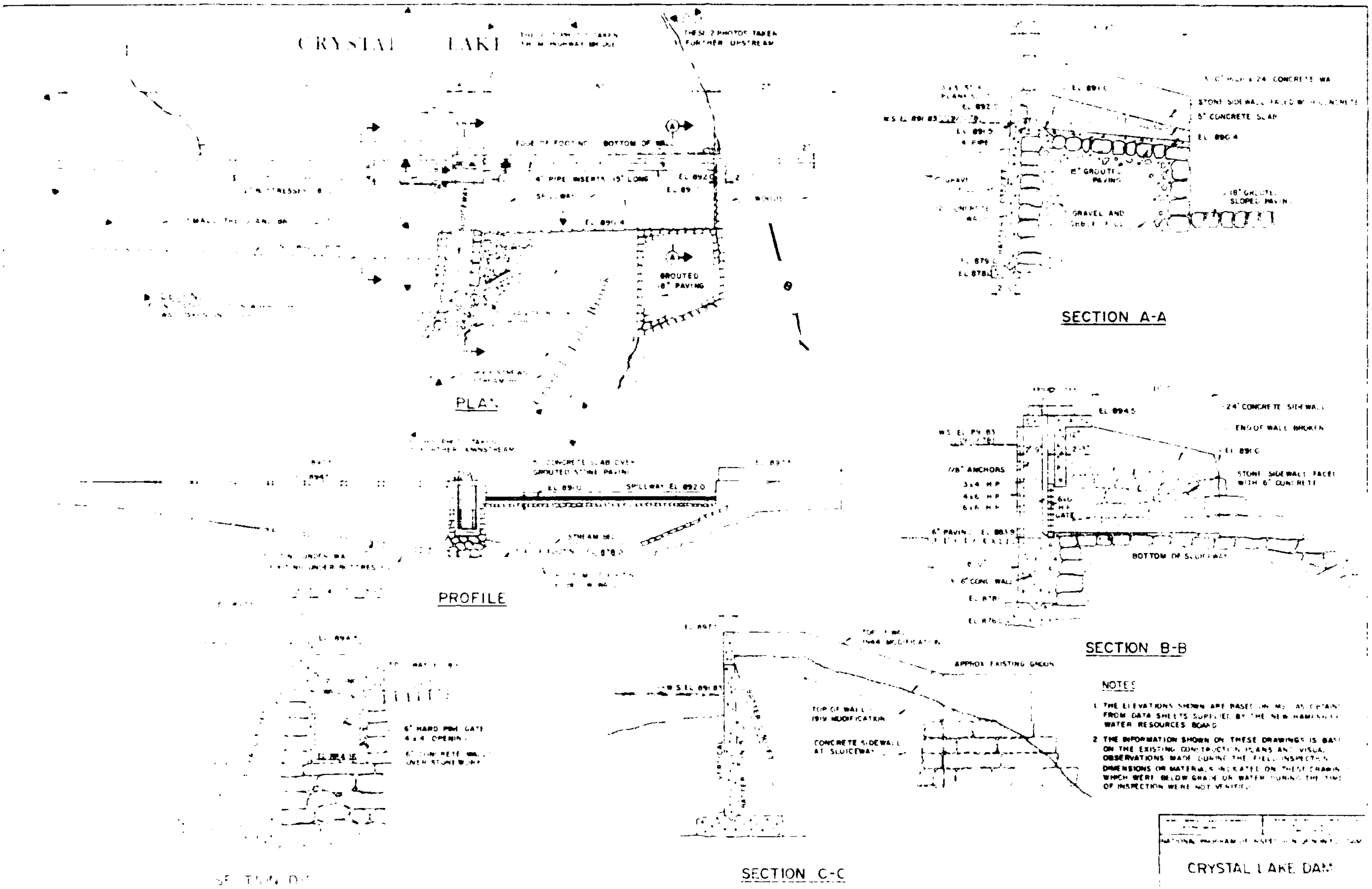
AREA EVALUATED	CONDITION
OUTLET WORKS - SERVICE BRIDGE	None.
a. Super Structure	
Bearings	
Anchor Bolts	
Bridge Seat	
Longitudinal Members	
Under Side of Deck	
Secondary Bracing	
Deck	
Drainage System	
Railings	
Expansion Joints	
Paint	
b. Abutment & Piers	
General Condition of Concrete	
Alignment of Abutment	
Approach to Bridge	
Condition of Seat & Backwall	

APPENDIX B

1. LIST OF DESIGN, CONSTRUCTION AND MAINTENANCE RECORDS
2. PLANS AND DETAILS
3. PAST INSPECTION REPORTS

AVAILABLE ENGINEERING DATA

A set of plans dated 1918 and 1919 (two sheets) showing plan, elevation, typical sections and details are available at the New Hampshire Water Resources Board, 37 Pleasant Street, Concord, New Hampshire 03301. A second set of plans dated 1943 and 1944 (two sheets) showing details for raising the upstream reinforced concrete retaining wall are also available at the Water Resources Board.


CRYSTAL LAKE
THESE 2 PHOTOS TAKEN FURTHER UPSTREAM
EDGE OF FOOTING
BOTTOM OF WALL
4" PIPE INSERTS 15' LONG
EL 892.0
EL 890.4
GROUTED 6" PAVING
PLAN
CONCRETE SLAB OVER GROUTED STONE PAVING
EL 891.0
SPILLWAY EL 892.0
STREAM BED
PROFILE
EL 891.C
24" CONCRETE WA
STONE SIDEWALL FACED WITH CONCRETE
5" CONCRETE SLAB
EL 890.4
6" GROUTED PAVING
18" GROUTED SLOPED PAVING
GRAVEL AND
EL 892.0
EL 891.5
4" PIPE
EL 879
EL 878
SECTION A-A
EL 894.5
24" CONCRETE SIDEWALL
END OF WALL BROKEN
EL 891.0
STONE SIDEWALL FACED WITH 6" CONCRETE
7/8" ANCHORS
3x4 H.P.
4x6 H.P.
6x6 H.P.
6" PAVING EL 883.9
BOTTOM OF SLUICEWAY
6" CONC WALL
SECTION B-B
APPROX EXISTING GROUND
1944 MODIFICATION
TOP OF WALL 1919 MODIFICATION
CONCRETE SIDEWALL AT SLUICEWAY
SECTION C-C
6" HARD PINE GATE
4 x 4 OPENING
6" CONCRETE WALL OVER STONEWORK
NOTES
1. THE ELEVATIONS SHOWN ARE BASED ON MSL AS OBTAINED FROM DATA SHEETS SUPPLIED BY THE NEW HAMPSHIRE WATER RESOURCES BOARD.
2. THE INFORMATION SHOWN ON THESE DRAWINGS IS BASED ON THE EXISTING CONSTRUCTION PLANS AND VISUAL OBSERVATIONS MADE DURING THE FIELD INSPECTION. DIMENSIONS OR MATERIALS INDICATED ON THESE DRAWINGS WHICH WERE BELOW GRADE OR WATER DURING THE TIME OF INSPECTION WERE NOT VERIFIED.
CRYSTAL LAKE DAM

PAST INSPECTION REPORTS

REPORT ON CRYSTAL LAKE DAM

ENFIELD, NEW HAMPSHIRE

On April 5, 1944 I visited and inspected the dam at the outlet of Crystal Lake in the Town of Enfield, New Hampshire. Although the gate was closed the pond level was some two or three feet below the crest of the spillway. This permitted the examination of a considerable portion of the upstream face of the concrete. One inch flash boards about eight to ten inches in height and supported by hollow pins, were in place along the crest of the spillway. No leakage was noted through any portion of the dam.

In my opinion this dam is in very good condition. It was evident that it had been maintained in a very satisfactory manner.

Submitted by [signature]
Bridge Engineer
New Hampshire State Highway Department

MEMORANDUM

DATE: March 26, 1973

FROM: Vernon A. Knowlton, Chief Engineer, Water Resources Board

SUBJECT: Inspection of Mascoma Dams

TO: Peter J. Merkes, Water Resources Engineer

On Friday, March 23, I inspected three of the dams at Mascoma and found the following:

Mascoma: Exceptional amount of trash over the area which will probably be picked up by Pickard. We should be raising the water level to keep some water on the planking.

Crystal: Concrete on spillway has eroded showing steel in one area, and the joint between the spillway and the crest should be sealed. Noted signs posted on our (?) property regarding "no parking within 300 feet of bridge."

Goose: Concrete at outlet of discharge facility show signs of eroding - has steel showing. Should be corrected as need arises.

VAK:js

APPENDIX C

PHOTOGRAPHS

FOR LOCATION OF PHOTOS, SEE FIGURE 1
LOCATED IN APPENDIX B

PHOTO NO. 1 - General view of reservoir from roadway bridge.

PHOTO NO. 2 - General view of reservoir from left side of reservoir area.

PHOTO NO. 3 - Reservoir, view from roadway along left bank.

PHOTO NO. 4 - General view of dam from roadway, upstream of dam.

PHOTO NO. 5 - View of dam from roadway.

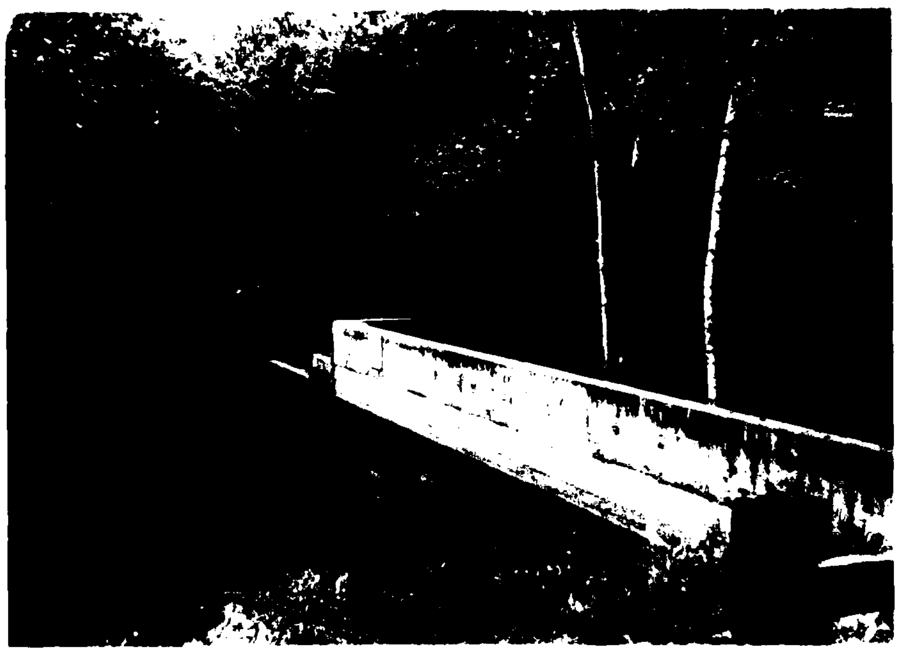


PHOTO NO. 6 - Close-up view of dam from right abutment.

PHOTO NO. 7 - Dam crest and downstream slope from right abutment.

PHOTO NO. 8 - Spillway crest and spillway slab from embankment.

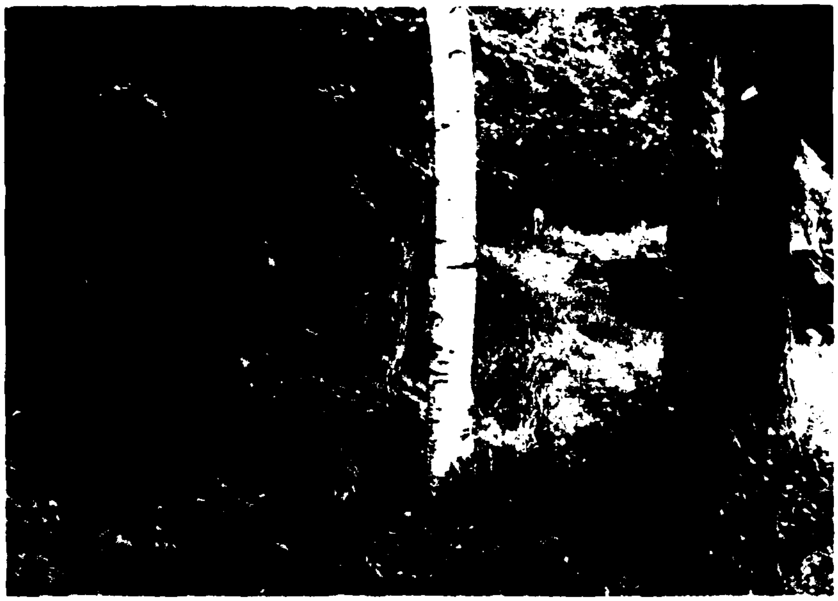


PHOTO NO. 9 - Trees growing on embankment.

PHOTO NO. 10 - Remnants of original downstream rock dam.

PHOTO NO. 11 - Outlet works and spillway structure from below dam.

PHOTO NO. 12 - Spillway structure from outlet channel.

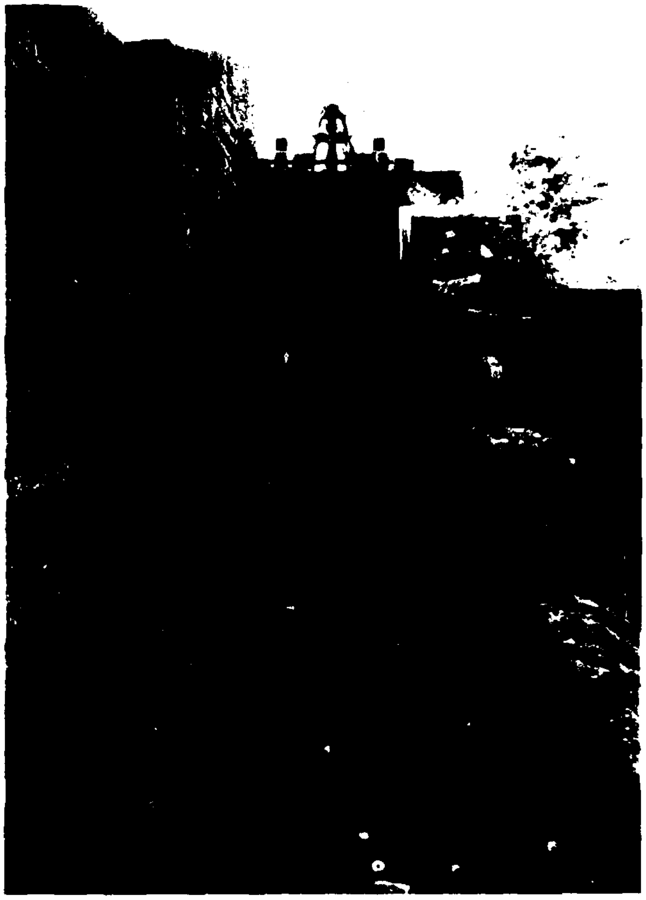


PHOTO NO. 13 - Close-up view of outlet works structure, from below dam.

PHOTO NO. 14 - Control mechanism of outlet works structure.

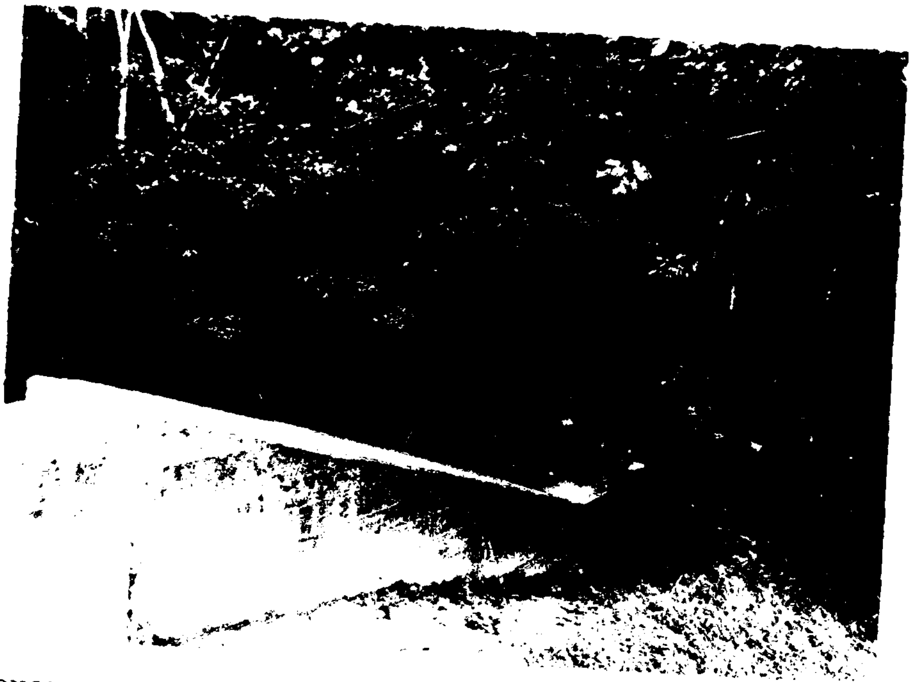


PHOTO NO. 15 - Retaining wall separating embankment and outlet works structure.

PHOTO NO. 16 - Spillway and outlet channel from dam crest.

PHOTO NO. 17 - Dam and river channel from downstream river.

PHOTO NO. 18 - Debris dam in stream below dam.

APPENDIX D

HYDROLOGIC AND HYDRAULIC COMPUTATIONS

HNTB HOWARD NEEDLES TAMMEN & BERGENDOFF	Made by HM	Date 10/13/78	Job No. 5622-11-01
	Checked by [illegible]	Date 10/20/78	Sheet No 1

For CRYSTAL LAKE DAM - ENFIELD

BASIC DATA

D.A. = 13.2 Square Miles (NH WATER RES. BOARD)

DAM CLASSIFICATION: (Based on Corps of Engineers Guidelines)

1. SIZE : Intermediate (Storage > 1000 AF)

2. HAZARD POTENTIAL CLASSIFICATION : SIGNIFICANT

Note: For dams with an "Intermediate Size Classification" and "Significant Hazard Potential" a Test Flood equal to ½ PMF is indicated in the Corps' Guidelines. Use ½ PMF.

TABLE 1

WATER ELEV. (MSL)	LOCAL GAGE ELEV.	SURFACE AREA (AC)	VOLUME (A-F)	FLOW ① OVER SPILLWAY (CFS)	FLOW ② OVER CREST (CFS)	TOTAL FLOW (CFS)
884	0	308	0	No FLOW	No Flow	No FLOW
885	1	316	312	"	"	"
886	2	324	632	"	"	"
887	3	332	960	"	"	"
888	4	340	1296	"	"	"
889	5	348	1640	"	"	"
890	6	356	1,992	"	"	"
891	7	364	2,352	"	"	"
892*	8	372	2,720	0	"	0
893	9	380	3,096	154	"	154
894	10	388	3,430	433	"	433
895	11	388	3,868	793	"	793
896	12	388	4,256	1216	"	1,216
897.5	13.5	388	4,836	1949 ✓	0	1,949
899	15	388	5,032	2270	139	2,409
900	16	388	5,308	3496	1604	5,100

TABLE 1 (CONT.)

WATER ELEV. [FT MSL]	LOCAL GAGE ELEV.	SURFACE AREA [Ac]	VOLUME (AF)	FLOW OVER SPWAY CFS	FLOW OVER CREST CFS	TOTAL FLOW CFS
902	18	388	6584	4,885	3,986	8,872
904	20	388	7360	6422	7,119	13,541
906	22	388	8136	8,093	10,942	19,035
908	24	388	8912	9,888	15,430	25,318
910	26	388	9688	11,799	20,570	32,369
912	28	388	10,464	13,819	26,359	40,178
914	30	388	11,240	15,942	32,798	48,740
916	32	388	12,016	18,165	39,889	58,054
918	34	388	12,792	20,482	47,639	68,121
920	36	388	13,568	22,891	56,053	78,944

Volume of Surcharge = V_1 − Volume at elev. 892'*
= V_1 − 2720 AF

* Normal pool elevation

HNTB	Made by HM	Date 10/13/78	Job No. 5623-11-01
HOWARD NEEDLES TAMMEN & BERGENDOFF	Checked by DWB	Date 10/20/78	Sheet No. 3

For CRYSTAL LAKE DAM - ENFIELD

① For flow over the spillway use formula of Broad-crested Weir:

$$Q_S = 3.09 \times L \times H_S^{3/2}$$

Where:
H_S = Water Surface Elev. - Spillway crest Elev. (892')
L = Length of weir (Adjusted up to crest elev. only)
L = (L' - 0.1 × N × H_S) ... (N = # of contractions) (L' = 50')

② For flow over the crest (retaining wall) use formula of Sharp-Crested Weir:

$$Q_c = \left(3.27 + 0.4\frac{H_c}{P}\right) \times L \times H_c^{3/2}$$ For $0.5 < H/P < 1$

Where:
H_c = Water Elev. - Crest Elev. (897.5') (Head)
P = Height of weir (P_{avg} = 8 Feet)
L = Length of Crest (L = 119.5')

SPILLWAY DATA

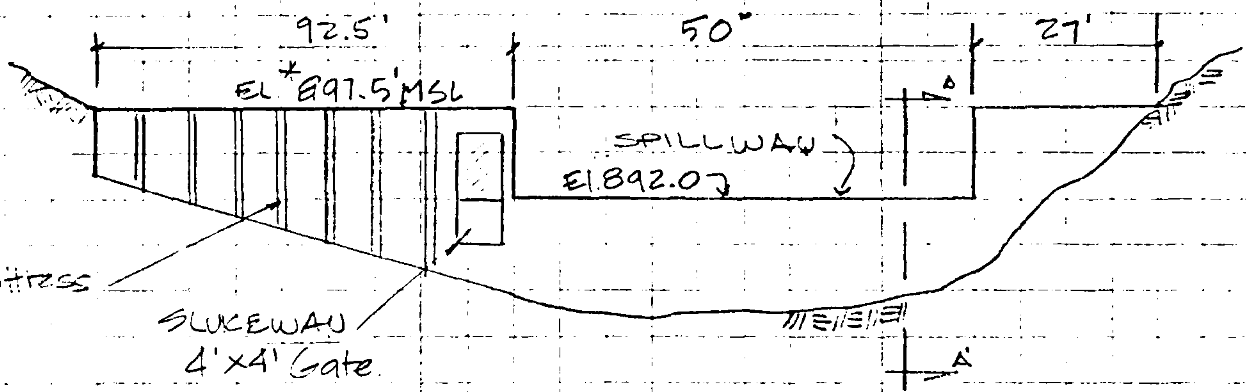
TYPE: Broad-Crested weir (12' wide)
LENGTH = 50'
TOP ELEV. = 892' MSL
FLASHBOARDS: Not used for this analysis

CREST DATA

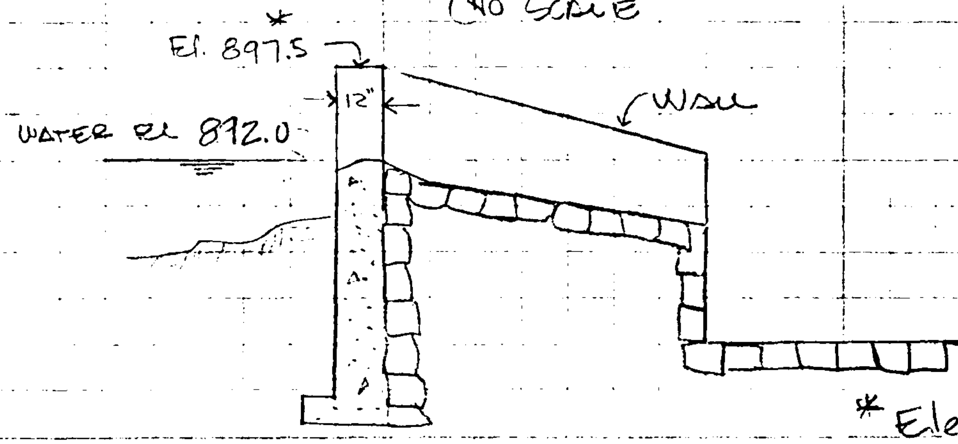
TYPE: CONCRETE WALL (12" wide) w/ BUTTRESSES
LENGTH = 119.5 Feet
CREST ELEV. = 897.5 MSL
AVERAGE HEIGHT = 8 Feet (Above existing ground).

HNTB
HOWARD NEEDLES TAMMEN & BERGENDOFF

Made by HM	Date 9/6/78	Job No. 5328-11-01	
Checked by [illegible]	Date 10/20/78	Sheet No. 4	
For CRYSTAL LAKE - ENFIELD -			



PROFILE
(NO SCALE)



*Elev. shown are Mean Sea Level

SECTION A-A'
(THROUG SPILLWAY)

ESTIMATING EFFECT OF SURCHARGE STORAGE ON MAXIMUM PROBABLE DISCHARGE

Drainage Area = 13.2 S.M. (NHWRB checks ok!)
Basins Characteristics : Rolling Zone (Averg. Slope: 4%)
Test Flood: 1/2 PROBABLE MAXIMUM FLOOD

Step 1. Determine peak inflow (Q_{P1}) from guide curves.
Select Rolling Zone curve. For d.a. of 13.2 SM and Rolling curve the rate is : 1500 CFS/S.M.

MF101 374-20M

EFFECT OF SURCHARGE STORAGE (CONT.)

then $Q_{P_1} = \frac{1}{2} \times [1,560 \; CFS/SM \times 13.2 \; SM] = 10,296$ CFS

For Test Flood, say: $Q_{P_1} = 10,300$ CFS

STEP 2. From fig No 1 determine the surcharge Elevation to pass Q_P.

a. For Q_{P_1} = 10,300 CFS → Elev. = 902.75'

b. Volume of surcharge storage ($STOR_1$) in inches of runoff:

$$STOR_1 = \frac{\text{Volume of surcharge Storage} \times 12''/Ft}{\text{Drainage Area}}$$

$$STOR_1 = \frac{(902.75' - 892')\,388A \times 12''/Ft}{13.2^{SM} \times 640A/SM} = 5.92''$$

$STOR_1$ = 5.92" of runoff

c. Compute $Q_{P_2} = Q_{P_1} \times \left(1 - \frac{STOR_1}{9.5''}\right) =$

$$= 10,300^{CFS} \times \left[1 - \frac{5.92''}{9.5''}\right] = 3,881 \text{ CFS}$$

Q_{P_2} = 3,880 CFS

Step 3

a. Determine surcharge Height and $STOR_2$ to pass Q_{P_2}.

From Fig. 1 The Surcharge Elev. 899.20' MSL

EFFECT OF SURCHARGE STORAGE (CONT.)

B. $STOR_2 = \frac{388\ Ac\ (899.20' - 892.0') \times 12''/FT}{13.2\ S.M. \times 640\ A/SM} = 3.97''$

C. Compute Average Storage

$STOR_{Avg} = \frac{5.92 + 3.97''}{2} = 4.94''$

D. $Q_{P_3} = 10{,}300\ CFS \times \left[1 - \frac{4.94''}{9.5''}\right] = 4{,}940\ CFS$

STEP 4-A. Determine Surcharge Storage for $Q_{P_3} = 4{,}940 \longrightarrow El. = 899.9'$

B. Compute $STOR_3$

$STOR_3 = \frac{388\ Ac \times (899.9' - 892.0') \times 12''/FT}{13.2\ S.M. \times 640\ Ac/SM} = 4.35''$

C. $STOR_{AVG} = \frac{4.94'' + 4.35''}{2} = 4.64''$

D $Q_{P_4} = 10{,}300\ CFS \times \left[1 - \frac{4.64''}{9.5''}\right] = 5{,}270\ CFS$

STEP 5 A. Determine Surcharge Height to pass $Q_{P_4} = 5{,}270\ CFS \longrightarrow EL. 900.10'$

B. $STOR_4 = \frac{388\ Ac \times (900.10' - 892.0') \times 12''/FT}{13.2\ SM \times 640\ A/SM} = 4.46''$

C. $STOR_{Avg} = \frac{4.64'' + 4.46''}{2} = 4.55''$

HNTB HOWARD NEEDLES TAMMEN & BERGENDOFF	Made by HM	Date 10/31/79	Job No. 5628-11-01
	Checked by	Date	Sheet No. 6A
For CRYSTAL LAKE DAM - ENFIELD			

EFFECT OF SURCHARGE STORAGE (CONT.)

D. $Q_{P_5} = 10{,}300 \text{ CFS} \times \left[1 - \frac{4.55''}{9.5''}\right] = 5{,}370$ CFS

EL. 900.2'

$$STOR = \frac{388 \text{ Ac} \times (900.2' - 892.0')}{13.2 \text{ SM} \times 640 \text{ Ac/SM}} \times 12''/FT = 4.52''$$

STOR = 4.52" OK

Use Q_{P_5} = 5,400 CFS

CONCLUSIONS:

1. The test flood discharge Q_{P_5} = 5,400 CFS will overtop the dam by approx. 2.7 Feet.

2. The Spillway (50-FT Long) with crest elev. 892' MSL and with water surface 897.5' has a capacity of 1950 CFS which is the 36.1 % of the test flood discharge.

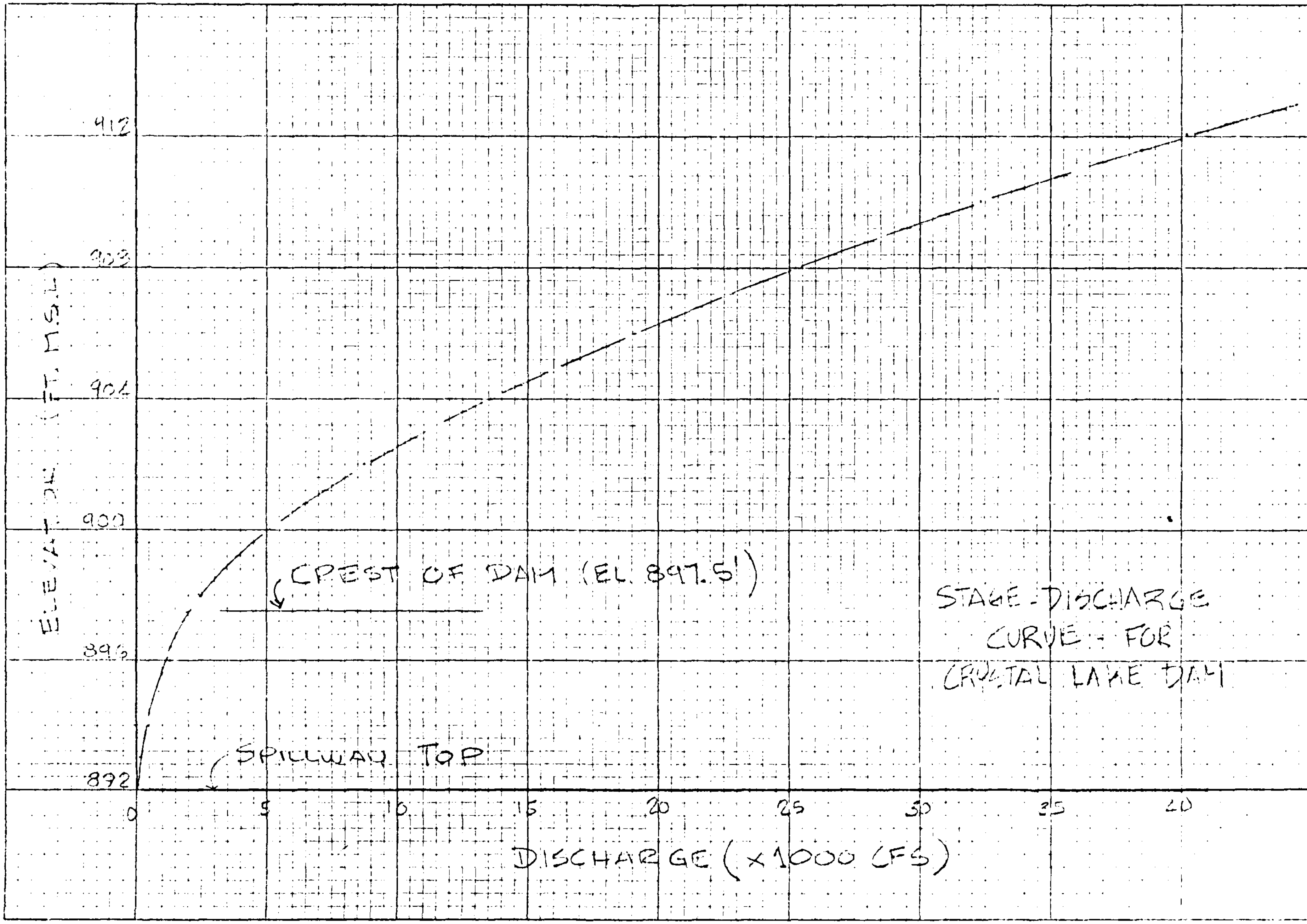

912
908
904
900
896
892
ELEVATION (FT. MSL)
0
5
10
15
20
25
30
35
40
DISCHARGE (×1000 CFS)
CREST OF DAM (EL. 897.5')
SPILLWAY TOP
STAGE - DISCHARGE
CURVE - FOR
CRYSTAL LAKE DAM

FIG. 1

HNTB	Made by	Date 12/17/78	Job No 5323-11-01
HOWARD NEEDLES TAMMEN & BERGENDOFF	Checked by	Date 12/20/78	Sheet No 7
For ... LAKE - ENFIELD			

ESTIMATING DOWNSTREAM DAM FAILURE HYDROGRAPHS

The method called "The Rule of Thumb" is used to estimate the effects of the failure hydrographs. The analysis is done downstream to the town of Enfield. The stream length is divided in four reaches:

Reach 1

REACH DATA

LENGTH = 3,000'
SLOPE = 0.02%
Mannings "n" = 0.08

CHANNEL DATA
Sta 10+00
Shape: Trapezoidal
Bank Slopes:
LEFT: 1.5:1
RIGHT: 2.5:1
Base width: 40'

STEP 1. Determine the Reservoir Storage (S) in A.F at time of failure.
From table 1 the volume is 4,838 AF @ 897.5' MSL (water up to the top of dam).
S = 4,838 Acre-Feet.

STEP 2. Calculate the peak failure outflow (Q_{P_1})

$$Q_{P_1} = \frac{8}{27} \times W_b \sqrt{g} \times Y_0^{3/2}$$

Where
W_b = Breach width - (40% of total Length)
= 0.4 × 169.5' = 67.8'
Y_0 = Total height from streambed to top of dam (17.5').

Then: Q_{P_1} = 1.681 × 67.8 × $\overline{17.5}^{1.5}$ = 8,345 CFS

HNTB HOWARD NEEDLES TAMMEN & BERGENDOFF	Made by HH	Date 10/17/78	Job No 5328-11-01
For	Checked by VJB	Date 10/20/78	Sheet No 3

STEP 3: Prepare Stage-Discharge curve for this section.

STEP 4: a) From Fig #2 the stage is 12.12' and the area: 778□'

$$\text{Volume } V_1 = \frac{L \times A}{43560} = \frac{3000' \times 778□'}{43560 \text{ CF/AF}} = 53.62 \text{ AF}$$

$V_1 = 53.62\text{AF} < S/2$ OK!

b) Determine $Q_{P_2(\text{Trial})} = Q_{P_1} \times \left[1 - \frac{V_1}{S}\right]$

$$= 8,345 \text{ CFS} \times \left[1 - \frac{53.62 \text{ AF}}{4838 \text{ AF}}\right]$$

$Q_{P_2(\text{Trial})} = 8,252 \text{ CFS}.$

c) Compute V_2 using the stage produced by Q_{P_2}

Stage = 12.05' — Area = 772□'

$$V_2 = \frac{3000' \times 772□'}{43560 \text{ CF/AF}} = 53.20 \text{ AF}.$$

d) Average V_1 & V_2 and Compute Q_{P_2}

$$V_{AVG} = \frac{53.62^{AF} + 53.20^{AF}}{2} = 53.41^{AF}$$

$$Q_{P_2} = Q_{P_1} \times \left[1 - \frac{V_{AVG}}{S}\right] = 8,253 \text{ CFS}.$$

SAY Q_{P_2} = 8,250 CFS

HNTB HOWARD NEEDLES TAMMEN & BERGENDOFF	Made by HN	Date 10/17/78	Job No 5628-11-01
	Checked by	Date	Sheet No 9

For

ESTIMATING D.S. DAM FAILURE. (CONT.)

REACH 2 (Q_{P_1} = 8,250 CFS)

REACH DATA
Length = 9,000'
Bottom Slope = 0.00173'/'
Manning's (n) = 0.080

CHANNEL DATA Sta 80+00
Shape: Non-Symmet. Trapezoidal
Bank Slopes LT. = 4.8; RT = 6.16
Base Width = 1,500'

STEP 3: Using USGS Topo, a Stage-Discharge relationship curve is developed as shown on figure No 2

STEP 4: Estimate reach outflow (Q_{P_2}) using the following iteration:

A. Applying Q_P = 8250 CFS to stage rating, determine Stage and accompanying volume (V_1) in reach in Acre-Feet. (Note: If V_1 exceeds 1/2 of S a shorter reach will be selected).

Stage = 3.24 Feet ; Area = 4,918 ft²

$$\text{Volume } (V_1) = \frac{9000' \times 4918 \text{ ft}^2}{43560 \text{ CF/AF}} = 1016 \text{ AF} < S/2$$

Where S = 4838 AF

B. Compute $Q_{P_2 (Trial)} = Q_{P_1} \times \left[1 - \frac{V_1}{S}\right]$

$$= 8,250 \text{ CFS} \times \left[1 - \frac{1016 \text{ AF}}{4838 \text{ AF}}\right]$$

$$Q_{P_2} = 6,517 \text{ CFS}$$

C. From figure 2 determine $Stage_2$

Q_{P_2} = 6517 CFS ⟶ Stage = 2.31 Feet ±
A = 4,258 S.F.

$$V_2 = \frac{9000' \times 4,258 \text{ SF}}{43560 \text{ C.F/A.F}} = 880 \text{ A-F} \pm$$

ESTIMATING D.S. DAM FAILURE EFFECTS (CONT.)

D. Average V_1 & V_2 and compute Q_{P_2}

$$Q_{P_2} = Q_{P_1} \times \left[1 - \frac{V_{avg}}{S}\right]$$

$$V_{avg} = \frac{1016\,AF + 880\,AF}{2} = 948\,AF$$

$$Q_{P_2} = 8{,}250\,CFS \times \left[1 - \frac{948\,AF}{4838\,AF}\right] = 6{,}633\ CFS$$

Say Q_{P_2} = 6,630 CFS

REACH 3

REACH DATA
Length = 17,000'
Bottom Slope = .000173
Manning's (n) = 0.080

CHANNEL DATA (STA 211+50)
Shape = Trapezoidal
Bank Slope = 20:1
Base Width = 60'

STEP 3: For stage-discharge curve see figure 2

STEP 4: Estimate reach outflow (Q_{P_2}) using following iteration.

A. Apply Q_{P_1} to stage rating, the corresponding stage, for Q_P = 6630 CFS is 10.18' and the area = 2,683 ft² and compute V_1:

$$V_1 = \frac{17{,}000' \times 2{,}683\,ft^2}{43560\,CF/AF} = 1{,}047\ AF < S/2\ ok$$

B. Determine $Q_{P_2} = Q_{P_1} \times \left[1 - \frac{V_1}{S}\right]$

$$Q_{P_2} = 6630\,CFS \times \left[1 - \frac{1047\,AF}{4838\,AF}\right] = 5196$$

ESTIMATING D.S DAM FAILURE EFFECTS (CONT)

C. Compute V_2 using Q_{P_2} (Trial)

$Q_{P_2}(\text{Trial}) = 5,194$ ⟶ Stage = 9.17'
Area = 2,239#

$$V_2 = \frac{17,000' \times 2,239\#}{43560\ CF/AF} = 871\ AF$$

D. Average V_1 & V_2 and compute Q_{P_2}

$$V_{avg} = \frac{1047\ AF + 871\ AF}{2} = 959\ AF$$

$$Q_{P_2} = 6630\ CFS \times \left[1 - \frac{959\ AF}{4838\ AF}\right] = 5,316\ CFS$$

SAY $Q_{P_2} = 5,320$ CFS

REACH 4

REACH DATA

LENGTH = 6,600'
BOTTOM SLOPE = 0.0042'/'
MANNING'S (n) = 0.060

CHANNEL DATA
STA 290+00

SHAPE = Trapezoidal
BANK SLOPE = LT = 7.7 RT = 5
BASE WIDTH = 10

STEP 3 : For stage-discharge curve see fig. 2

STEP 4 : Estimate reach outflow Q_{P_2} using the following iteration

A. Using Curve No 4 (Fig 2) the corresponding stage for Q_{P_1} = 5,320 CFS is 11.83' and the area = 978# compute Volume V_1

$$V_1 = \frac{978\# \times 6600'}{43560\ CF/AF} = 148\ AF$$

ESTIMATING D.S. DAM FAILURE EFFECTS (CONT.)

3. Determine trial Q_{P_2}

$$Q_{P_2} = Q_{P_1} \times \left[1 - \frac{V_1}{S}\right] = 5320\ CFS \times \left[1 - \frac{148}{4838}\right]$$

$= 5,157$ CFS ✓

C. Compute V_2 using Q_{P_2} (Trial)

The stage for $Q_{P_2} = 5,157$ CFS → is 11.73 Feet

$A = 954 \square'$

$$V_1 = \frac{6,500' \times 954 \square'}{43560\ CF/AF} = 144.6\ AF$$ ✓

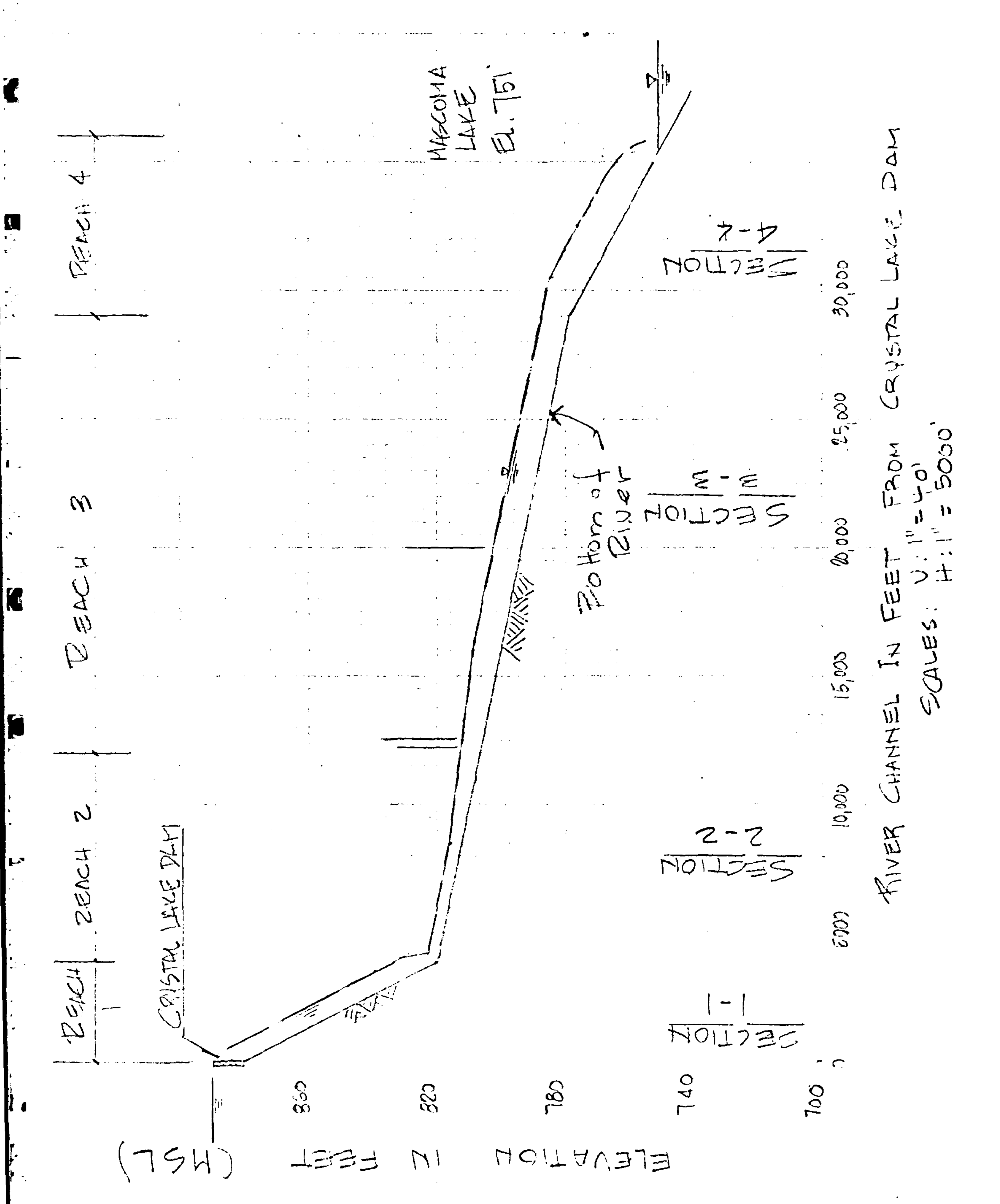
D. Average V_1 and V_2 and compute Q_{P_2}

$$V_{AVG} = \frac{148 + 144.6}{2} = 146.3\ AF$$ ✓

Where $Q_{P_2} = 5,370^{CFS} \times \left[1 - \frac{146.3\ AF}{4838\ AF}\right] = 5159$ CFS

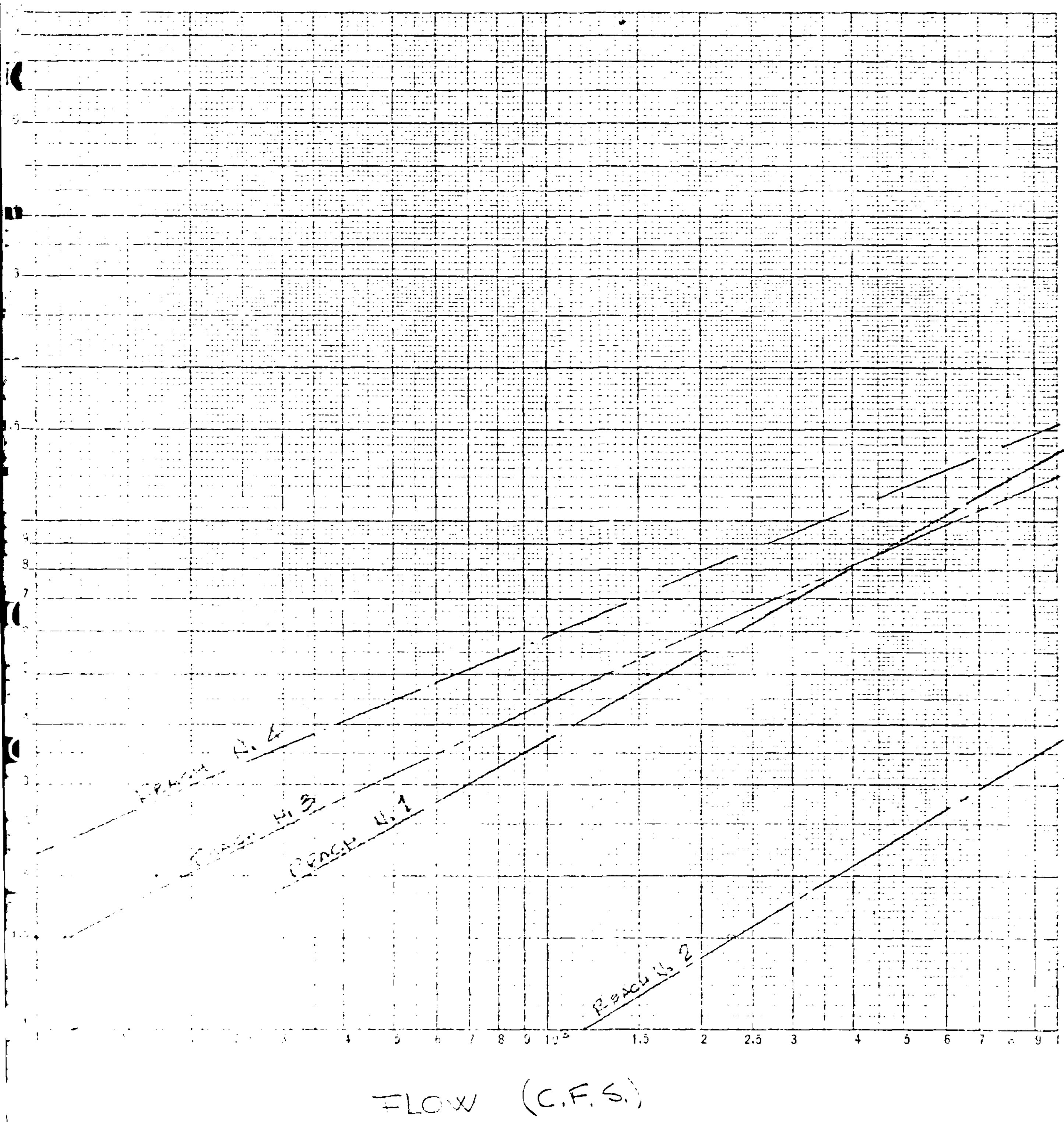
Say $Q_{P_2} = 5160$ CFS. OK ✓

HNTB HOWARD NEEDLES TAMMEN & BERGENDOFF	Made by HM	Date 9/07/93	Job No. 5605-11-01
	Checked by	Date	Sheet No.
Calculations For CRYSTAL LAKE DAM			



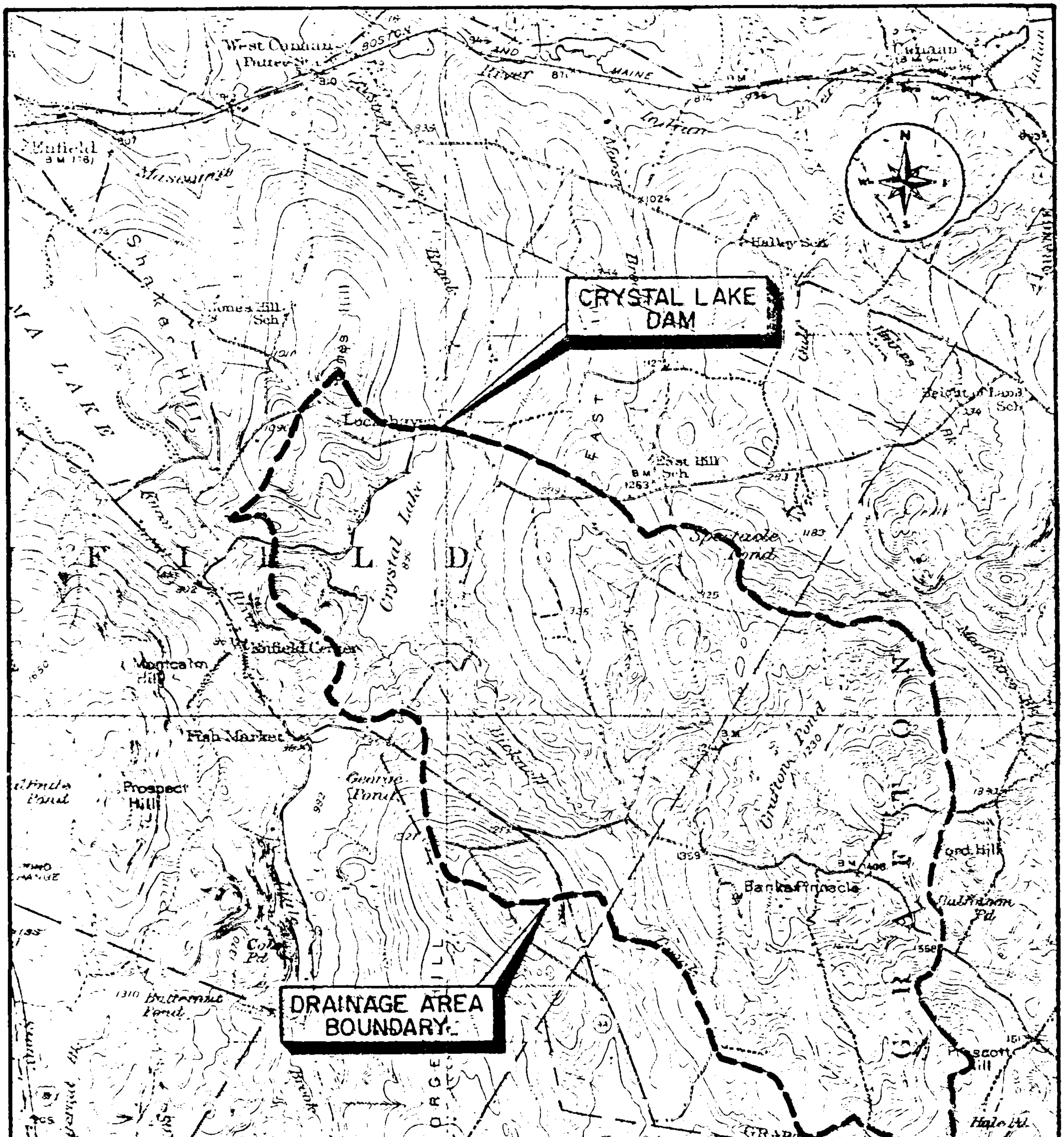
GN102-1173-12M

CRYSTAL LAKE BROOK - ENFIELD



STAGE - DISCHARGE CURVES

FIG 2



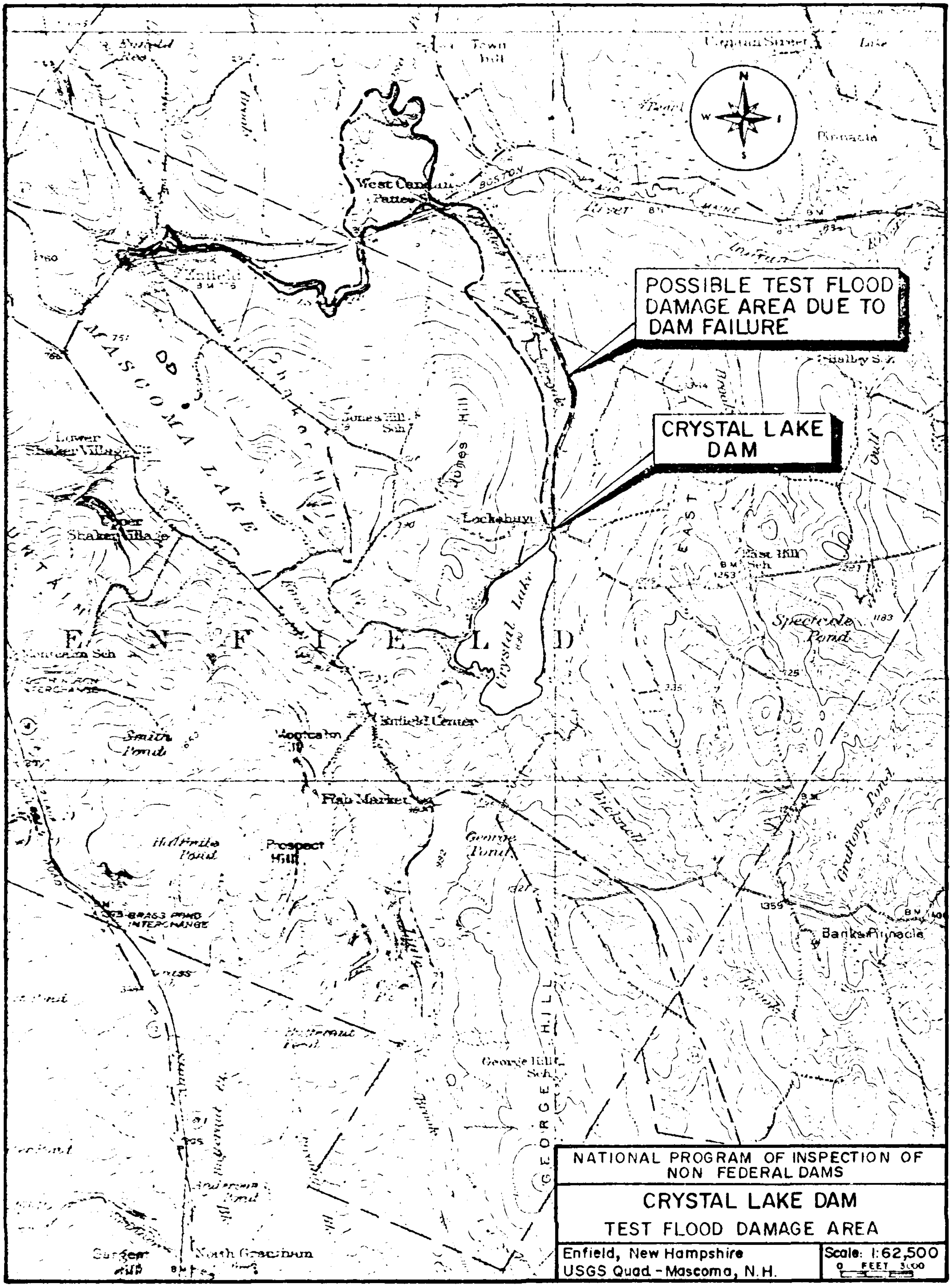
NATIONAL PROGRAM OF INSPECTION OF NON FEDERAL DAMS

CRYSTAL LAKE DAM

DRAINAGE AREA

Enfield, New Hampshire
USGS Quad.-Mascoma, N.H.

Scale: 1:62,500



POSSIBLE TEST FLOOD DAMAGE AREA DUE TO DAM FAILURE
CRYSTAL LAKE DAM
MASCOMA LAKE
Crystal Lake
ENFIELD
Lockehaven
Enfield Center
West Canaan
Spectacle Pond
Smith Pond
George Pond
Grafton Pond
Prospect Hill
East Hill Sch
Jones Hill
Lower Shaker Village
Upper Shaker Village
Banks Pinnacle
George Hill Sch
GEORGE HILL
EAST
BOSTON AND MAINE
NATIONAL PROGRAM OF INSPECTION OF NON FEDERAL DAMS
CRYSTAL LAKE DAM
TEST FLOOD DAMAGE AREA
Enfield, New Hampshire
USGS Quad - Mascoma, N.H.
Scale: 1:62,500

APPENDIX E

INFORMATION AS CONTAINED IN

THE NATIONAL INVENTORY OF DAMS

END

FILMED

8-85

DTIC