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ENFIELD RESERVOIR DAM. (U) CORPS OF ENGINEERS WALTHAM
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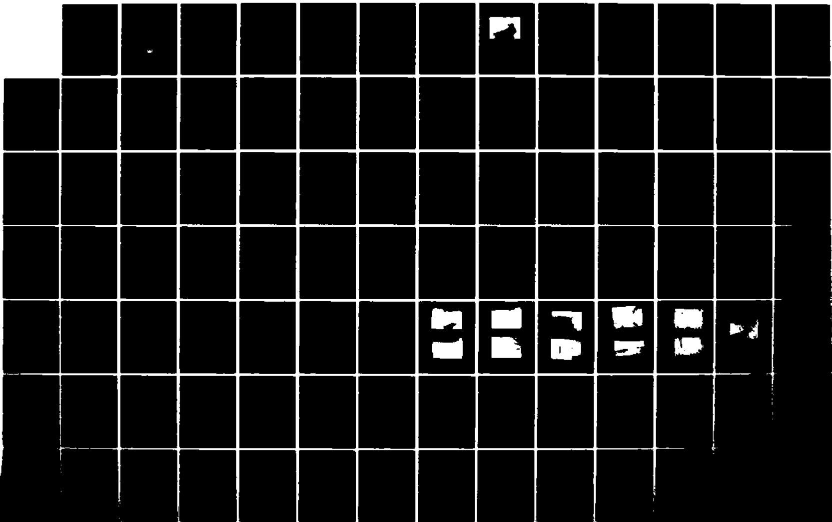

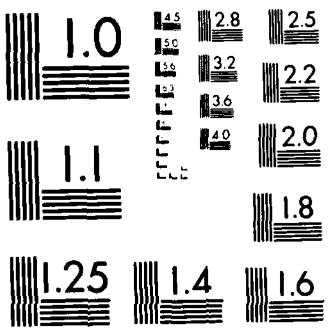

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

CONNECTICUT RIVER BASIN
HANOVER, NEW HAMPSHIRE

ENFIELD RESERVOIR DAM
NH 00354

STATE NO 36.08

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

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

APRIL 1979

REPRODUCED AT GOVERNMENT EXPENSE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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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
Hanover, New Hampshire
Unnamed tributary of the Mascoma River

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

The dam is a 730 ft. long earth embankment with a hydraulic height of 22 ft. The dam is in fair condition. Apparent seepage problems and erosion of the upstream slopw above the riprap are of principal concern. It is small in size with a significant hazard potential. A major breach at top of dam could result in the loss of 3-5 lives and excessive property damage.

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NATIONAL DAM INSPECTION PROGRAM
PHASE I INSPECTION REPORT

Identification No.:	NH00354
Name of Dam:	Enfield Reservoir Dam
Town:	Canaan
County and State:	Grafton County, New Hampshire
Stream or River:	Unnamed tributary of the Mascoma River
Date of Inspection:	November 8, 1978

BRIEF ASSESSMENT

Enfield Reservoir Dam is a 730-foot long earth embankment, having a hydraulic height of 22 feet, a 10-foot topwidth, and 2H:1V sideslopes. The east end of the dam consists of a 28-foot long concrete spillway and a 33-foot long emergency spillway. The dam spans a reach of an unnamed tributary of the Mascoma River and is located in west central New Hampshire. Maximum storage capacity is about 203 acre-feet. Enfield Reservoir Dam is used for a water supply for Enfield Village. The pond is about ¼ mile in length with a surface area of 21 acres.

The dam is in fair condition. Principal concerns are: apparent seepage problems, erosion of the upstream slope above the riprap, and potential for erosion of the embankment at the west abutment of the spillway under high flow conditions.

Based on small size and significant hazard classifications in accordance with Corps guidelines, the test flood is ½ the Probable Maximum Flood (PMF). A test flood outflow of 1,860 cfs (1,208 csm) would overtop the dam by about 0.4 foot. The spillway will pass 1,270 cfs or about 68 percent of the test flood. A major breach at top of dam could result in the loss of 3-5 lives and excessive property damage (See Section 5.1 f., page 5-1).

The owner, Enfield Water Department, should implement the results of the recommendations and remedial measures given in Sections 7.2 and 7.3 respectively, within one year after receipt of this Phase I inspection report.

Warren A. Guinan

Warren A. Guinan
Project Manager
N.H. P.E. 2339

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 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. 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

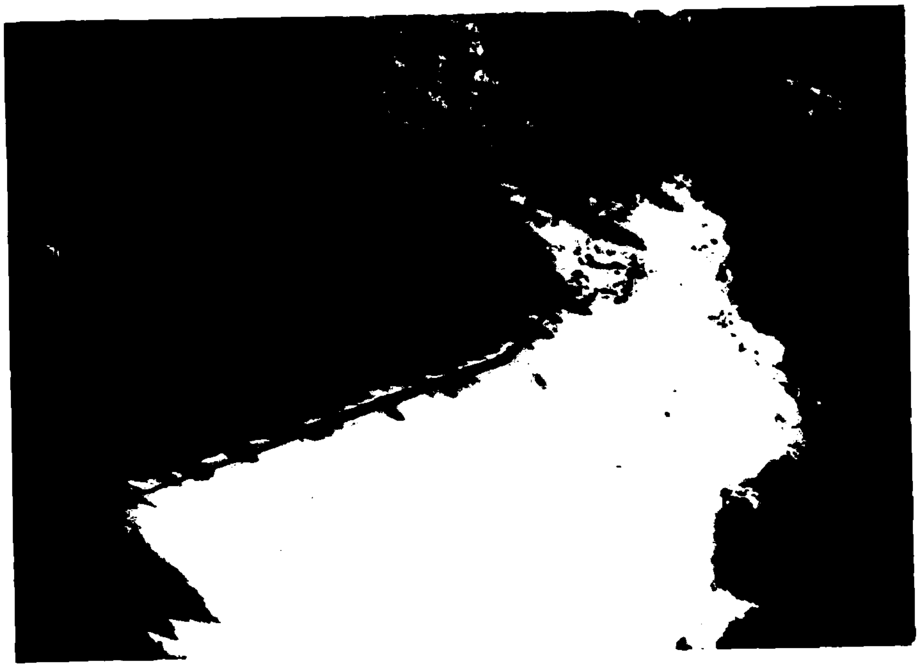
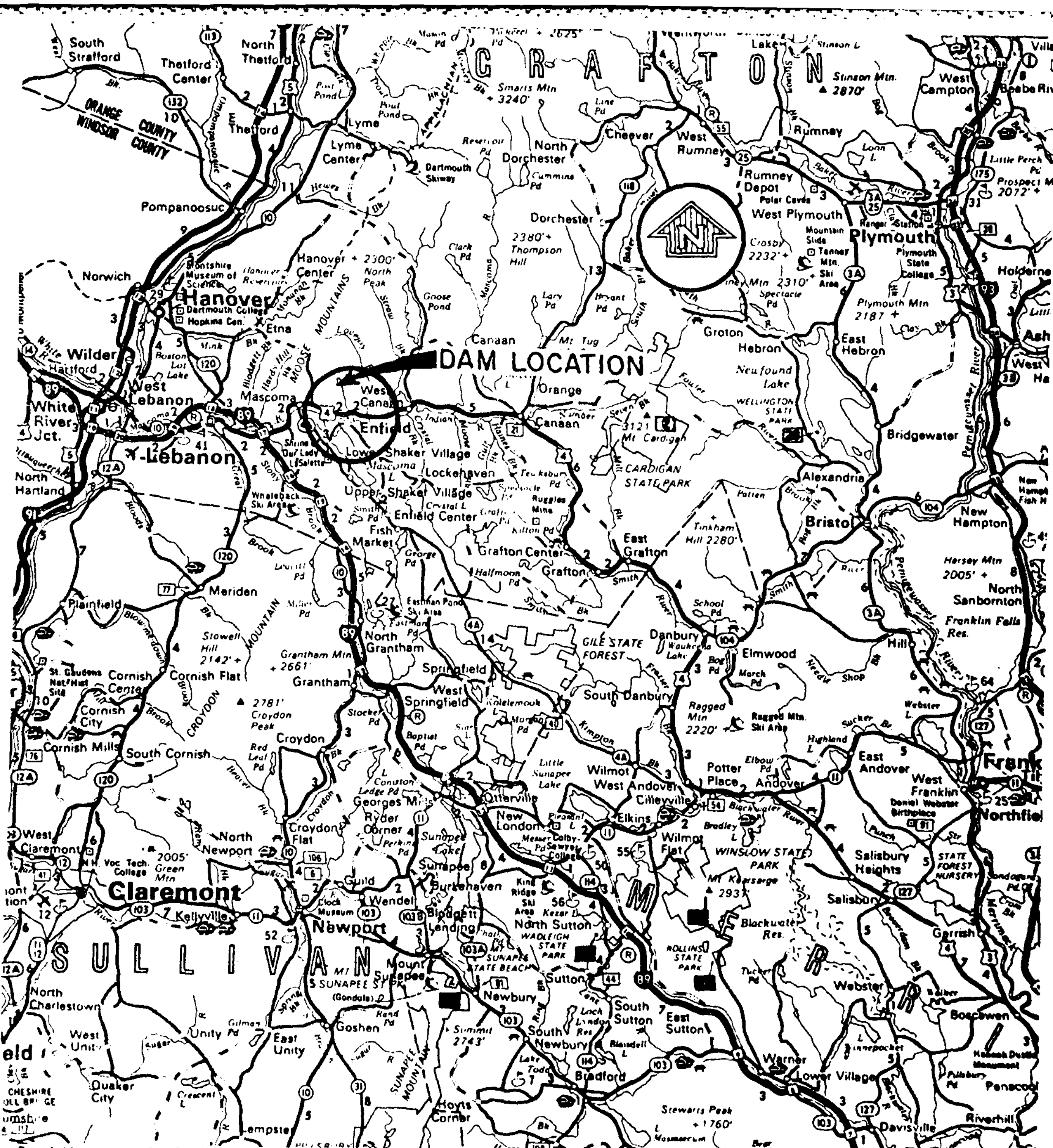


Figure 1 - Overview of Enfield Reservoir Dam.



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SCALE IN MILES

0 5 10

MAP BASED ON STATE OF NEW HAMPSHIRE OFFICIAL HIGHWAY MAP

Anderson-Nichols & Co., Inc. CONCORD NEW HAMPSHIRE	U.S. ARMY ENGINEER DIV. NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS.

NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

ENFIELD RESERVOIR DAM LOCATION MAP

ENFIELD RESERVOIR NEW HAMPSHIRE

			SCALE: SEE BAR SCALE
			DATE: APRIL, 1979

NATIONAL DAM INSPECTION PROGRAM
PHASE I INSPECTION REPORT
ENFIELD RESERVOIR 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. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. Anderson-Nichols & Company, Inc. 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 Anderson-Nichols & Company, Inc. under a letter of November 20, 1978 from Max B. Scheider, Colonel, Corps of Engineers. Contract No. DACW33-79-C-0009 has been assigned by the Corps of Engineers for this work.

b. Purpose

(1) To perform technical inspection and evaluation on 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 programs for non-Federal dams.

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

1.2 Description of Project

a. Location. Enfield Reservoir Dam is located in the Town of Canaan, New Hampshire. The dam spans a minor unnamed tributary of the Mascoma River in the Connecticut River Basin. The dam is shown on the U.S.G.S. Quadrangle, Mascoma, New Hampshire - Vermont with coordinates approximately at N43° 39' 48", W72° 09' 00", Grafton County, New Hampshire. (See Location Map, page vii.)

b. Description of Dam and Appurtenances. Enfield Reservoir Dam consists of an earthen embankment totaling 730 feet in length with a principal and emergency spillway, both located at the east end of the dam. The principal spillway is a 28-foot long concrete spillway with a 0.5-foot high stoplog.

This stoplog is broken at the center. The spillway crest, which is 3.4 feet below the top of the dam embankment, has a top width of about 2.5 feet The downstream face has a slight batter and the upstream face is sloped at about 10H:1V. Adjacent to the prinicpal spillway and extending 33 feet easterly is a section which would act as an emergency spillway. The crest of this emergency spillway is 2.5 feet below the top of the dam embankment crest. To the west of the spillway is an earthen embankment about 647 feet long that ties into natural ground. About 530 feet to the west of the spillway the dam alignment changes by about 33 degrees to the south. The upstream face of the embankment is protected with riprap while the crest and downstream face are grass covered. Located 320 feet west of the spillway is a gatehouse that controls the low-level outlet and the water supply conduit. The low-level outlet is a 12-inch diameter cast iron pipe. The gatehouse is about 8 feet upstream of the dam and accessible by a wooden footbridge.

c. Size Classification. Small (hydraulic height - 22 feet; storage - 208 acre-feet), based on storage ($\geq$50 to $<$1,000 acre-feet) as given in the Recommended Guidelines for Safety Inspection of Dams.

d. Hazard Classification. Significant hazard. A major breach in the dam could result in the possible loss of 3-5 lives and appreciable property damage. (See Section 5.1 f.)

e. Ownership. Enfield Reservoir Dam was built in 1903 by the Enfield Village Fire Precinct, the predecessor to the Enfield Village Fire District, which since has been dissolved. The dam is now owned by the Enfield Water Department.

f. Operator. The Enfield Water Department is responsible for the operation of the dam. Address: Town Clerk's Office, Main Street, Enfield, New Hampshire; Telephone: (603) 632-5001. The selectmen are the water commissioners.

g. Purpose of Dam. The dam impounding Enfield Reservoir was originally constructed to provide a water supply for the Enfield Village Fire Precinct. The dam and reservoir continue to be used for water supply.

h. Design and Construction History. Construction of the dam was completed in 1903 by the Stone Construction Company under the direction of Robert Fletcher, Consulting Engineer, Hanover, New Hampshire. No original design or construction information was found. A few sketch plans showing proposed changes were found in the files of the New Hampshire Water Resources Board (NHWRB). No records were found stating whether these changes were ever completed. Obtained from the Town of Enfield was a Report on Water Works Improvements, dated December 23, 1963, and performed by Camp, Dresser & McKee. Sections of this report can be seen in Appendix B. This report states that considerable leakage had been observed emanating from the western portion of the dam. It was recommended that a concrete corewall be constructed on the southwest wing of the dam where none existed. Corewall construction was begun and completed in October, 1963. Seepage at this area was reported to be decreased from 190 gpm to 10 gpm.

i. Normal Operational Procedures. No written operational procedures were disclosed. The water department flushes the water system intake two times per year. Maintenance such as mowing grass and cutting saplings is done on an as needed basis.

1.3 Pertinent Data

a. Drainage Area. The drainage area consists of 1.54 square miles (986 acres) of predominantly wooded terrain. The normal level has a surface area of 21 acres, which is equivalent to 2 percent of the watershed.

b. Discharge at Damsite

(1) Outlet works (conduit) - One low-level 12-inch diameter cast iron pipe @ invert elevation 928.0'. Conduit capacity at top of dam - 12 cfs @ 950.4' MSL.

(2) The maximum discharge at damsite is unknown. No records of past overtopping were disclosed.

(3) Ungated spillway capacity @ top of dam -

Principal spillway - 530 cfs @ 950.4' MSL
Emergency spillway - 740 cfs @ 950.4' MSL

(4) Ungated spillway capacity @ test flood elevation -

Principal spillway - 620 cfs @ 950.8' MSL
Emergency spillway - 760 cfs @ 950.8' MSL

(5) Gated spillway capacity @ top of dam - not applicable

(6) Gated spillway capacity @ test flood elevation - not applicable

(7) Total spillway capacity @ test flood elevation - 1380 cfs @ 950.8' MSL

(8) Total project discharge @ test flood elevation - 1860 cfs @ 950.8' MSL

c. <u>Elevation.</u> (feet above MSL; see (6) below)

(1) Streambed at centerline of dam - 928.0 (downstream toe)

(2) Maximum tailwater - unknown

(3) Upstream invert low-level outlet - 928.0 (approximate)

(4) Recreation pool - not applicable

(5) Full flood control pool - not applicable

(6) Spillway crest - 947 (Shown on USGS Quadrangle sheet and assumed to be principal spillway crest elevation.)

(7) Emergency spillway crest - 947.9

(8) Design surcharge (original design) - unknown

(9) Top of dam - 950.4

(10) Test flood pool - 950.8

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

(1) Length of maximum pool - 0.25 (approximate)

(2) Length of spillway crest pool - 0.25 (approximate)

(3) Length of flood control pool - not applicable

e. <u>Storage</u> (acre-feet)

(1) Recreation pool - not applicable

(2) Flood control pool - not applicable

(3) Spillway crest pool - 125 (approximate)

(4) Emergency spillway crest pool - 145

(5) Top of dam - 208 (approximate)

(6) Test flood pool-218 (approximate)

f. <u>Reservoir Surface</u> (acres)

(1) Recreation pool - not applicable

(2) Flood control pool - not applicable

(3) Spillway crest - 21 (approximate)

(4) Emergency spillway crest pool - 23 (approximate)

(5) Test flood pool - 29 (approximate)

(6) Top of dam - 28 (approximate)

g. Dam

(1) Type - earth embankment

(2) Length - 730'

(3) Height - 22' (structural height)

(4) Sideslope - approximately 2H:1V downstream and upstream

(5) Top width - approximately 10'

(6) Impervious core - heavy granite corewall placed on bedrock and heaving cement mortar joints from spillway to break in alignment; concrete corewall on southwest wing.

(7) Zoning - unknown

(8) Cutoff - unknown

(9) Grout curtain - none

h. Diversion and Regulating Tunnel - not applicable

i. Spillway

(1) Type - ungated concrete overflow principal spillway; emergency spillway that consists of an earthen embankment with a concrete corewall that ties into natural ground at east abutment.

(2) Length of weir - 28' principal; 33' emergency

(3) Crest elevation - principal spillway - 947.0' MSL
- emergency spillway - 947.9' MSL

(4) Gates - none

(5) U/S Channel - Enfield Reservoir. Rocks and sediment cover the bottom of the approach channel; the east shore of the reservoir along the outlet channel is covered with trees and brush.

(6) D/S Channel - The channel immediately downstream of the dam is bedrock. The banks are covered with trees and some brush. After discharging at the dam, the unnamed tributary flows about 1.4 miles before becoming confluent with the Mascoma River. Located along this reach is the May Street and the U.S. Route 4

crossings.

j. Regulating Outlets. The low-level reservoir drain conduit and the water supply main are the only controlled outlets. The gatehouse inlet is controlled by a 16-inch diameter gate valve that is operated manually by a wheel handle attached to a rising stem. The low-level outlet is a 12-inch diameter cast iron pipe controlled from the gatehouse by one valve. The water supply main is controlled by two valves. The gatehouse is accessible from the embankment via a wooden footbridge.

SECTION 2
ENGINEERING DATA

2.1 Design

No original design data were disclosed for Enfield Reservoir Dam. However, an undated memo addressed to Leonard (Frost, Water Resources Engineer, N.H.) subsequent to 1936 contains the following quotation,"....the Enfield Water Dept. apparently raised their flashboards to carry water appreciably above top of cutoff wall in embankment." (See Appendix B.) This statement implies that the dam contains a cutoff wall, but its extent is unknown. Sketches dated 1960 and 1962 were found and seem to relate to modification of the embankment and spillway. (See Appendix B.) Obtained from the Town of Enfield was a Report on Water Works Improvements, dated December 23, 1963, and performed by Camp, Dresser & McKee. Sections of this report can be seen in Appendix B. This report states there is a heavy granite rubble corewall placed on bedrock and having cement-mortar joints from the spillway to break in alignment. The report states that considerable leakage had been observed emanating from the western portion of the dam (at break of alignment). It was recommended that a concrete corewall be constructed on the southwest wing of the dam where none existed. Corewall construction was begun and completed in October, 1963. Seepage at this area was reported to be decreased from 190 gpm to 10 gpm.

2.2 Construction

No construction data were found other than that mentioned above.

2.3 Operation

No engineering operational data were disclosed.

2.4 Evaluation

a. Availability. Little engineering data were disclosed for Enfield Reservoir Dam. A search of the files of the NHWRB and contact with the owner revealed only a limited amount of recorded information.

b. Adequacy. Because of the limited amount of detailed data available, the final assessments and recommendations are based on the visual inspection, hydrologic and hydraulic calculations, and the sketch plans of the dam.

c. Validity. Visual inspection of the dam and spillway reflect that the sketch plans and sections seem related to the existing conditions but not in all details.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. General. Enfield Reservoir Dam is a low dam which impounds a reservoir of small size. The watershed above the reservoir is mountainous and heavily wooded. The downstream area is rolling and is wooded in the valley bottom along the channel.

b. Dam. Enfield Reservoir Dam is an earthen embankment with a hydraulic height of 22 feet, 730 feet long and 10 feet wide at the crest.

The portion of the upstream face of the embankment that was visible above the water level in the reservoir at the time of the inspection has a slope of 2H:1V.(See Appendix C-Figure 2.) Coarse riprap, with stones in the range of 1 to 3 feet in size, covers the upstream face from an elevation about one foot below the crest to an unknown elevation below the reservoir level. The riprap itself appears to be in good condition. There appears to be minor erosion and undermining of the turf on the upstream face along the top edge of the riprap. Several stumps of saplings (up to about 1-inch diameter) appear to have been cut recently on the upstream face. The crest of the dam is in good condition; it is covered with grass and appears to have been mowed regularly.(See Appendix C-Figure 3.)

The downstream face of the dam has a slope of 2H:1V (See Appendix C-Figure 4.). Near the top of the slope it is covered primarily with grass. Locally, near the top of the slope and more extensively near the bottom of the slope, it was covered with brush and coarse weeds; these had been cleared recently. The area immediately downstream of the toe is heavily wooded.

Several wet, soft areas were noted adjacent to the toe of the downstream slope, and in some of these areas water is standing. Visual inspection alone is not sufficient to determine whether these soft, wet areas are the result of seepage through and under the dam or are merely a reflection of a generally high water table in the valley immediately downstream of the dam. At one wet area near the directional change in alignment of the dam, water is discharging at about 10 gpm (0.02 cfs) and does appear to be due to seepage. (See also Section 6.1 c and Appendix B.)

The presence of a dense cover of trees, brush, and coarse weeds makes it difficult to inspect the area downstream of the dam.

c. Appurtenant Structures

(1) Concrete Overflow Spillway. A concrete principal spillway 28 feet long and an emergency spillway 33 feet long are located on the east abutment of the dam. (See Appendix C - Figures 5 and 6.) The crest of the principal spillway is 3.4 feet below the top of the dam embankment. The spillway crest is approximately 2.5 feet wide with the downstream face battered at approximately 1H:6V. The spillway was cast against an existing ledge bottom. The concrete was exposed at the time of the inspection and was observed to be in good condition. Erosion of the concrete surface was limited to the loss of surface laitance. One vertical crack through the primary spillway was observed near the center of spillway and appeared to be aged with no evidence of recent movement or instability.

The top of the concrete abutment of the west end of the spillway is about two feet lower than the crest of the earth embankment which is next to the abutment and is about 0.9 foot higher than the crest of the spillway. Therefore, if the spillway crest is overtopped more than 0.9 foot, erosion of the adjacent earth embankment is likely to occur. Evidence of erosion in the embankment here was observed.

A total of 8 stoplog supports and hold-down mechanisms are located on top of the primary spillway crest. (See Appendix C-Figure 5.) The steel supports were observed to be badly rusted, and the threads on the stoplog hold-down mechanisms badly deteriorated and bent. The two wooden stoplogs measuring approximately 6 inches high were badly deteriorated. One section approximately 3 feet wide has been ripped away.

(2) Gatehouse. A gatehouse is located near the center of the dam on the upstream face housing the control for the inflow to the Enfield water system and the low-level outlet. (See Appendix C - Figure 7.) The gatehouse and foundation were observed to be in good condition. The exterior face of the concrete wall has some deterioration near the water line. (See Appendix C - Figure 8.) The surface has eroded a maximum of 1 inch exposing the coarse aggregate. The service bridge to the gatehouse is 2-inch painted wood planking. The paint on the top surface of the deck has peeled exposing some of the wood to the weather.

From a discussion with Robert Blain, the Village of Enfield Water Commissioner, the gate valves were found to be exercised frequently to keep them in good operating condition and to flush the wet well. The inlet to the wet well is a 16-inch gate valve operated manually with a wheel handle attached to a rising stem. One gate valve controls the 12-inch diameter low-level reservoir drain conduit and two gate valves control the water supply main.

d. Reservoir Area. The watershed above the reservoir is mountainous and heavily wooded. No camps or other structures were noted on the shore of the reservoir. Gravel was noted behind the spillway; it is practically up to the spillway crest. It appears that this gravel was placed there as part of the construction (or rehabilitation) of the spillway.

e. Downstream Channel. The valley immediately downstream of the dam is broad, flat and heavily wooded. The discharge channel downstream of the overflow spillway is narrow and trees and brush overhang this channel. Bedrock is exposed in the channel immediately downstream of the spillway. The low-level outlet consists of a 12-inch diameter cast iron pipe.

The discharge channel downstream of the low-level outlet is narrow. (See Appendix C - Figures 10 & 11.) Trees and brush overhang this channel.

3.2 Evaluation

Based on the visual inspection, Enfield Reservoir Dam appears to be in fair condition.

The presence of extensive soft, wet areas near the downstream toe of the dam may indicate seepage through and under the dam. Seepage could lead to a potential stability problem. At one wet area near the directional change in alignment (See plan, p. B-24.) of the dam, water is discharging at about 10 gpm (0.02 cfs) and does appear to be due to seepage. Erosion and undermining of the turf immediately above the riprap on the upstream face could lead to serious deterioration of the top of the embankment if not corrected.

The discharge channels downstream of the overflow spillway and the low-level outlet are both narrow. Trees and brush overhang both channels.

A heavy cover of trees, brush and coarse weeds immediately downstream of the toe of the dam make it difficult to inspect that area, and it should be inspected again after the clearing operations recommended in 7.3 are completed.

There is a potential for erosion under high water conditions of the earth embankment where it abuts the west end of the spillway, because the embankment crest is about 2 feet higher than the top of the concrete abutment of the spillway. Some evidence of such erosion was observed.

The stoplog supports and holddowns are badly bent and rusted; the single stoplog has rotted leaving it in two pieces with a 3-foot gap.

SECTION 4
OPERATIONAL PROCEDURES

4.1 Procedures

No written operational procedures were disclosed for the Enfield Reservoir Dam. Oral communication with the water department indicates that they flush the water system 2 times per year. Mowing and cutting brush on the embankment is performed as required.

4.2 Maintenance of Dam

The Enfield Water Department is responsible for the maintenance of the Enfield Reservoir Dam.

4.3 Maintenance of Operating Facilities

Operating facilities are maintained by the Enfield Water Department. No formal maintenance program was disclosed.

4.4 Description of Any Warning System in Effect

No written warning system was disclosed for the Enfield Reservoir Dam.

4.5 Evaluation

The water department flushes the water system 2 times per year. The appearance of the dam indicates that some maintenance is performed such as mowing of grass and cutting of saplings. However, the condition of the stoplog and the stoplog supports, erosion at the spillway abutment and above the riprap on the upstream face of the embankment reflect that maintenance is incomplete.

SECTION 5
HYDROLOGY AND HYDRAULIC ANALYSIS

5.1 Evaluation of Features

a. General. Enfield Reservoir Dam impounds a pond having relatively little storage. The total length of the dam is 730 feet of which 28 feet consists of a primary spillway and 33 feet is emergency spillway. The dam is an earthen embankment structure in fair condition.

b. Design Data. No original hydrologic and hydraulic design data were found for Enfield Reservoir Dam.

c. Experience Data. In the undated memo addressed to Leonard (Frost, Water Resources Engineer), it is stated that the spillway is not designed for flashboards. At some unknown date, flashboards were installed on the spillway raising the level of the lake above the cutoff wall in the embankment. This resulted in leakage along the downstream slope and slumping of fill in the embankment.

d. Visual Observations. At the time of inspection, visual evidence of some minor erosion of the dam was noted. Erosion of the earth embankment above the cutoff wall on the west end of the spillway was observed. This was previously noted in a memo found in the NHWRB files (Appendix B).

e. Test Flood Analysis. Enfield Reservoir Dam is classified as small, having a hydraulic height of 22 feet and a maximum storage capacity of 208 acre-feet. The dam impounds a reservoir of small size, containing runoff from a 1.54 $mi.^2$ drainage area characterized by mountainous, forested terrain. Using a CSM value of 2550, a Probable Maximum Flood (PMF) of 3,927 cfs was obtained. The Recommended Guidelines for Safety Inspection of Dams dictated use of ½ the PMF.

Using ½ PMF, the test flood inflow was determined to be 1,960 cfs. After routing the test flood discharge was calculated to be 1,860 cfs, reflecting negligible surcharge storage effects on reducing inflows. The overtopping analysis indicates that the dam would be overtopped by 0.4 feet during the test flood. The maximum spillway capacity at top of dam is 1,270 cfs, which is about 68% of the test flood discharge. Because of the condition of the stoplogs and the recommendation made in Section 7.3 a. (8), the stoplogs were not considered in the analysis.

f. Dam Failure Analysis. The impact of failure of the dam at top of dam was assessed using the Guidance for Estimating Downstream Dam Failure Hydrographs issued by the Corps of Engineers. The analysis covered the reach extending from the dam to U.S. Route 4, a distance of about 7,200 feet downstream. A breach at top of dam would raise the stage at May Street crossing (double barrel culvert located 6,100 feet downstream of dam) by about 4 feet, bringing the total stage to six feet above top of road. Three inhabited structures located just upstream of May Street would be inundated by at least 4.5 feet of water. Downstream of May Street two inhabited structures would experience about 3 feet of flooding. Appreciable property damage and loss of 3-5 lives could occur.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations. The visual examination indicates the following evidence of potential problems:

(1) Extensive wet, soft areas adjacent to the downstream toe of the dam which may be the result of seepage through and under the embankment, and one area where seepage is actively discharging (at change of alignment).

(2) Erosion and undermining of the turf directly above the riprap on the upstream face.

(3) Narrow discharge channels which are overhung by trees and brush downstream of the overflow spillway and low-level outlet.

(4) Potential for erosion of the crest caused by overtopping of the west abutment of the spillway.

Because there is a heavy cover of trees, brush, and coarse weeds downstream of the toe of the dam, it was difficult to inspect that area for other evidence of potential problems, and such an inspection should be made after the area is cleared.

b. Design and Construction Data. The original dam was built in the period 1901-1903. No data pertinent to either the design or construction for that period were disclosed.

c. Operating Records. One undated memorandum from the files of the NHWRB contains the following statements:

> "....the Enfield Water Department apparently raised their flashboards to carry water appreciably above top of cutoff wall in embankment. This caused a slumping of the fill and several leaks have developed at toe and partway up downstream slope. They have lowered top of flashboards now but leaks continue...."

> "....In 1937, they stoned the dyke and regraded top for 600 feet. Did cement job on spillway."

> "Apparently has been slight leak at right end where angle in dam due to fault in ledge foundation but apparently didn't get worse. (1936)...."

d. Post Construction Changes. Two sketch drawings dated 1960 and one dated 1962, and an undated memorandum indicate that plans were made to raise and rehabilitate both the embankment and the spillway. There are no records to indicate whether this work was carried out. Visual evidence reflects that some of the planned work was accomplished although not in strict accord with the sketches. Embankment slopes were made 2H:1V; however, a west training wall about 36 feet long and extending 2'-8" above faced top of spillway section to top of embankment was not accomplished. Had this wall been constructed the erosion noted would have been prevented. In addition, the sketch plans call for deepening the channel upstream of the spillway. Instead of deepening, it appears that gravel has been dumped in the approach channel up to the crest elevation. In the Report on Water Works Improvements, done by Camp, Dresser & McKee in December 1963, it is recommended that a concrete corewall be constructed on the southwest wing of the dam. It is stated that corewall construction was begun and completed in October 1963. (See Appendix B.)

e. Seismic Stability. This dam is located in Seismic Zone 2 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. The visual inspection indicates that the Enfield Reservoir Dam is in fair condition. Major concerns with respect to the integrity of the dam are:

(1) Extensive wet, soft areas adjacent to the downstream toe of the dam, which may be the result of seepage through and under the embankment, and one area where seepage is actively discharging (at change of alignment).

(2) Minor erosion and undermining of the turf directly above the riprap on the upstream face.

(3) Potential for erosion of the embankment at the west abutment of the spillway under high discharges.

In addition, there are trees and brush overhanging the narrow discharge channels downstream of the overflow spillway and low-level outlet.

b. Adequacy of Information. The information available is such that the assessment of this dam must be based primarily on the visual inspection. The presence of trees, brush, and coarse weeds immediately downstream of the toe of the dam made it difficult to inspect that area, and an inspection should be made when the trees, brush, and weeds have been removed.

c. Urgency. The recommendations and remedial measures made in 7.2 and 7.3 below should be implemented by the owner within 1 year after receipt of this Phase I report.

d. Need for Additional Investigation. The information available from the visual inspection is adequate to identify the potential problems that are listed in 7.1 a. above. An inspection of the area immediately downstream of the toe of the dam after the trees, brush and weeds have been cleared should be made. Further engineering studies are needed of spillway adequacy and the observed erosion at the spillway.

7.2 Recommendations

The owner should engage a Registered Professional Engineer to:

(1) Recommend corrective measures regarding inadequate spillway capacity.

(2) Remove trees, brush, and weeds for a distance of 25 feet downstream from the downstream toe of the dam.

(3) Investigate the wet, soft areas downstream of the toe, and if needed, design seepage control measures.

(4) Raise the west abutment of the spillway to top of dam elevation.

7.3 Remedial Measures

a. Operating and Maintenance Procedures. The owner should:

(1) Provide adequate erosion protection on the upstream slope between the top of the riprap and the crest of the dam, and between top of west spillway abutment and top of dam embankment.

(2) Clear the trees and brush for a distance of 20 feet on either side of the spillway discharge channel and the low-level outlet discharge channel and for a distance of 200 feet downstream from the dam to the limits of town property, whichever is less.

(3) Visually inspect the dam and appurtenances once each month.

(4) Establish a surveillance program for use during and immediately after heavy rainfall and also a warning program to follow in case of emergency conditions.

(5) Engage a Registered Professional Engineer to make a comprehensive inspection of the dam once every year.

(6) Repair spalled concrete at gatehouse.

(7) Remove stoplog supports and hold-down mechanisms.

7.4 Alternatives

No reasonable alternatives are recommended.

APPENDIX A

VISUAL INSPECTION CHECKLIST

VISUAL INSPECTION CHECKLIST
PARTY ORGANIZATION

PROJECT Enfield Reservoir Dam, N.H. DATE November 8, 1978

TIME 8:30 AM

WEATHER Clear, cloudy, 45°F

W.S. ELEV. U.S. 945.6 DN.S. ____

PARTY:

1. Robert Langen	6.
2. Stephen Gilman	7.
3. Douglas Ford	8.
4. Robert Ojendyk	9.
5. Ronald Hirschfeld	10.

PROJECT FEATURE	INSPECTED BY	REMARKS
1. Hydrology/Hydraulics	R. Langen/D. Ford	
2. Structural Stability	S. Gilman	
3. Soils & Geology	R. Hirschfeld	
4.		
5.		
6.		
7.		
8.		
9.		
10.		

PERIODIC INSPECTION CHECKLIST

PROJECT Enfield Reservoir Dam, N.H. DATE ~~November 8, 1978~~

PROJECT FEATURE Dam Embankment NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
DAM EMBANKMENT	
Crest Elevation	950.4' MSL
Current Pool Elevation	945.6' MSL
Maximum Impoundment to Date	Unknown
Surface Cracks	None apparent
Pavement Condition	Not paved
Movement or Settlement of Crest	None apparent
Lateral Movement	None apparent
Vertical Alignment	Good
Horizontal Alignment	Good
Condition at Abutment and at Concrete Structures	Good
Indications of Movement of Structural Items on Slopes	None apparent
Trespassing on Slopes	None apparent
Sloughing or Erosion of Slopes or Abutments	None apparent
Rock Slope Protection - Riprap Failures	Riprap on upstream slope, in good condition
Unusual Movement or Cracking at or Near Toe	None apparent
Unusual Embankment or Downstream Seepage	Several wet, soft areas close to downstream toe; some standing water
Piping or Boils	None apparent
Foundation Drainage Features	None apparent
Toe Drains	None apparent
Instrumentation System	None
Vegetation	Grass on crest and downstream slope; stumps of some brush, up to about 1" dia. on upstream edge of crest and on downstream slope.

PERIODIC INSPECTION CHECKLIST

PROJECT Enfield Reservoir Dam, N.H. DATE November 8, 1978

PROJECT FEATURE Outlet Works NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
OUTLET WORKS - INTAKE CHANNEL AND INTAKE STRUCTURE	
a. Approach Channel	No approach channel, gatehouse is on upstream face of dam near center of valley.
Slope Conditions	
Bottom Conditions	Not applicable
Rock Slides or Falls	Not applicable
Log Boom	Not applicable
Debris	Not applicable
Condition of Concrete Lining	Not visible
Drains or Weep Holes	Not visible
b. Intake Structure	
Condition of Concrete	Surface eroded to ¼", exposed aggregate . Fair condition.
Stop Logs and Slots	None

PERIOD INSPECTION CHECKLIST

PROJECT Enfield Reservoir Dam, N.H. DATE November 8, 1978

PROJECT FEATURE Outlet Works NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
OUTLET WORKS - TRANSITION AND CONDUIT	
General Condition of Concrete	Not visible
Rust or Staining on Concrete	Not applicable
Spalling	Not applicable
Erosion or Cavitation	Not applicable
Cracking	Not applicable
Alignment of Monoliths	Not applicable
Alignment of Joints	Not applicable
Numbering of Monoliths	Not applicable

PERIODIC INSPECTION CHECKLIST

PROJECT Enfield Reservoir Dam, N.H. DATE November 8, 1978

PROJECT FEATURE Spillway NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
OUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS	
a. Approach Channel	
General Condition	Good
Loose Rock Overhanging Channel	None
Trees Overhanging Channel	None
Floor of Approach Channel	Channel filled with gravel up to elevation of crest of weir.
b. Weir and Training Walls	
General Condition of Concrete	Surface laitance gone - one 1/8" vertical crack from top to bottom
Rust or Staining	At stoplog supports
Spalling	Little
Any Visible Reinforcing	None
Any Seepage or Efflorescence	None visible
Drain Holes	None
c. Discharge Channel	
General Condition	Fair
Loose Rock Overhanging Channel	None
Trees Overhanging Channel	Many small trees, up to 2-inch dia overhanging channel
Floor of Channel	Cobbles and boulders, bedrock immediately next to weir.
Other Obstructions	None
d. Stoplogs	2"x 6" deteriorated - one section missing. Hold down mechanism rusted.

PERIODIC INSPECTION CHECKLIST

PROJECT Enfield Reservoir Dam, N.H. DATE November 8, 1978

PROJECT FEATURE Outlet Works NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
OUTLET WORKS - OUTLET STRUCTURE AND OUTLET CHANNEL	
General Condition of Concrete	Outlet of 12" CI pipe visible and in fair condition; stone masonry headwall.
Rust or Staining	Not applicable
Spalling	Not applicable
Erosion or Cavitation	Not applicable
Visible Reinforcing	Not applicable
Any Seepage or Efflorescence	Not applicable
Condition at Joints	Not applicable
Drain holes	None apparent
Channel	
Loose Rock or Trees Overhanging Channel	Trees and brush overhang discharge channel.
Condition of Discharge Channel	Fair

PERIODIC INSPECTION CHECKLIST

PROJECT Enfield Reservoir Dam, N.H. DATE November 8, 1978

PROJECT FEATURE Service Bridge NAME

DISCIPLINE NAME

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - SERVICE BRIDGE</u>	
a. Super Structure	
Bearings	Not applicable
Anchor Bolts	Not applicable
Bridge Seat	Not applicable
Longitudinal Members	Painted wood - fair condition
Underside of Deck	Not visible
Secondary Bracing	None apparent
Deck	2" thick wood - fair condition
Drainage System	Not applicable
Railings	Not applicable
Expansion Joints	None
Paint	Some peeling
b. Abutment & Piers	
General Condition of Concrete	Not applicable
Alignment of Abutment	Not applicable
Approach to Bridge	Not applicable
Condition of Seat & Backwall	Not applicable

PROJECT Enfield Reservoir Dam

DATE November 8, 1979

PROJECT FEATURE Reservoir

NAME D. Ford

AREA EVALUATED	REMARKS
Stability of Shoreline	Good
Sedimentation	Minor
Changes in Watershed Runoff Potential	None
Upstream Hazards	None
Downstream Hazards	Houses adjacent to stream about 1 mile downstream; May Street and U.S. Route 4 crossings.
Alert Facilities	None posted
Hydrometeorological Gages	None
Operational & Maintenance Regulations	None posted

APPENDIX B

ENGINEERING DATA

State of New Hampshire

WATER RESOURCES BOARD

37 Pleasant St.
CONCORD 03301

January 19, 1976

Town of Enfield
Enfield
New Hampshire 03748

Gentlemen:

Under the provisions of RSA-Chapter 482, Sections 8 through 15, the New Hampshire Water Resources Board is authorized to inspect all dams in the state which by reason of their physical condition, height, and location may be a menace to the public safety.

The dam structure (Dam # 36.08) located on your property in Canaan, N.H. was inspected on August 18, 1975 and as a result of this inspection no discrepancies were found at the time of the inspection which would require any corrective measures.

This letter is provided for your information only. If you have any questions, please feel free to call or write.

Sincerely,

George M. McGee, Sr.

George M. McGee, Sr.
Chairman

GMM/SCB:L

cc: Board of Selectmen
Canaan

N. H. WATER RESOURCES BOARD
Concord, N. H. 03301

DAM SAFETY INSPECTION REPORT FORM

Town: Canaan   Dam Number: 36.08

Inspected by: S Burritt   Date: 18 Aug 1975

Local name of dam or water body: Enfield Res

Owner: Town of Enfield   Address: ______

Owner was/was not interviewed during inspection.

Drainage Area: ______ sq. mi.   Stream: ______

Pond Area: 2 20± Acre, Storage 200 Ac-Ft. Max. Head 15' Ft.

Foundation: Type Earth & Ledge, Seepage present at toe - Yes/No ______

Spillway: Type Over flow, Freeboard over perm. crest: 2,

Width 30' ± in flash board Area, Flashboard height 1',

Max. Capacity ______ c.f.s.

Embankment: Type Earth, Cover Grass Width 15' ±,

Upstream slope 2 to 1; Downstream slope 2 to 1

Abutments: Type Concrete, Condition: Good, Fair, Poor

Gates or Pond Drain: Size ? Capacity ______ Type Pipe

Lifting apparatus ______ Operational condition ?

Changes since construction or last inspection: ______

Downstream development: ______

This dam would/would not be a menace if it failed.

Suggested reinspection date: ______

Remarks: ______

NEW HAMPSHIRE
WATER RESOURCES BOARD

SITE EVALUATION DATA

OWNER: Town of Enfield TELEPHONE NO.

MAILING ADDRESS: Enfield

SITE LOCATION (TOWN OR CITY) Canaan

NAME OF STREAM OR WATERBODY: Enfield Res

QUADRANGLE: LOCATION

HEIGHT OF (PROPOSED, EXISTING) DAM 15 LENGTH 700'

TYPE OF (PROPOSED, EXISTING) STRUCTURE Earth embankment with concrete overflow spillway

DRAINAGE AREA POND AREA 20 A

AVAILABLE ARTIFICIAL STORAGE: PERMANENT: TEMPORARY: TOTAL 200 A

EXISTING DEVELOPMENT DOWNSTREAM OF (PROPOSED, EXISTING) STRUCTURE

Enfield Village Approx 1 mi

POTENTIAL DEVELOPMENT DOWNSTREAM OF (PROPOSED, EXISTING) STRUCTURE

POTENTIAL DAMAGE DOWNSTREAM OF STRUCTURE (EXPLAIN IN DETAIL AND INCLUDE ANY POTENTIAL LOSS OF LIFE ESTIMATE) Possable damage To Roads

OTHER COMMENTS:

CLASS OF STRUCTURE -- NON MENACE: MENACE A B C DAM # 36.03

DATE OF INSPECTION: 19 Aug 75

SIGNED S Burnett

SIGNATURE

DATE:

THOMAS R. CAMP
HERMAN G. DRESSER
JOSEPH C. LAWLER
ROLAND S. BURLINGAME
DARRELL A. ROOT
ROBERT H. CULVER
FRANK L. HEANEY
JOSEPH E. HENEY
R. ERNEST LEFFEL
FRANK T. SMITH, JR.
BERNAL H. SWAB

CAMP, DRESSER & McKEE
CONSULTING ENGINEERS
18 TREMONT STREET
BOSTON 8, MASSACHUSETTS
TELEPHONE RICHMOND 2-1710

WATER RESOURCES
WATER AND AIR POLLUTION
WATER WORKS - WATER TREATMENT
SEWERAGE - WASTES TREATMENT
REFUSE DISPOSAL - FLOOD CONTROL
REPORTS DESIGN SUPERVISION

December 23, 1963

Mr. Clinton Tupper
Board of Commissioners
Enfield Village Fire District
Enfield, New Hampshire

Dear Mr. Tupper: Report on Water Works Improvements

In accordance with the terms of our proposal to the Enfield Village Fire District, dated April 12, 1963 and accepted verbally by the Commissioners, we have made an engineering investigation, and present herewith our report of the problem of water supply and distribution for the Enfield Village Fire District. The results of our investigations are described in detail in the main body of the report, together with preliminary plans and cost estimates. Our conclusions and recommendations are summarized below.

Summary

Source of Supply

The Enfield Village Fire District has obtained water from the Enfield Reservoir since 1903. This reservoir was formed by the construction of an earth-filled dam on bedrock with a corewall of granite-rubble for the major portion of the dam's length. Through the years considerable leakage has been observed emanating from the western portion of the dam. During a drought it becomes necessary to pump water from Mascoma Lake into the system to supplement the supply. It has been necessary to pump from Mascoma Lake for nearly a month in both 1961 and 1963.

We have made studies of the adequacy of the present supply and find that, even with the relatively high rate of water consumption which presently prevails in the Village, the existing supply is adequate to meet the demands of the District, at least to the year 2000, provided that the considerable amount of leakage through the dam which occurs at or near full pond level is reduced or greatly diminished.

Investigations made in the summer of 1963 of the nature of the composition of the Enfield dam, and subsequent discussion of our observations with

Dr. Aldrich of Haley & Aldrich, Inc., Consulting Soil Engineers, of Cambridge, Massachusetts led us to recommend the construction of a concrete corewall on the southwest wing of the dam where none existed. Corewall construction was begun on October 7, 1963 and completed on October 19, 1963 under our supervision. Although the leakage has appeared to be drastically reduced, the degree of success of the construction cannot be evaluated until the reservoir has been filled. There are indications that a certain amount of leakage persists through deeper crevices and that its prevention can only be accomplished by a pressure grouting operation. Measurements necessary to ascertain the volume of leakage which still persists at full pond will indicate whether or not pressure grouting can be economically justified as outlined in Dr. Aldrich's letter appended to this report.

We recommend that the District engage the services of a qualified land surveyor or engineer to make the necessary measurements for the purpose of constructing an elevation-volume (storage) curve for the Enfield Reservoir in order to assist in the operation of the supply.

Distribution System

Our investigations show that major reinforcement of the periphery of the distribution system is necessary if water is to be made available for fire protection in the amounts recommended by the Fire Underwriters' standards. High resistance to flow is offered by the many 4-in and 6-in mains in the existing system, the carrying capacity of which has been reduced further by corrosion since their installation over fifty years ago.

Tests of the water meter located in the chlorination vault on Maple Street indicated the main-line meter to be recording only 67 per cent to 74 per cent of the actual flow; therefore, we recommended its immediate repair.

Although no significant leakage was found in the distribution system, there is evidence that household water waste is significant. Therefore, we recommend that metering of households be undertaken upon completion of the metering program for commercial and industrial consumers. A rigid plumbing inspection should be undertaken to reduce household waste and the inspection repeated periodically until the metering program is completed.

The Public Works Acceleration Act of 1962 (Public Law 87-658) authorized the allocation of $900 million for public works projects across the nation. Grants-in-aid from 50 to 75 per cent of the cost may be made to those public works projects of communities for which Federal financial assistance is authorized under the terms of this Act. It is our understanding that the Town of Enfield is eligible for APW aid. Although it may not be possible to obtain a grant this year, should the District desire to embark on a program of rehabilitating the system, it would be to its advantage to file application immediately with the Federal government for a grant if and when more funds become available.

Acknowledgements

We wish to express our appreciation for the cooperation we received from the District Commissioners. We wish to acknowledge the information provided by Mr. William Laffee, the assistance provided by Mr. William Hayes, Jr. and Mr. Clinton Tupper in conducting the leakage study, and for his participation in nearly all phases of the investigation. We are grateful to Dr. Harl P. Aldrich, Jr. of Haley & Aldrich, Inc., Consulting Soil Engineers, of Cambridge, Massachusetts for guiding our inspections and subsequent recommendations relative to the studies at the dam. To these individuals and any others who cooperated or participated directly in the investigation, we express our sincere thanks.

Very truly yours,

CAMP, DRESSER & McKEE

By Roland S. Burlingame

Roland S. Burlingame

RSB/w

Enfield Village Fire District
Enfield, New Hampshire

Report on Water Works Improvements

List of Figures

List of Tables

SOURCE OF SUPPLY

General

The Enfield Village Fire District has derived its water from the present source of supply since 1903. This source of supply is a reservoir located about 1.5 miles north of Enfield Village formed by the construction of an earth-filled dam on bedrock with a granite-rubble corewall for the major portion of its length. The Enfield Reservoir has served the village well during its 60 years of existence even though considerable leakage has been observed emanating from the west 100 ft section of the dam. It is very likely that this leakage has existed for a number of years, for attempts have been made by local citizens in the past to reduce this waste of the supply. During a year of ample rainfall this leakage may not be serious, but during a drought water must be pumped from Mascoma Lake to supplement the supply. It was necessary to pump from Mascoma Lake in the summer of 1961 for nearly a month, and in 1963, pumping was begun on October 7 and continued until the pumping equipment broke down at the end of the month.

Safe Yield

The safe yield of a water supply is defined as the maximum dependable draft which can be made continuously upon a source of water supply during a period of years during which the probable driest period, or period of greatest deficiency of water supply, is likely to occur. In order to determine the adequacy of a water supply to meet the needs of a community, the safe yield of the supply must be ascertained and the water consumption requirements of the community determined. The water consumption of the Enfield Village Fire District is as shown in Table 1.

TABLE 1. WATER CONSUMPTION OF THE ENFIELD VILLAGE FIRE DISTRICT

	Total for Period	Average Per Day	*Corrected Average Per Day
1963 (Jan-June only)	29,108,000 gallons	160,400 gallons	225,000 gallons
1962	60,417,300	165,300	232,000
1961	64,813,200	177,400	250,000

*Corrected according to comparison of actual measured quantities of flow with those recorded on main-line meter.

The Fire District system presently serves an estimated 1,100 persons based on 315 services at an average of 3.5 persons per service. It can be seen from the above figures, therefore, that the consumption is equivalent to about

200 gpcd (gallons per capita per day). For a village of the nature of Enfield, we would expect the average use to not exceed 60 or 75 gpcd unless a substantial amount of water is being used for commercial or industrial purposes or is being lost in leakage in the system. In any event, even if the present high consumption rate of 250, 000 gpd (gallons per day) were to continue until the year 2010 and the district population increases from 1, 100 persons to 1, 800 persons (New Hampshire Department of Public Health estimates 1, 400 persons in the year 2010), the demand on the system would be but 410, 000 gpd.

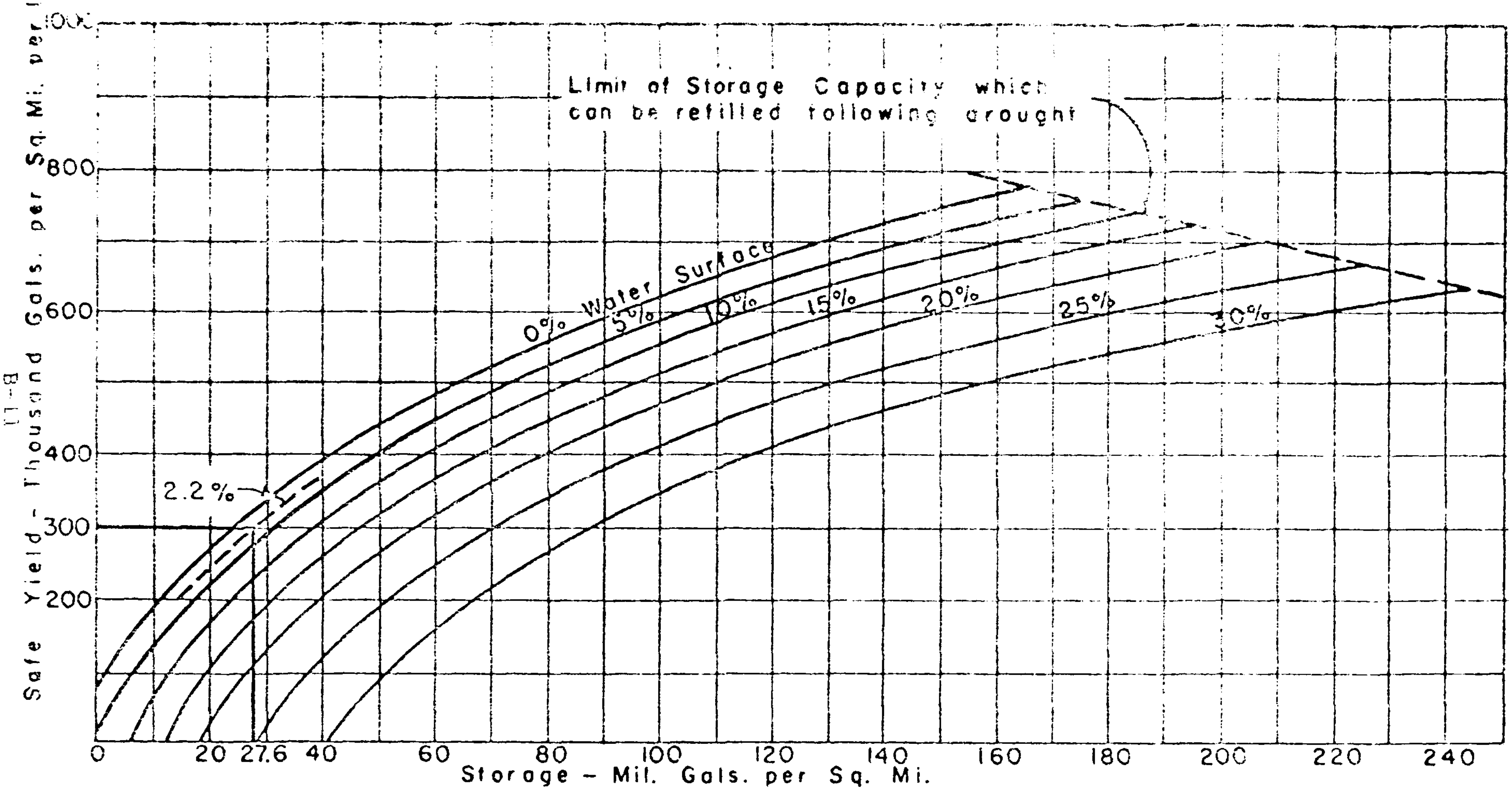
In order to make a reliable estimate of the safe yield of water supply, it is desirable to have a continuous record of water runoff at the source of supply month by month over a long period of years, including several consecutive years of continuous drought. In the absence of such records, records of similar nearby drainage areas or watersheds may be used with judgment. In 1914 and in 1945, the New England Water Works Association compiled runoff data from a number of watersheds located in New England. The results of this study are shown on Fig. 1.

There are four factors which govern the yield of a surface water supply: the amount of rainfall, the area of runoff or watershed area, the volume of storage, and the amount of exposed water surface. The effect of rainfall and drainage area are obvious. Storage is required to collect water during periods of high runoff for use during periods of low runoff and high consumption. However, if the volume of potential depletion is greater than can be refilled by runoff, the excess storage is of no value in increasing the safe yield. The limit of storage which can be refilled following a drought is shown by means of a broken line on Fig. 1. The amount of exposed water surface has a substantial effect on the safe yield of a supply in that evaporation takes place from the water surface. It may be seen from Fig. 1 that the safe yield of a supply decreases considerably as the amount of water surface increases.

The Enfield Dam impounds a reservoir of 21 acres in surface area at full pond and has an estimated total usable storage of 41.4 mg (million gallons). The drainage area of the stream at the dam site is 1.5 sq miles (960 acres). From Fig. 1 it can be seen that for a usable storage of 27.6 mg per square mile and a 2.2 per cent ratio of water surface to drainage area, a safe yield of 300, 000 gals per square mile per day can be counted on. This amounts to a safe yield of 450, 000 gpd for the Enfield Reservoir, which is more than the 410, 000 gpd previously cited as a high demand estimated for the year 2010. The reason for the reservoir appearing to be inadequate for even a present day demand of only 250, 000 gpd is explained by the fact that a considerable amount of leakage of water has been occurring through the dam.

Enfield Dam

Construction of the Enfield Reservoir was completed in the summer of 1903, by the Stone Construction Company under the direction of Robert Fletcher,



YIELD OF WATERSHEDS IN NEW ENGLAND

Based on Composite from N.E.W.W.A. Reports of 1914 & 1945

Camp, Dresser & McKee
Consulting Engineers
Boston, Mass.

FIG. I

consulting engineer, of Hanover, New Hampshire. The dam is a gravity-type 755 ft long including a 40 ft long spillway and is composed of a heavy granite rubble corewall placed on bedrock for the most part and having cement-mortar joints. On top of the corewall an impervious fill has been placed and compacted up to the top of the dam. This corewall extends for a distance of 650 ft along the main axis of the dam (bearing N 76° - 30' E magnetic) and varies in height from a minimum of 4.5 ft just west of the spillway to a maximum of 13.5 ft east of the gate house. The remaining 105 ft portion of the dam deflects at an angle of 31° - 45' from the main axis toward the southwest. We have found that this portion of the dam is composed of the impervious fill resting directly upon a shallow zone of natural soil and weathered rock atop the bedrock, there being no corewall.

Over a period of years water has appeared on the downstream toe of the dam adjacent to the deflection point, and the question has arisen as to whether the source of this water was from leakage through the dam or from springs. On July 1, 1963, we made three determinations of the flow issuing from the downstream toe of the dam adjacent to the deflection point and estimated the leakage to be about 170 gpm (gallons per minute). Another leak at the west end of the concrete spillway was observed to be about 20 gpm. The total leakage through the dam therefore was about 190 gpm with the reservoir water level less than 1 ft below the top of the flashboards (almost 4 ft below the top of the dam). On July 26, 1963, Test Pit No. 1 was dug along the axis of the dam at Sta. 1+00 (5 ft SW of the deflection point). The water level in the reservoir was 4 ft below the top of the dam. Examinations of the bedrock at this location revealed it to be sound while examinations of the embankment soils revealed them to be relatively impervious - sandy silt, silty sand, some clay and fine gravel. The small amount of inflow to the pit (less than 0.1 gpm) served to indicate this area to be trouble free. The contention that the water appearing on the downstream toe of the dam was spring water was dispelled by a study of water temperatures at various depths in the reservoir as well as in the pit and on the downstream toe. Fig. 2 shows the findings of Test Pit No. 1 and the water temperatures observed. The variance of flow with reservoir stage also seemed to discount the spring theory. Subsequent determinations on two later dates indicated that the rate of flow varied with the water level of the reservoir;as the water level decreased so did the rate of flow.

On August 17, 1963, Test Pit No. 2 was dug at Sta. 1+15, 10 ft East of the deflection point. The water level in the reservoir was 6 ft below the top of the dam on this date. At this location the earth fill rests directly on the granite corewall. Owing to the depth of the earth fill, the inadequate maneuvering area for the backhoe, and the limited space available atop the dam for storing the excavated material, the backhoe could not excavate deeper than about 9 ft. The hole was further deepened by hand, and the corewall sounded with an iron bar. The excavated material was uniform with a noticeable increase

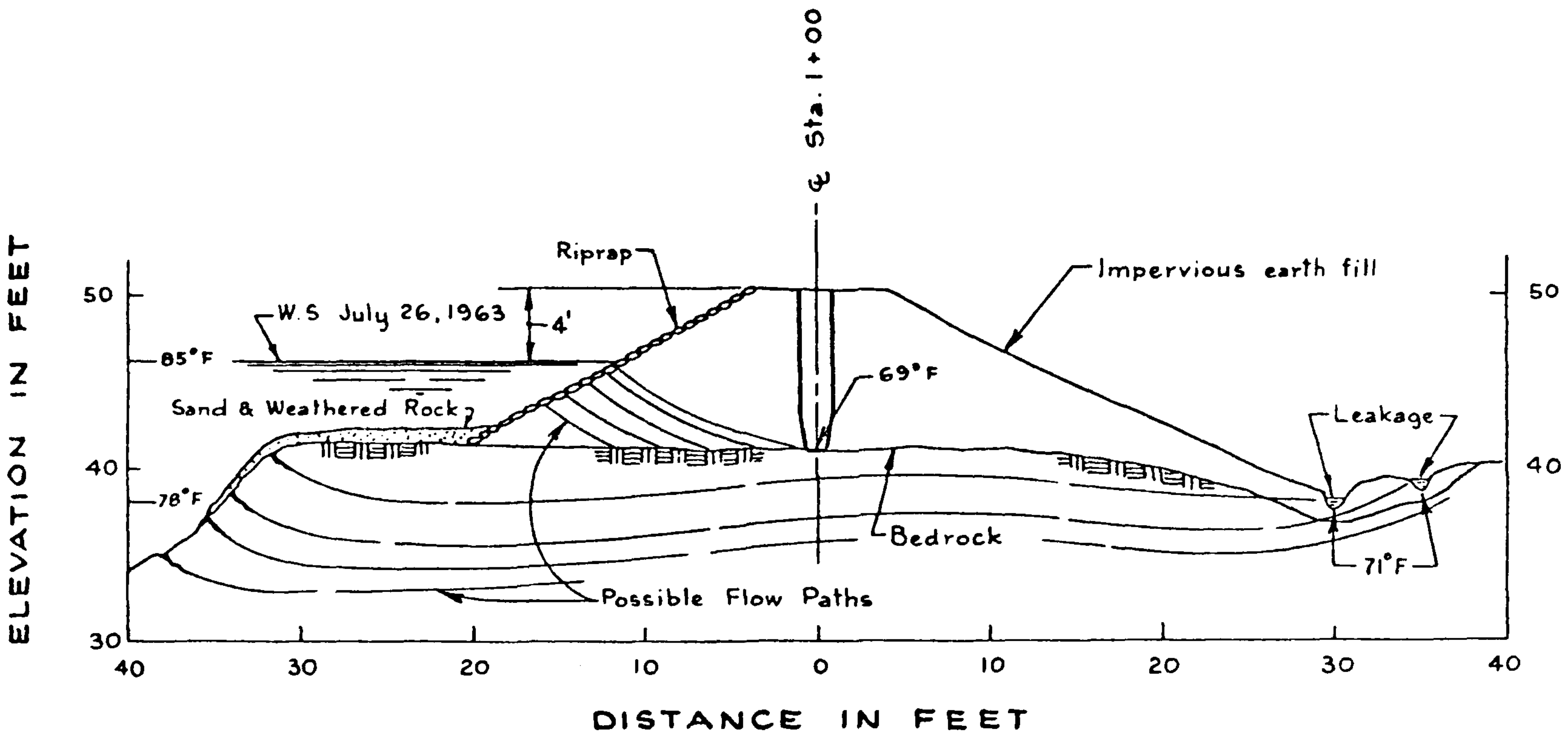


FIG.2 TEST PIT NO.1 - JULY 26, 1963

316-5428

in clay content on the bottom foot or so. The corewall was sounded within 3-in of the plan depth, the walls being the full depth, with a slight increase in dampness noticeable below 8 ft. Only a very little water entered the pit.

Test Pit No. 3 was also dug on August 17, 1963, with some most interesting findings. The embankment soil was found to be saturated at a depth not much greater than the then reservoir level. The water filled this test pit much faster than it had either of the two previous pits. Most unusual, however, was the absence of bedrock at the plan depth in this pit - instead, fractured bedrock was observed for 1 ft to 2 ft below the level of bedrock indicated on the plans. This observation seemed to support the theory that seepage was most likely occuring in a shallow zone of natural soil and weathered rock sandwiched between compacted fill and sound bedrock. The weathered rock had in all likelihood been exposed to alternate freezing and warming cycles before and even while it was acquiring its 1 to 2 ft of organic topsoil many, many years before construction of the dam was even considered. Fig. 3 shows the findings of Test Pit No. 3.

On October 1, 1963, after discussion of our observations with Dr. Aldrich, of Haley & Aldrich, Incorporated, Consulting Soil Engineers, of Cambridge, Massachusetts, we recommended the construction of a concrete corewall on the southwest wing of the dam where none existed. The trench which would be excavated along the axis of the dam would serve as an inspection trench for more thorough investigation, would permit the removal of weathered bedrock where it was found to exist, and would permit the construction of a concrete corewall extending from sound bedrock to an elevation within the compacted impervious fill. We also recommended that this work be undertaken as soon as possible in order to take advantage of the favorable weather conditions that then prevailed, as well as a low water level in the reservoir; otherwise, costs would have to be increased if the contractor was forced to handle any volume of water. We further recommended that the scope of the remedial measures would be largely determined by the observations made by the engineer on the project and for this reason we did not recommend that the repairs be let out to competitive bidding for construction under contract with a private firm. We received approval of our recommendation by telephone from Commissioner Tupper on October 3, and he stated he would be doing the general contracting for the District.

Construction of the concrete corewall was begun on October 7, 1963, with a resident engineer from our firm, Mr. Tupper, and two laborers present. On the afternoon of October 7 the pumping operations were commenced at Mascoma Lake by the Fire District in order that the water level in the reservoir would not be lowered to a critical level by a serious fire. On the morning of October 8 the water level in the reservoir reached its lowest level, 6.9 ft below the concrete sill of the gate house (8 ft below the top of the dam), and it is well to note that these repairs conducted at this time would have been most difficult if they had been attempted with the reservoir at a higher stage. Water entering our trench presented a problem even with the low water level in the reservoir.

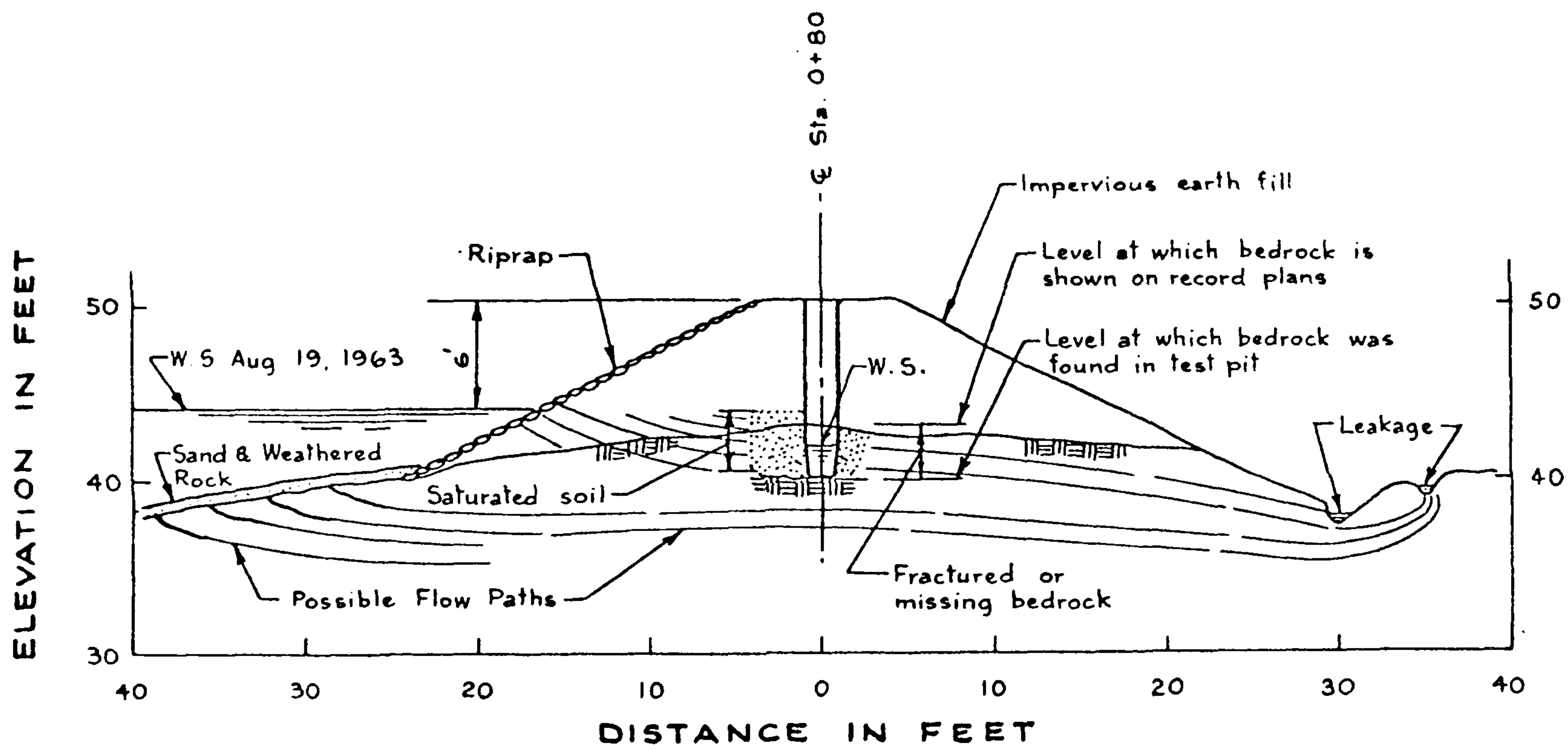


FIG.3 TEST PIT NO. 3 - AUGUST 17, 1963

316-5429

The scope of our repairs is best illustrated by Fig. 4, which shows a plan and section of the west portion of the dam. The plan shows the relationship between the concrete corewall as constructed and the granite rubble corewall with cement mortar where it exists. The two spots where leakage intercepts the ground surface are also indicated on this plan. The section shows the bedrock elevation as well as the original ground surface, the top of original earthfill and the depth and limits of the original granite rubble corewall as indicated on the original construction drawing of the dam by Mr. Robert Fletcher, consulting engineer. Fig. 4 shows the sparse depth of overburden (less than 2 ft) that prevailed over the bedrock on the deflected 105 ft portion of the dam prior to the original construction. Fig. 4 also indicates the depth and limits of the new concrete corewall, the present top of the dam, and the elevation of sound bedrock as determined beneath the new corewall. The four 2-1/2-in diameter holes which were drilled in vertical cracks in the bedrock and grouted with cement mortar are also indicated on Fig. 4. The vertical cracks in the bedrock were discovered during the construction of the concrete corewall; their presence had not been revealed by the test pits. Corewall construction was completed on October 19, 1963. Dr. Aldrich inspected the work at the dam on October 18. His letter report summarizing his observations and conclusions, as well as some photographs taken at the dam, will be found in the Appendix of this Report.

The degree of success of the concrete corewall construction cannot be evaluated until the reservoir has been filled. It is significant to note that the total leakage eminating from the dam was a mere 11 gpm on October 19, 1963, at the conclusion of corewall construction. It should be borne in mind, however, that this vast reduction in leakage from 200 gpm at full pond is partially due to the decrease in pressure acting on the water transmitting passages and not necessarily to the concrete corewall construction. However, there is ample evidence that the concrete corewall construction sealed many of the passages through which leakage was taking place. Whether or not the water will now find new jointing planes or crevices through which to move will dictate what future action, if any, should be taken. Indications are that a certain amount of leakage persists through deeper crevices and that its prevention can only be accomplished by a pressure grouting operation. Whether or not pressure grouting can be economically justified will in turn depend on how much the leakage increases with a full pond.

Recommendations

From the foregoing discussion it is evident that the present source of supply is adequate to meet the needs of the Town for the foreseeable future. The water shortages which have occurred in the past may be attributed not to a shortage of supply but to one of waste caused by leakage from the reservoir. The leakage rate of 190 gpm observed on July 1, 1963, represents more water than the District's present demand rate of 175 gpm (250,000 gpd) and is a significant portion of the 310 gpm (450,000 gpd) estimated safe yield of the supply.

We recommend, therefore, that the concrete corewall construction completed in October be evaluated by those measurements necessary to ascertain the volume of leakage which still persists. Should measurements indicate that the leakage has been reduced to a value of, say 20 gpm at full pond, further repairs could not be economically justified. However, should a large percentage of the leakage still persist, it would then become necessary to consider a pressure grouting program as outlined in Dr. Aldrich's letter (Appendix A). The cost of such a program which would effectively seal the rock he estimates to be between $5, 000 and $9, 000.

We also recommend that the relatively small leak around the west end of the spillway be repaired when the reservoir is at or near full pond level. This leak only transmits water at reservoir levels higher than 1 ft below the spillway level, so that its location and repair can be better effected while it is leaking.

We recommend that the District engage the services of a qualified land surveyor or engineer to make a topographic survey of the reservoir bottom between the elevation of the lower intake and the top of the spillway for the purpose of computing a storage curve for the Enfield reservoir. In order to develop the full safe yield of a surface water supply during times of drought, it is necessary to utilize all of the available storage in the supply reservoir. Theoretically, for instance, during a drought equal to that for which the safe yield has been computed, the reservoir should be empty at the conclusion of the drought period. At that time the reservoir will begin to fill, and the stored water will become available for use during the next dry period. The fact that the water level in a reservoir becomes very low in time of drought is an indication of its value in developing the safe yield of the watershed.

In order to operate the supply intelligently therefore, it is helpful to be able to know at all times the actual quantity of stored water available. It is for this reason that we recommend the survey of the reservoir for the purpose of constructing an elevation- volume (storage) curve for the Enfield reservoir. We estimate the cost of the survey and computations necessary to develop a storage curve for Enfield Reservoir to be in the order of $600.

September 23

Leonard:

Ed Fitzgerald called Tuesday P.M. saying that the Enfield Water Dept. apparently raised their flashboards to carry water appreciably above top of cut off wall in embankment. This caused a slumping of the fill and several leaks have developed at toe and part-way up downstream slope. They have lowered top of flashboards now but leaks continue. Suggests you call Charles Carroll, Water Works Supt. and Comm. School St., Enfield before going up. Phone: Enfield MEcury 2.4625.

Riprap has fallen down the upstream face of embankment due to erosion.

Dam 20' high, 740' long with 41' X 3' spillway built in 1901 - 1903. Pond Area: 15.5 acres. In 1937, they "stoned the dyke and regraded top for 600 feet. Did cement job on spillway.

Apparently has been slight leak at right end where angle in dam due to fault in ledge foundation but apparently didn't get worse. (1936)

Originally not designed for flashboards.
Total Storage - 93 Acre-Ft. or 30 million gallons.

NEW HAMPSHIRE WATER RESOURCES BOARD CONCORD, N. H.

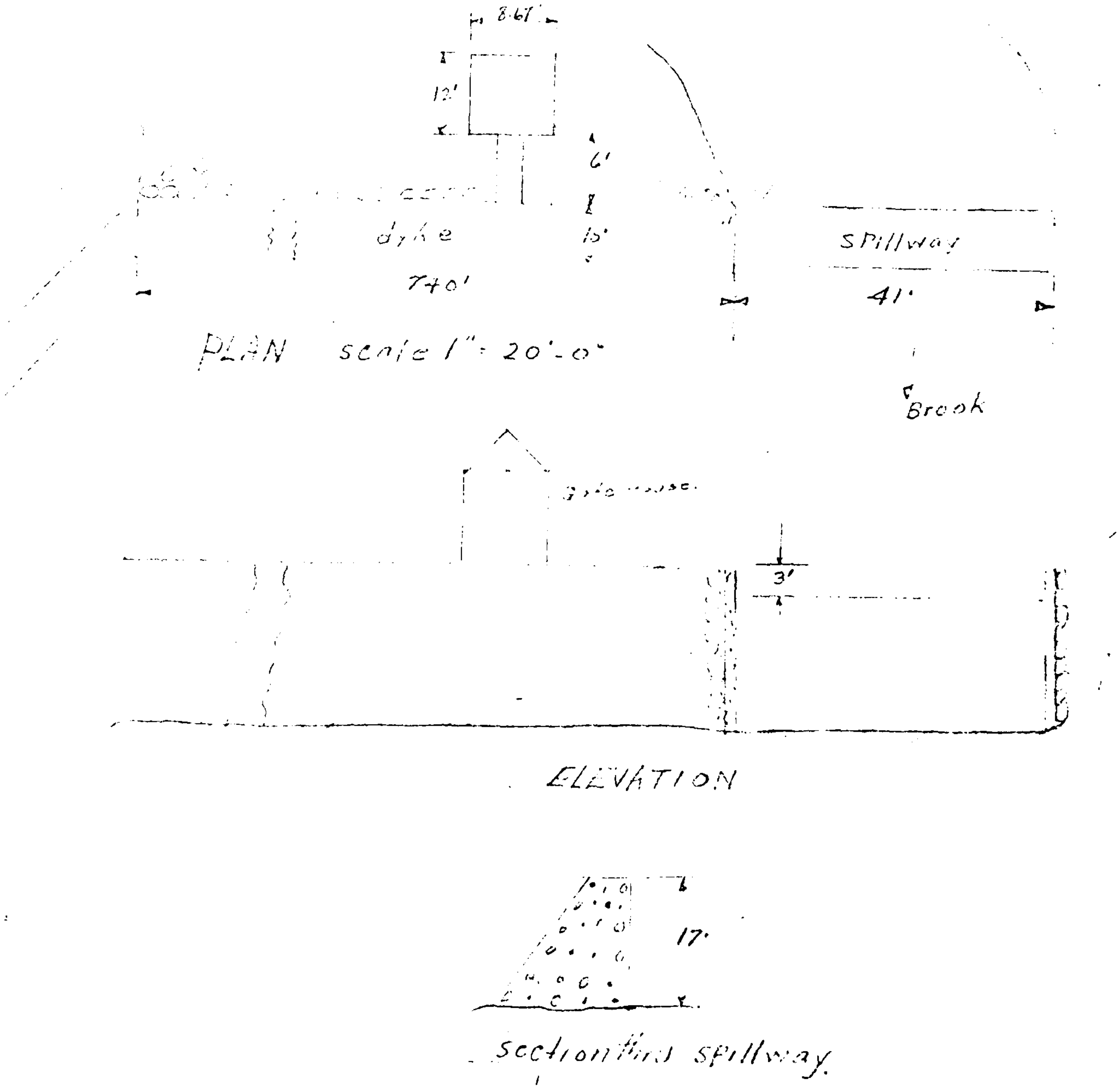
PROJECT

SUBJECT

FILE 36.08

ACC.

COMPUTER G.S.W CHECKER R.L.T CONT. FROM ACC. CONT. ON ACC. SUMMARY ON ACC. DATE



36.08
NH 00354

NEW HAMPSHIRE WATER CONTROL COMMISSION
DATA ON DAMS IN NEW HAMPSHIRE

LOCATION

STATE NO. 36.08

Town Canaan : County Grafton

Stream Nameless - Brook

Basin-Primary Conn R. : Secondary Mascoma R.

Local Name Enfield Reservoir

Coordinates—Lat. 45° 40' -1400 : Long. 72° 10' - 4300

GENERAL DATA

Drainage area: Controlled .... Sq. Mi.: Uncontrolled .... Sq. Mi.: Total 1.57 Sq. Mi.

Overall length of dam 240 ft.: Date of Construction 1901-1903

Height: Stream bed to highest elev. 20 ft.: Max. Structure 17' ft.

Cost—Dam .... : Reservoir ....

DESCRIPTION Gravity-E-Concrete

Waste Gates

Type ....

Number .... : Size .... ft. high x .... ft. wide

Elevation Invert .... : Total Area .... sq. ft.

Hoist ....

Waste Gates Conduit

Number .... : Materials ....

Size .... ft.: Length .... ft.: Area .... sq. ft.

Embankment

Type ....

Height—Max. .... ft.: Min. .... ft.

Top—Width .... : Elev. .... ft.

Slopes—Upstream .... on .... : Downstream .... on ....

Length—Right of Spillway .... : Left of Spillway ....

Spillway

Materials of Construction ....

Length—Total .... ft.: Net 41' ft.

Height of permanent section—max. 17' ft.: Min. .... ft.

Flashboards—Type .... : Height .... ft.

Elevation—Permanent Crest .... : Top of Flashboard ....

Flood Capacity 355 cfs.: 180 cfs/sq. mi.

Abutments

Materials: ....

Freeboard: Max. 3.? ft.: Min. .... ft.

Headworks to Power Devel.—(See "Data on Power Development")

OWNER Town of Enfield

Condition Good.

REMARKS Water Supply-- Enfield,

B-20

Tabulation By [illegible] Date October 31, 1938.

NEW HAMPSHIRE WATER CONTROL COMMISSION

DATA ON RESERVOIRS & PONDS IN NEW HAMPSHIRE

LOCATION AT DAM NO. 36.28

Town Canaan : County Grafton

Stream Nameless Brook

Basin—Primary Conn. R. : Secondary Mascoma R.

Local Name Enfield Reservoir

DRAINAGE AREA

Controlled .... Sq. Mi.: Uncontrolled .... Sq. Mi.: Total ~~3.12~~ 1.57 Sq. Mi.

ELEVATION vs. WATER SURFACE AREA vs. VOLUME

	Point	Head Feet	Surface Area Acres	Volume Acre Ft.
(1)	Max. Flood Height			
(2)	Top of Flashboards			
(3)	Permanent Crest			
(4)	Normal Drawdown		~~21.10~~ 15.5	93
(5)	Max. Drawdown			
(6)	Original Pond	U.S.G.S. 947		

Base Used ....: Coef. to change to U.S.G.S. Base

RESERVOIR CAPACITY

	Total Volume	Useable Volume
Drawdown	ft.	ft.
Volume	ac. ft.	ac. ft.
Acre ft. per sq. mi.		
Inches per sq. mi.		

USE OF WATER Water Supply

OWNER Town of Enfield

REMARKS

B-21

Tabulation By M. & H. L. T. Date October 31, 1938.

NEW HAMPSHIRE WATER RESOURCES BOARD

INVENTORY OF DAMS AND WATER POWER DEVELOPMENTS

BASIN Connecticut NO. 10 — 36.08 [illegible]
RIVER Enfield Reservoir MILES FROM MOUTH 1.5 D.A.-SQ.MI. 3.12
TOWN Canaan OWNER Enfield Water Works
LOCAL NAME OF DAM
BUILT 1901-03 DESCRIPTION Gravity — Earth Concrete on Ledge & Earth
[illegible]
[illegible] 1955
POND AREA-ACRES [illegible] DRAWDOWN-FT. POND CAPACITY-ACRE FT.
HEIGHT-TOP TO BED OF STREAM-FT. 20 MAX. MIN.
OVERALL LENGTH OF DAM-FT. 740± MAX. FLOOD HEIGHT ABOVE CREST-FT.
PERMANENT CREST ELEV. U.S.G.S. 947USGS LOCAL GAGE
TAILWATER ELEV. U.S.G.S. LOCAL GAGE
SPILLWAY LENGTHS-FT. 41 FREEBOARD-FT. 3
FLASHBOARDS-TYPE, HEIGHT ABOVE CREST ?
WASTE GATES-NO. WIDTH MAX. OPENING DEPTH SILL BELOW CREST

REMARKS Condition Good. [illegible] 13.1 from mouth [illegible] R.
Slight leak at right end where angle in dam. Mr. King
[illegible] says due to fault in ledge foundation will not get worse.

Lat [illegible] 1400 [illegible]
Long 72° [illegible] 28' [illegible]

POWER DEVELOPMENT

UNITS	NO.	RATED HP.	HEAD FEET	C.F.S. FULL GATE	KW.	MAKE

USE Water Supply Town of Enfield.

REMARKS Shown by E.H. King, Water Commissioner who gave information below: Area watershed [illegible] acres. Pond area 21.6 acres. Storage capacity spilling level 66 MCF. 1st foot 7 MCF. Top 2 ft 15 MCF [illegible]

[illegible] = 6,860,000 gal. 1st foot does not check with King 7 MCF for 1st foot [illegible]
Letter [illegible] "Stoned the dyke and regraded top [illegible] ft.
did some [illegible] spillway"

9/9/37 [illegible]

B-22

DATE 7/24/36 [illegible]

PUBLIC SERVICE COMMISSION OF NEW HAMPSHIRE—DAM RECORD I-5833

TOWN	CANAAN	TOWN NO. 8	STATE NO. [illegible]
RIVER STREAM	Enfield Reservoir		
DRAINAGE AREA		POND AREA	
DAM TYPE	Gravity	FOUNDATION NATURE OF	Ledge, Earth
MATERIALS OF CONSTRUCTION	Earth, Concrete		
PURPOSE OF DAM	POWER—CONSERVATION—DOMESTIC—RECREATION—TRANSPORTATION—PUBLIC UTILITY		
HEIGHTS, TOP OF DAM TO BED OF STREAM	Approx 30'	TOP OF DAM TO SPILLWAY CRESTS	3'
SPILLWAYS, LENGTHS DEPTHS BELOW TOP OF DAM	41'	LENGTH OF DAM	740' Approx
FLASHBOARDS TYPE, HEIGHT ABOVE CREST			
OPERATING HEAD CREST TO N. T. W.		TOP OF FLASHBOARDS TO N. T. W.	
WHEELS, NUMBER KINDS & H. P.			
GENERATORS, NUMBER KINDS & K. W.			
H. P. 90 P. C. TIME 100 P. C. EFF.		H. P. 75 P. C. TIME 100 P. C. EFF.	
REFERENCES, CASES, PLANS, INSPECTIONS			

REMARKS

OWNER: Town of Enfield

CONDITION: Good

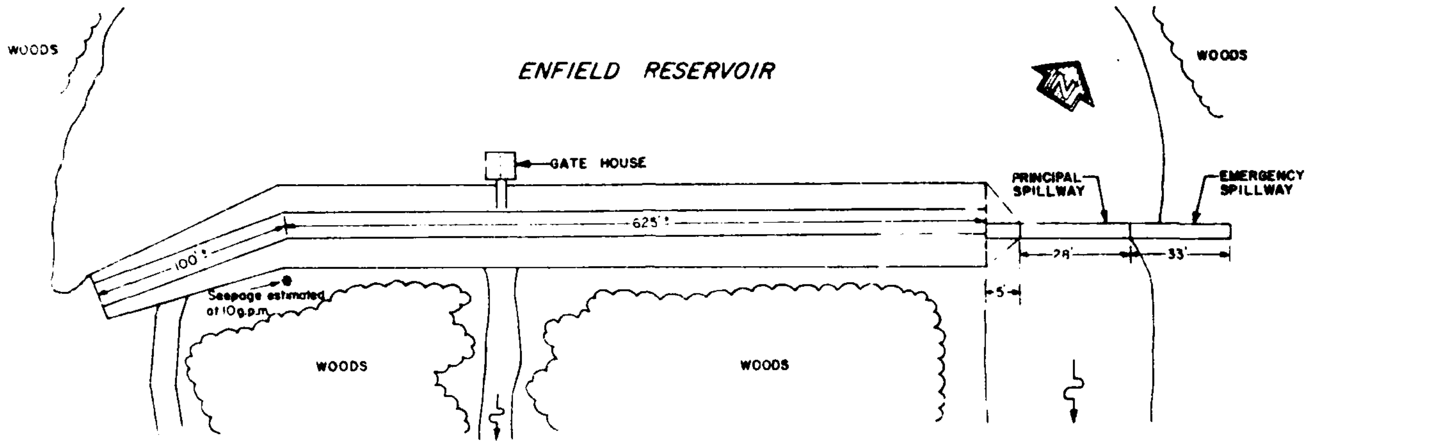
MENACE: Yes. Will be subject to periodic inspection.

To the Public Service Commission:

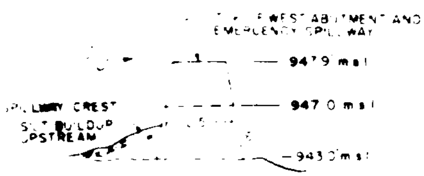
The foregoing memorandum on the above dam is submitted covering inspection made July 21, 1936, according to notification to owner dated June 25, 1936, and bill for same is enclosed.

D. Waldo White
Chief Engineer

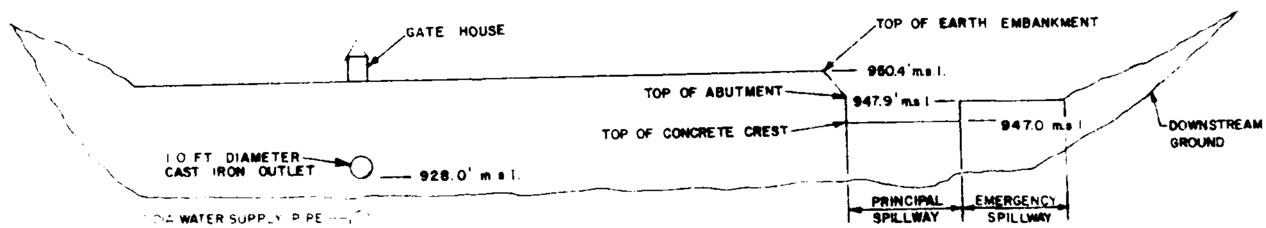
August 6, 1936
Copy to Owner



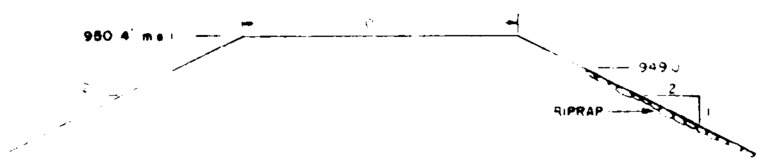
PLAN



SPILLWAY SECTION



ELEVATION



EARTH EMBANKMENT SECTION

Anderson-Nichols & Co., Inc. CONCORD NEW HAMPSHIRE	U.S. ARMY ENGINEER DIV. NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS.

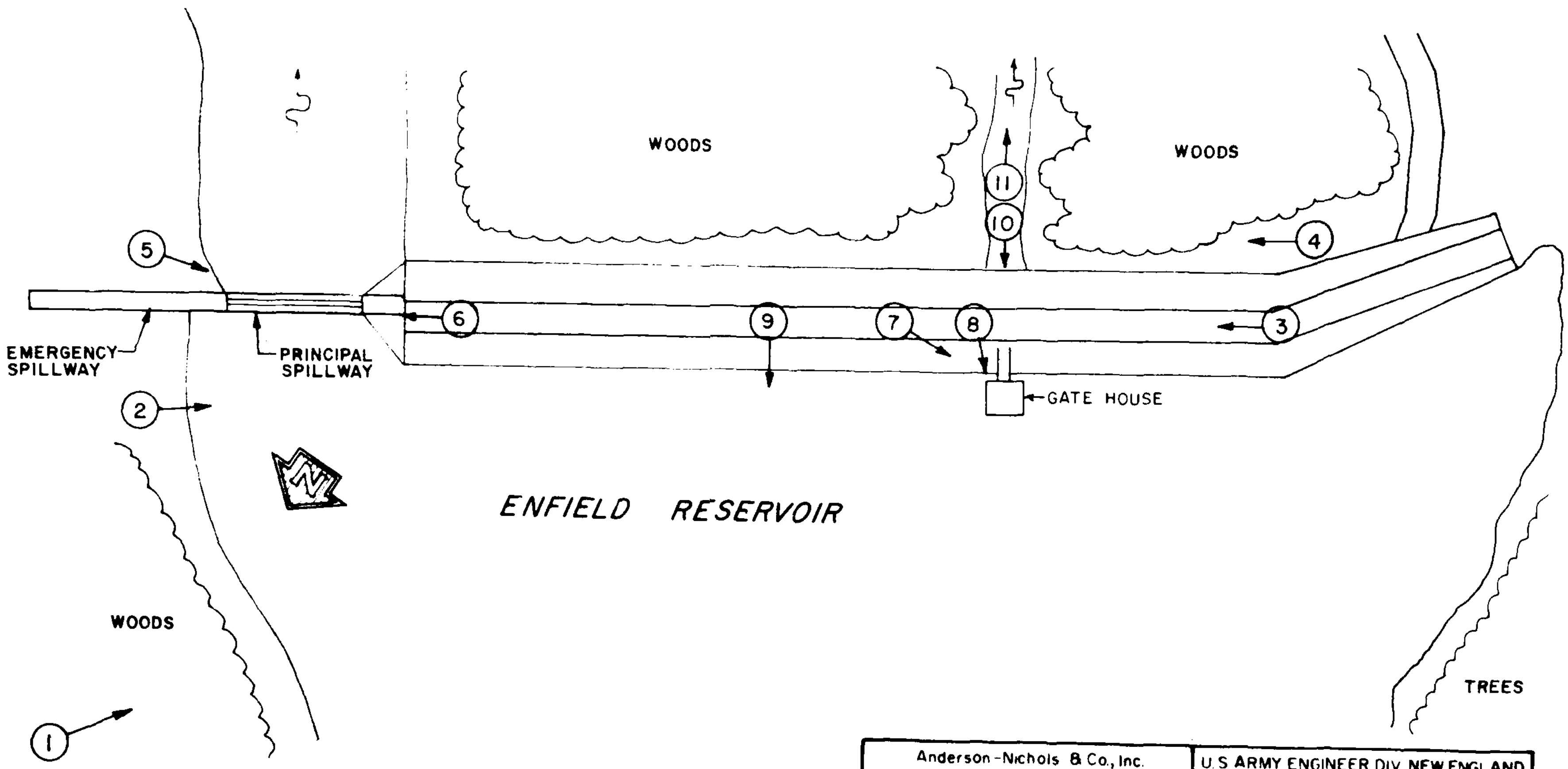
NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

ENFIELD RESERVOIR DAM

ENFIELD RESERVOIR NEW HAMPSHIRE

APPENDIX C

PHOTOGRAPHS



Anderson-Nichols & Co., Inc.
CONCORD NEW HAMPSHIRE

U.S. ARMY ENGINEER DIV. NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

ENFIELD RESERVOIR DAM
PHOTO INDEX

ENFIELD RESERVOIR NEW HAMPSHIRE

SCALE: NOT TO SCALE
DATE: APRIL, 1979

Figure 2 - Looking westerly at the upstream face of the dam.

Figure 3 - Looking easterly along the dam embankment crest.

Figure 4 - Looking easterly along the downstream face of the dam.

Figure 5 - View of the principal spillway located at the east end of the dam.

Figure 6 - Looking across the crest of the emergency spillway located adjacent to and east of the principal spillway.

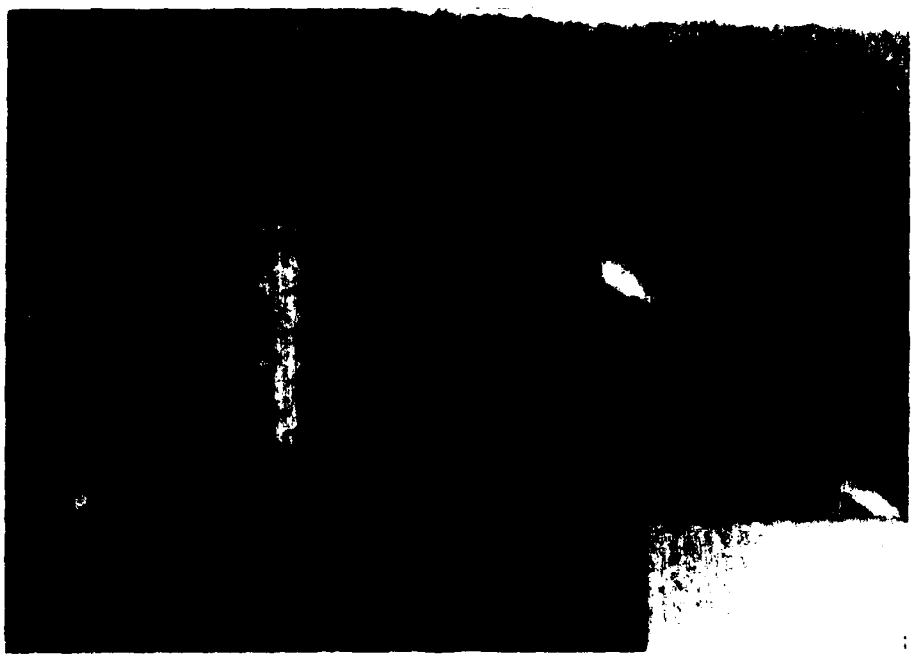


Figure 7- Looking at the gatehouse for the low-level outlet.

Figure 8 - Close-up of the gatehouse foundation.

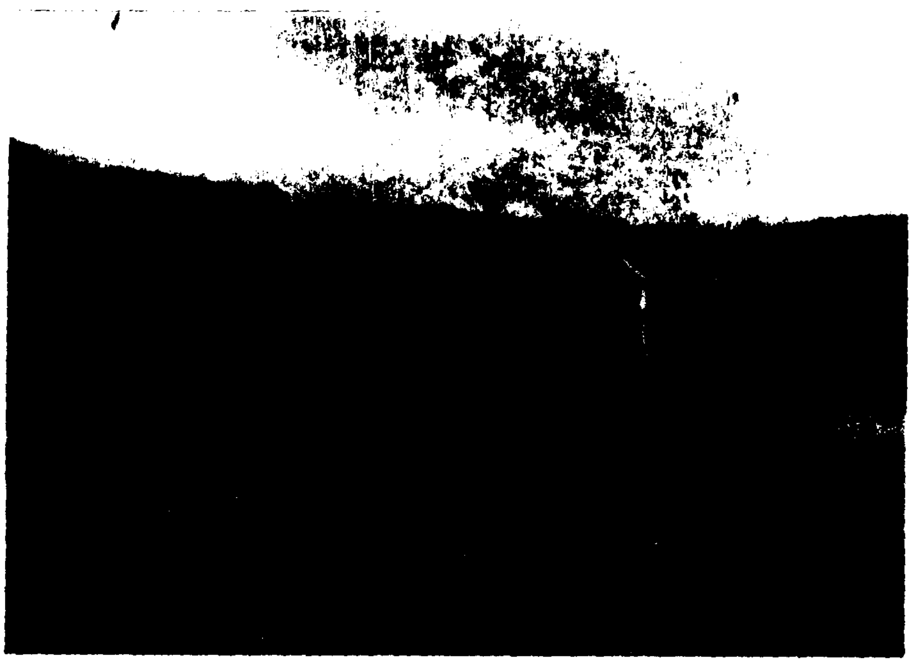


Figure 9 - Looking upstream into the reservoir from the dam embankment crest.

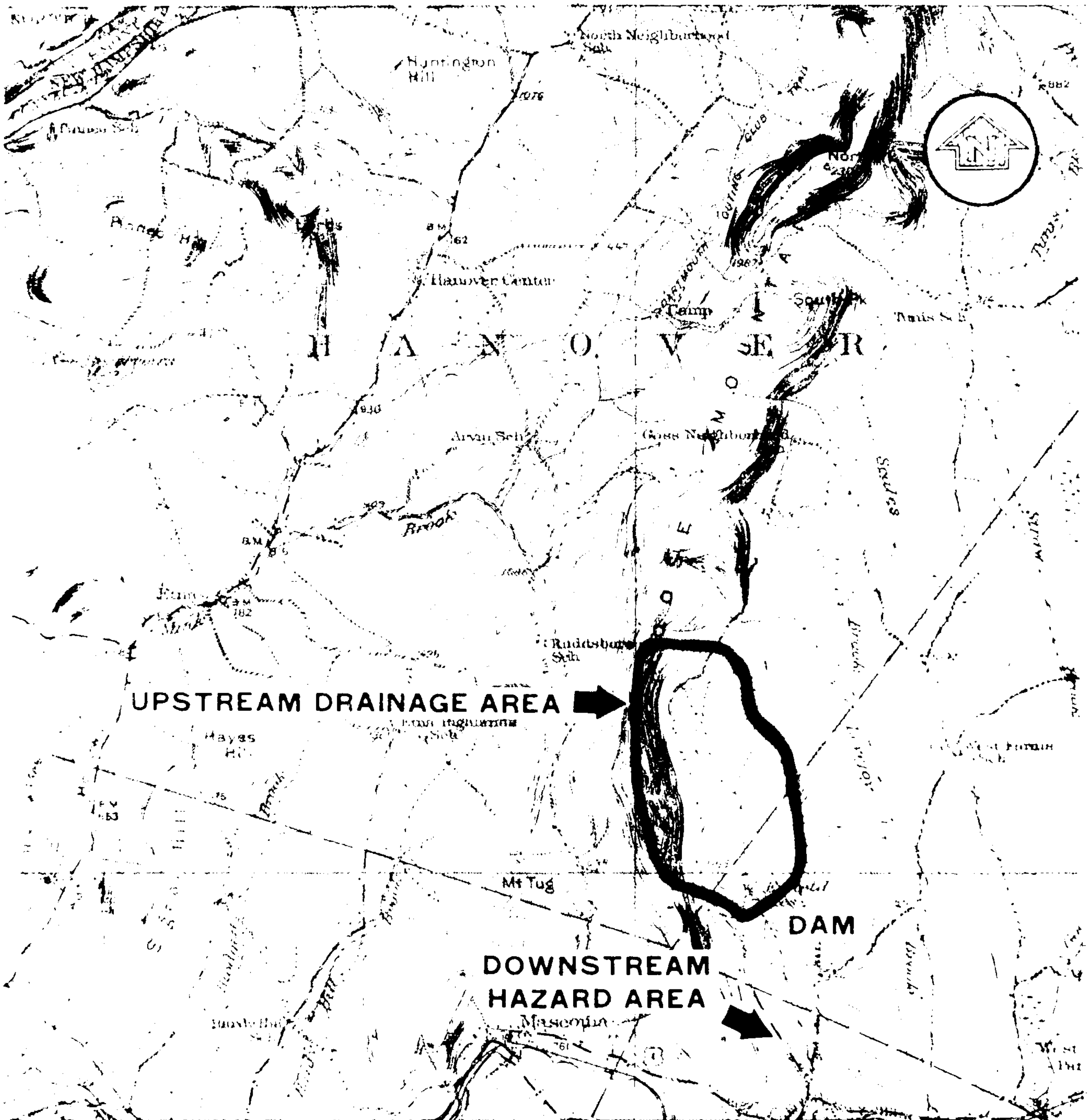
Figure 10 - Looking at the low-level outlet discharge conduit.

Figure 11 - View of the discharge channel from the low-level outlet.

Figure 12 - Looking across May Street crossing located 1.2 miles downstream of the dam. Note gray house to right of photo.

APPENDIX D

HYDROLOGIC AND HYDRAULIC COMPUTATIONS



NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

ENFIELD RESERVOIR DAM

CANAAN, NEW HAMPSHIRE

REGIONAL VICINITY MAP

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

ANDERSON NICHOLS & CO., INC. CONCORD, NH

SCALE IN MILES

1 ½ 0 1 2

MAP BASED ON U.S.G.S. 15 MINUTE QUADRANGLE SHEET. MASCOMA, N.H.-VT. 1927

HYDROLOGY / HYDRAULICS

Enfield Reservoir Dam

Drainage area ≐ 1.54 mi^2
Size classification: Small
Hazard classification: Significant
Test flood = 1/2 PMF

Calculate the PMF using "Preliminary Guidance for Estimating Maximum Probable Discharges in Phase I Dam Safety Investigations, March, 1978."

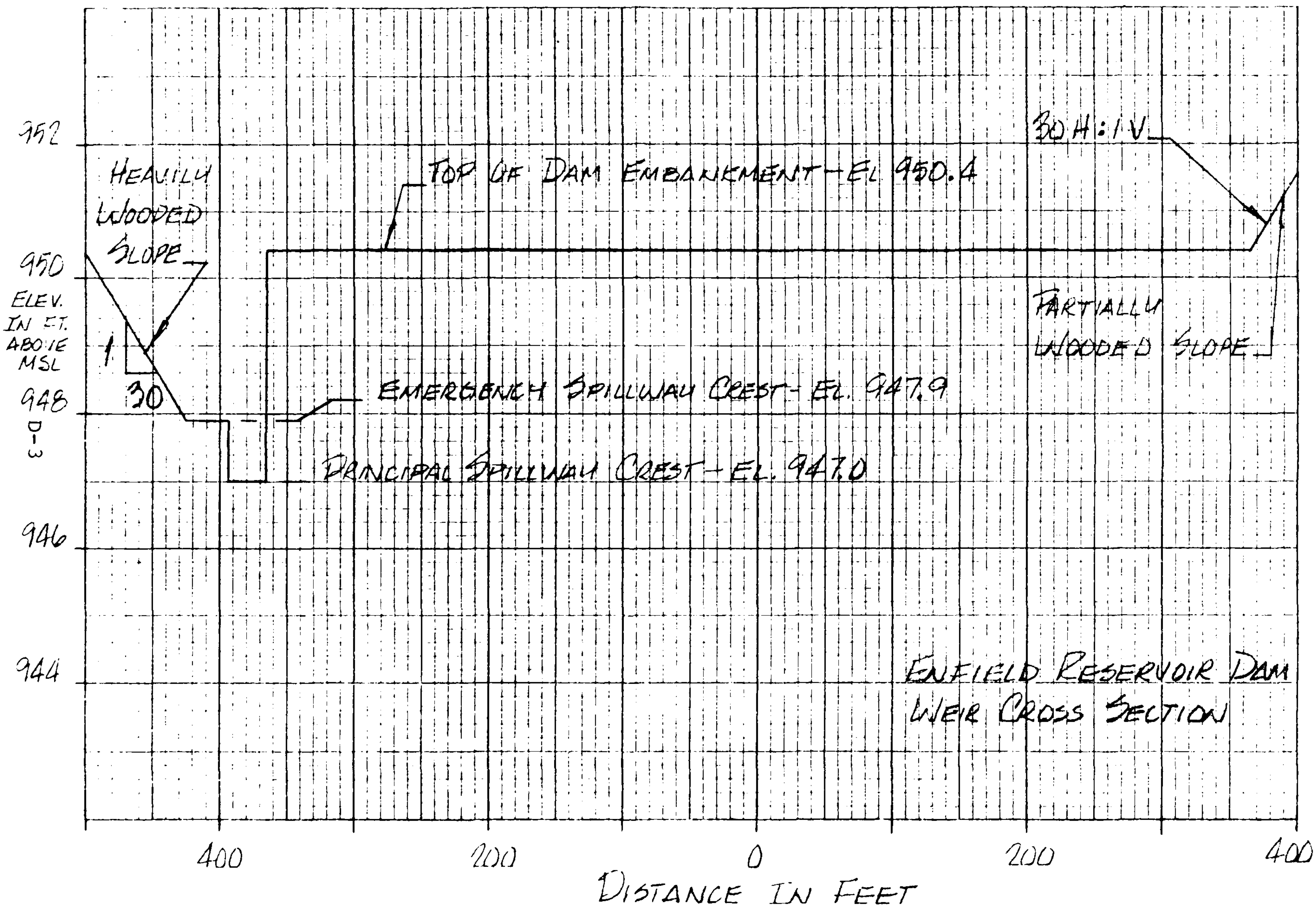
Average slope of drainage area is 155 ft/mile; therefore, the "mountainous" will be used to obtain a CSM value:

1.54 mi^2(2550 csm) = 3927 cfs = PMF
1/2 PMF = 3927/2 = 1964 cfs, say 1/2 PMF = 1,960 cfs

Determine surcharge height to pass Q_{p_1} of 1960 cfs, the test flood inflow. To obtain this, a discharge rating curve must be generated for Enfield Reservoir Dam.

Outflow would occur first over the concrete principal spillway and then over the concrete emergency spillway. Higher flood waters would inundate the dam embankment crest.

Due to the size (6" high) and condition (See Appendix B - Figure 5) of the principal spillway stoplog, the following analysis will be done assuming that no stoplog exists. Also, see section 7.3, Remedial Measures.



952
950
948
946
944
ELEV. IN FT. ABOVE MSL
HEAVILY WOODED SLOPE
1
30
TOP OF DAM EMBANKMENT - EL 950.4
30 H:1 V
PARTIALLY WOODED SLOPE
EMERGENCY SPILLWAY CREST - EL. 947.9
PRINCIPAL SPILLWAY CREST - EL. 947.0
ENFIELD RESERVOIR DAM
WEIR CROSS SECTION
400
200
0
200
400
DISTANCE IN FEET

Develop a rating curve at the dam ...

Use the weir equation to rate flow over the spillways and the dam embankment.

$Q = CLH^{3/2}$ where C = coefficient of discharge
L = length of weir
H = height of water above weir crest.

"C" for principal spillway = 3.0*
"C" for emergency spillway = 2.7*
"C" for dam embankment & natural ground = 2.6*

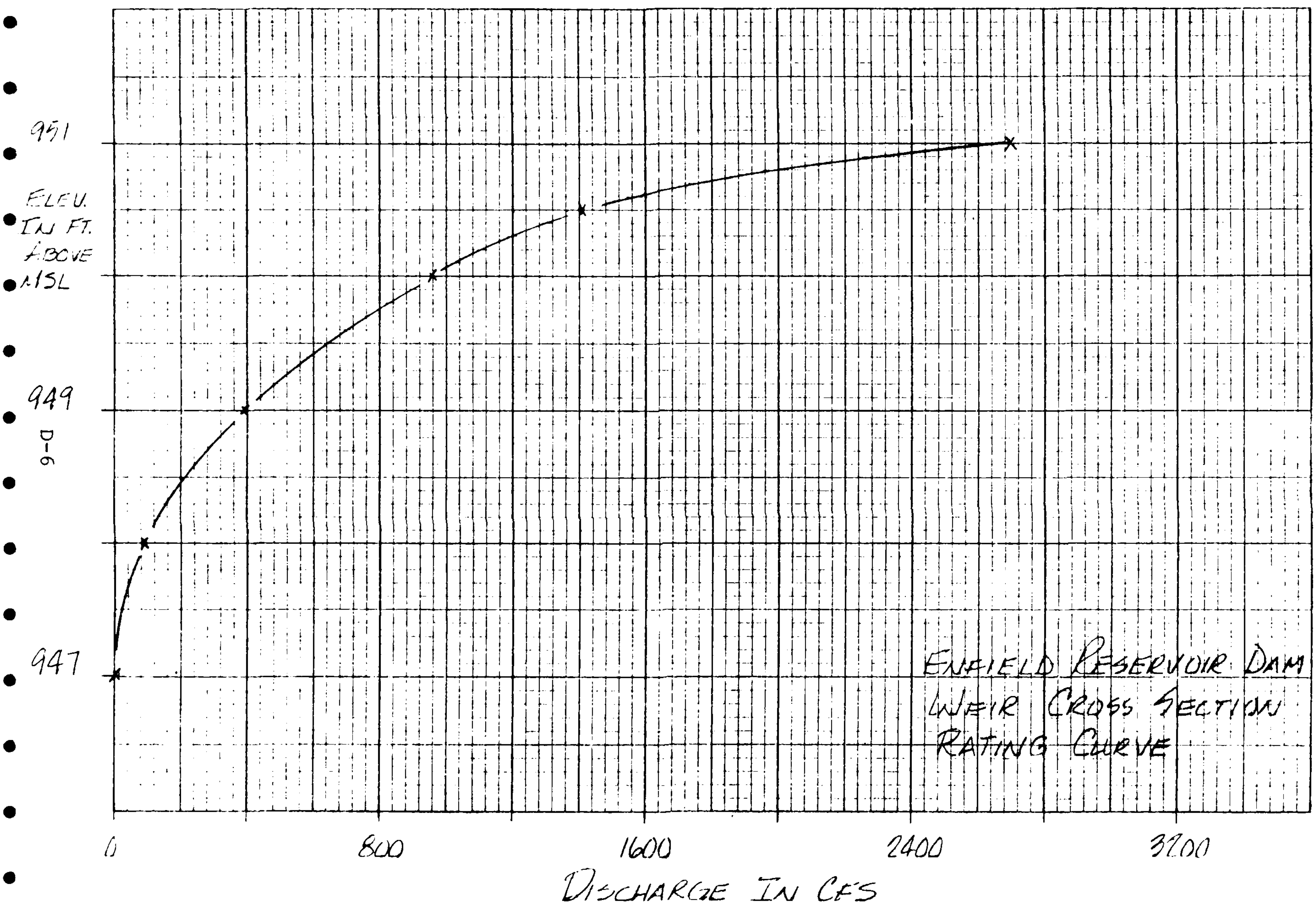
Outflow would begin when the reservoir surface elevation rises above el. 947.0.

The table below refers to the cross section on p. D-3.

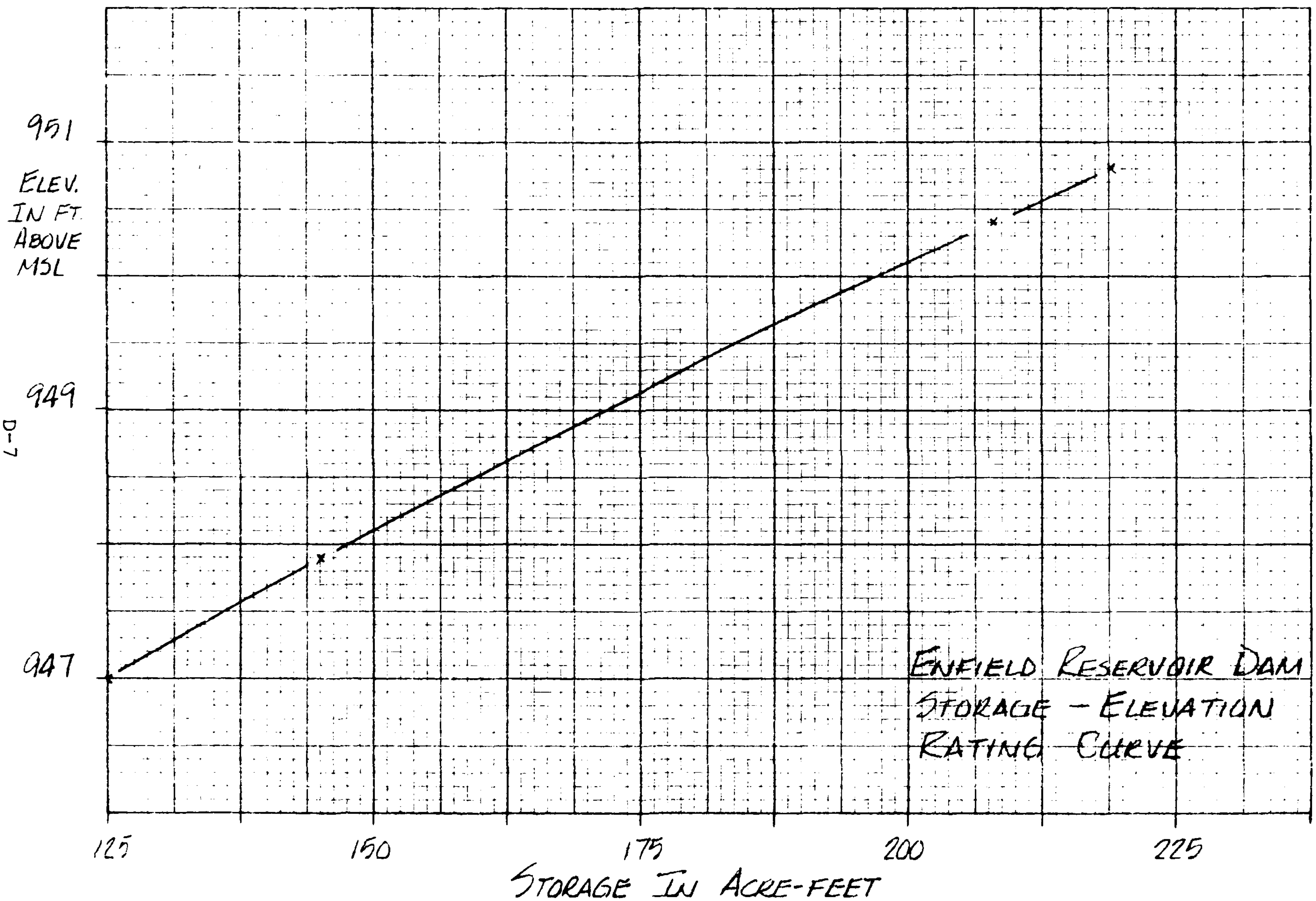
* Estimated from table 5-3, p. 5-40, Brater & King, Handbook of Hydraulics.

Trial No.	Stage (ft)	Discharge
1	1	$Q = 3.0(28)(1)^{3/2} + 2.7(33)(0.1)^{3/2} + 2.6(1/2)(0.1)(30)(0.1)^{3/2} = 87$ cfs
2	2	$Q = 3.0(28)(2)^{3/2} + 2.7(33)(1.1)^{3/2} + 2.6(1/2)(1.1)(30)(1.1)^{3/2} = 390$ cfs
3	3	$Q = 3.0(28)(3)^{3/2} + 2.7(33)(2.1)^{3/2} + 2.6(1/2)(2.1)(30)(2.1)^{3/2} = 957$ cfs
4	3.5	$Q = 3.0(28)(3.5)^{3/2} + 2.7(33)(2.6)^{3/2} + 2.6(1/2)(2.6)(30)(2.6)^{3/2} + 2.6(730)(0.1)^{3/2} + 2.6(1/2)(0.1)(30)(0.1)^{3/2} = 1{,}409$ cfs
5	4	$Q = 3.0(28)(4)^{3/2} + 2.7(33)(3.1)^{3/2} + 2.6(1/2)(3.1)(30)(3.1)^{3/2} + 2.6(730)(0.6)^{3/2} + 2.6(1/2)(0.6)(30)(0.6)^{3/2} = 2711$ cfs

Use the above data to develop a discharge rating curve for the dam (see p. D-6).



ENFIELD RESERVOIR DAM
WEIR CROSS SECTION
RATING CURVE
951
949
947
ELEV. IN FT. ABOVE MSL
0
800
1600
2400
3200
DISCHARGE IN CFS


951
ELEV. IN FT ABOVE MSL
949
947
ENFIELD RESERVOIR DAM
STORAGE - ELEVATION
RATING CURVE
125
150
175
200
225
STORAGE IN ACRE-FEET

STORAGE ROUTING - ENFIELD RESERVOIR DAM

Test flood = 1/2 PMF = 1960 cfs, stage = 950.8*

Normal storage = 125 ac-ft, stage = 947.0,
surface area = 21 acres

Q_{P_1} = 1960 cfs, stage = 950.8*, storage = 219$^{\nabla}$ ac-ft

219 - 125 = 94 ac-ft

$94\ ac\text{-}ft \cdot \frac{1}{1.54 mi^2} \cdot \frac{1 mi^2}{640 ac} \cdot \frac{12 in.}{ft} = 1.14\ in.\ runoff = STOR\ 1$

$Q_{P_2} = Q_{P_1}(1 - \frac{STOR\ 1}{9.5}) = 1960(1 - \frac{1.14}{9.5}) \doteq 1725\ cfs$

@ 1725 cfs, stage = 950.7*, storage ≐ 216 ac-ft

216 - 125 = 91 ac-ft

$91\ ac\text{-}ft \cdot \frac{1}{1.54 mi^2} \cdot \frac{1 mi^2}{640 ac} \cdot \frac{12 in}{ft} = 1.11\ in.\ runoff = STOR\ 2$

Average of (STOR 1 & STOR 2) ≐ 1.13 in. or 0.094 ft. runoff

$0.094\ ft. \cdot \frac{1.54 mi^2}{1} \cdot \frac{640 ac}{mi^2} = 92.6\ ac\text{-}ft$

* See rating curve, p. D-6.
∇ See rating curve, p. D-7.

STORAGE ROUTING (CONT.)

$92.6 + 125 = 217.6$ ac-ft.

@ 217.6 ac-ft, stage = 950.75^{∇}, $Q_{P_3} = 1860$ cfs*

$Q_{P_3} = 1860$ cfs, 1/2 PMF = 1960 cfs = Test flood

Inflow - Outflow $1960 - 1860 = 100$ cfs

∴ surcharge storage is negligible during the test flood.

Test flood = 1/2 PMF

Test flood discharge = 1860 cfs

Test flood elevation = 950.75, say 950.8

Top of dam embankment = 950.4, ∴ dam embankment would be overtopped by 0.4 feet during the test flood.

∇ See rating curve, p. D-7.
* See rating curve, p. D-6.

BREACH ANALYSIS - ENFIELD RESERVOIR DAM

Purpose: Determine degree of downstream hazard.

Assume: Water surface at maximum pool = 950.4
Upstream [illegible] elevation = 940.0

$Q_{P1} = 8/27\ W_b \sqrt{g}\ Y_o^{3/2}$ where
W_b = breach width
g = 32.2 ft/sec²
Y_o = pool elev. - u/s riverbed elev.

@ Enfield Reservoir Dam:
W_b = 100 ft. *
Y_o = 950.4 - 940.0 = 10.4 ft.

$Q_{P1} = 8/27(100)\sqrt{32.2}(10.4)^{3/2}$ = 5,635 cfs

Antecedent discharge = 1,300 cfs ▽

Total Breach Q = 5,635 + 1,300 = 6,935 cfs

* Breach width estimated with consideration given to [illegible] and dam embankment construction. Assume that the breach occurs at some point along the embankment + other than over the [illegible].

▽ See rating curve, p. D-6.

BREACH ANALYSIS (CONT.)

Use a typical cross section of the valley from the toe of the dam to a point about 4500 feet downstream. Downstream of this point, valley walls become more steep, necessitating use of a second cross section just upstream of the double barrel culvert. The culvert is located in the downstream hazard area, about 6100 feet downstream of the dam.

For the 4500-foot reach just downstream of the dam, use the Manning equation to develop a discharge rating curve...

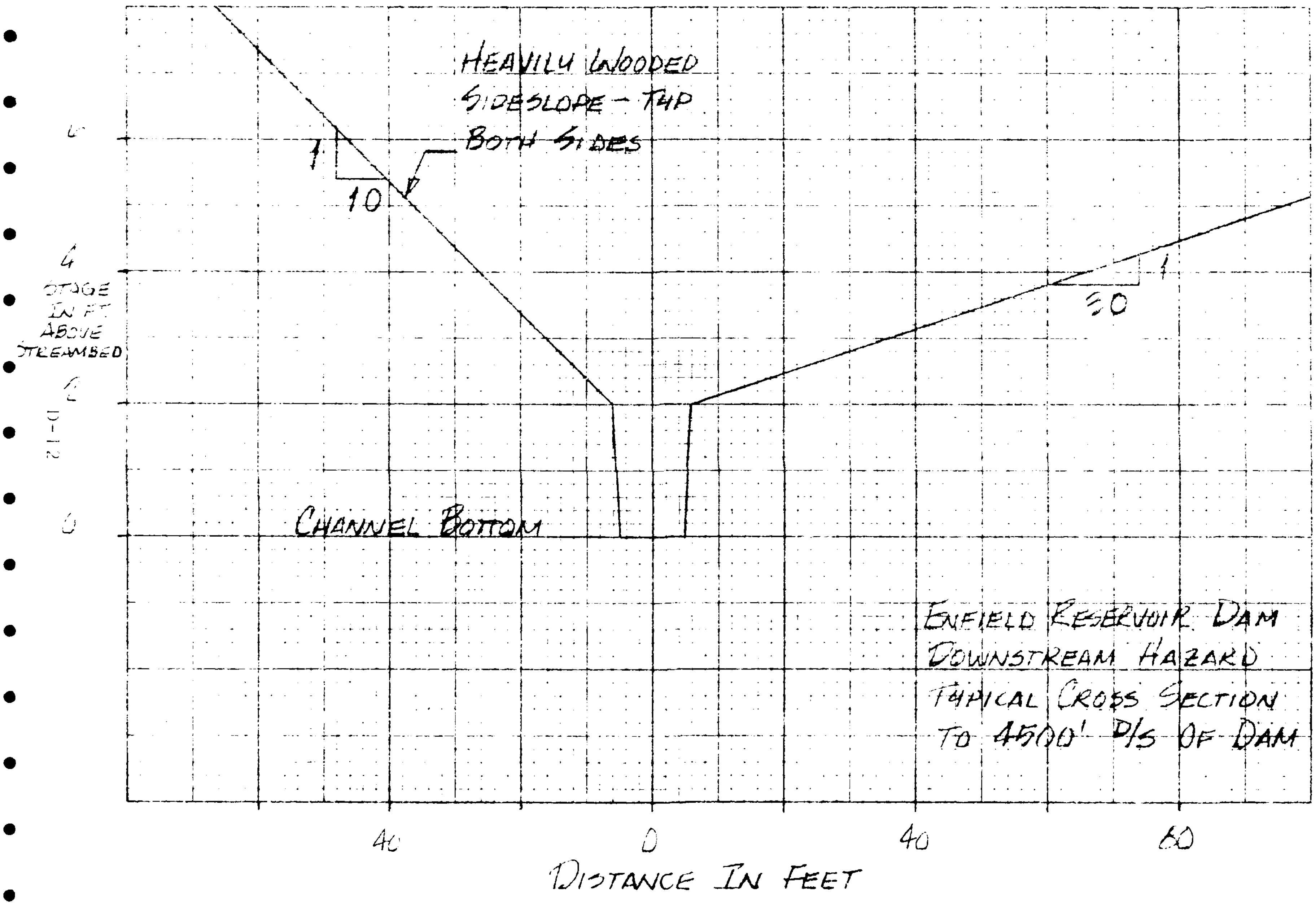
$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

where $n \equiv$ composite channel roughness coefficient
$A \equiv$ area of cross section (ft^2)
$R \equiv$ hydraulic radius (ft)
$S \equiv$ slope of reach (ft/ft)

... length of reach = 4500 ft
elevation at downstream toe of dam = 928.0
elevation at end of reach = 800.0
slope = 0.03
composite n = 0.07

$$K = \frac{1.49}{n} S^{1/2} = \frac{1.49}{0.07} (0.03)^{1/2} = 3.69$$

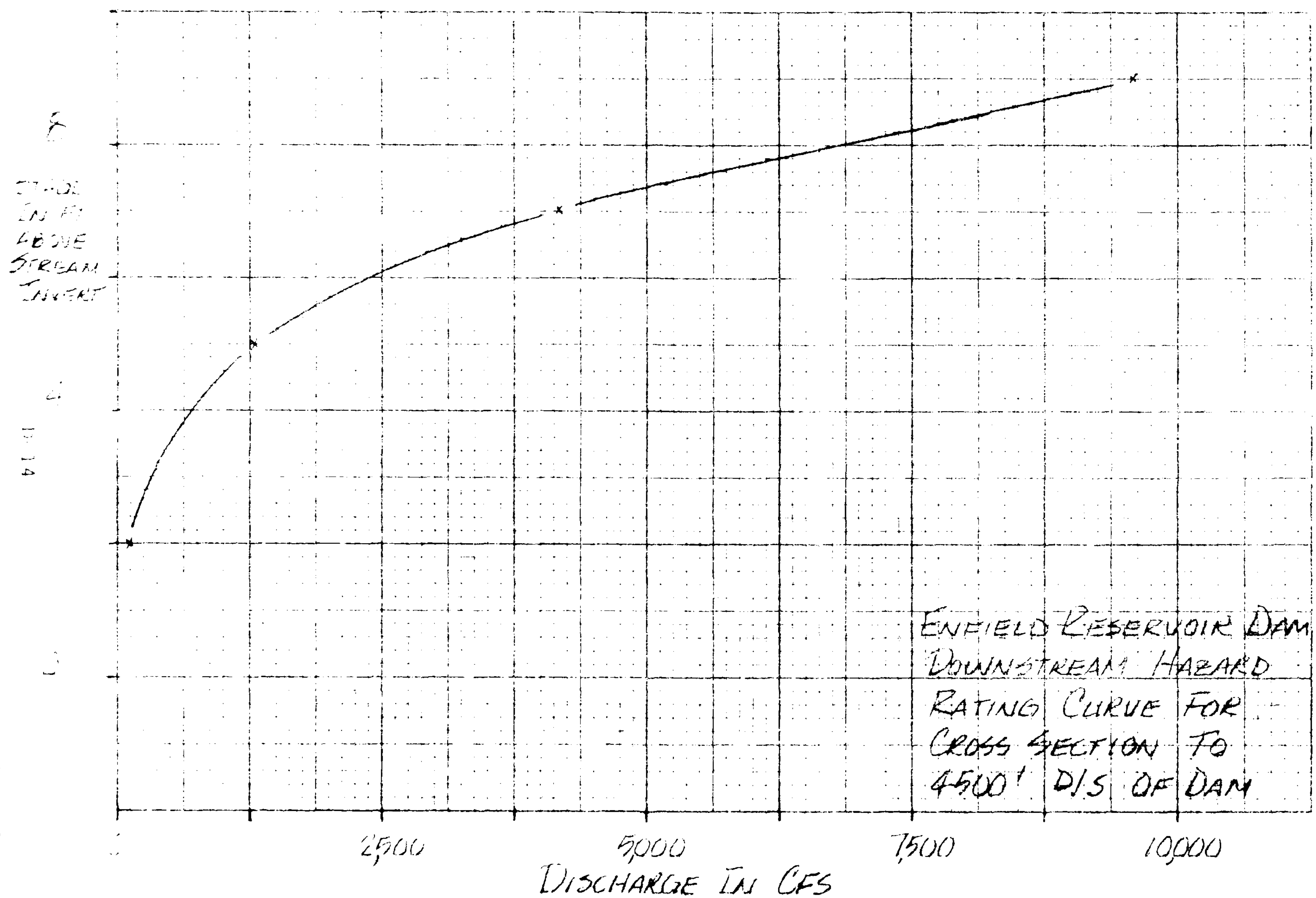
The [illegible] to the cross section [illegible] p. D-12.



HEAVILY WOODED SIDESLOPE - TYP BOTH SIDES
1
10
1
30
CHANNEL BOTTOM
ENFIELD RESERVOIR DAM
DOWNSTREAM HAZARD
TYPICAL CROSS SECTION
TO 4500' D/S OF DAM
STAGE IN FT ABOVE STREAMBED
6
4
2
0
40
0
40
60
DISTANCE IN FEET

Breach Analysis (Cont.)

Trial No.	Stage (ft.)	Discharge
1	2	$A = \frac{1}{2}(2)(10+12) = 22\ ft^2$ $WP = 10 + 2(2.2) = 14.4\ ft$ $R = A/WP = 22/14.4 = 1.53\ ft$ $Q = 3.69(22)(1.53)^{2/3} = 108\ cfs$
2	5	$A = 22 + 3(12) + \frac{1}{2}(3)^2(10) + \frac{1}{2}(3)^2(30) = 238\ ft^2$ $WP = 14.4 + 3(10) + 3(30) = 134.4\ ft$ $R = 238/134.4 = 1.77\ ft$ $Q = 3.69(238)(1.77)^{2/3} = 1{,}255\ cfs$
3	7	$A = 22 + 5(12) + \frac{1}{2}(5)^2(10) + \frac{1}{2}(5)^2(30) = 582\ ft^2$ $WP = 14.4 + 5(10) + 5(30) = 214.4\ ft$ $R = 582/214.4 = 2.71\ ft$ $Q = 3.69(582)(2.71)^{2/3} = 4{,}174\ cfs$
4	9	$A = 22 + 7(12) + \frac{1}{2}(7)^2(10) + \frac{1}{2}(7)^2(30) = 1{,}086\ ft^2$ $WP = 14.4 + 7(10) + 7(30) = 294.4\ ft$ $R = 1086/294.4 = 3.69\ ft$ $Q = 3.69(1086)(3.69)^{2/3} = 9{,}568\ cfs$


ENFIELD RESERVOIR DAM
DOWNSTREAM HAZARD
RATING CURVE FOR
CROSS SECTION TO
4500' D/S OF DAM
2500
5000
7500
10,000
DISCHARGE IN CFS
STAGE IN FT ABOVE STREAM INVERT

Referring to the rating curve on p. D-14 ...

@ Q = 1,300 cfs (antecedent conditions), stage = 5.0 ft.

@ Q = 6,935 cfs (total breach Q), stage = 8.0 ft.

∴ an increase in stage due to breach of 8.0 - 5.0 = 3.0 feet results.

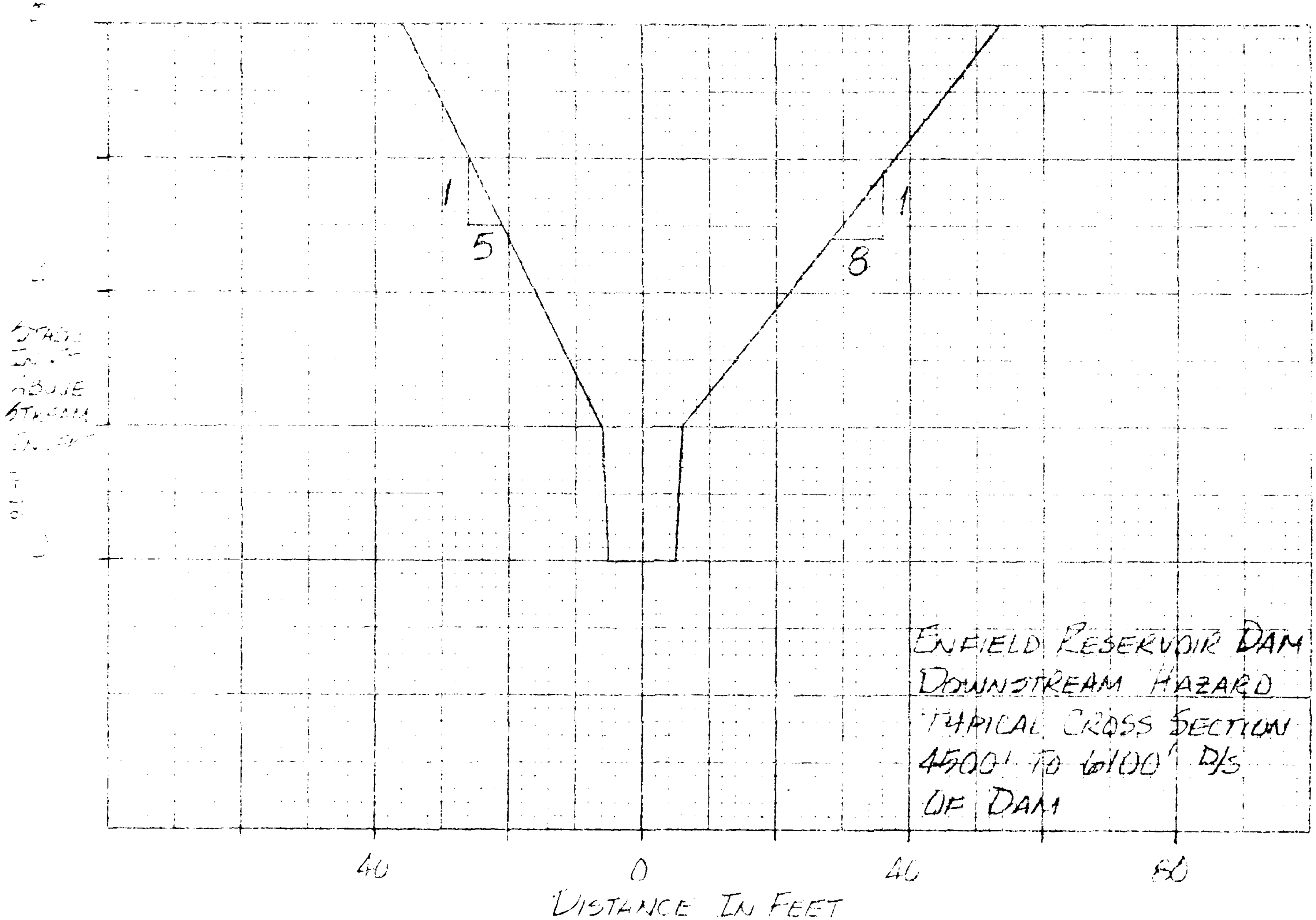
Analyze the next reach downstream, which extends from a point 4500 feet downstream of the dam to a point just upstream of the double barrel culvert that passes under May St. Use the Manning Equation to rate flow through this reach...

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \quad \text{where } K = \frac{1.49}{n} S^{1/2}$$

composite $n = 0.05$
$S = 10/1600 = 0.006$

$$K = \frac{1.49}{0.05} (0.006)^{1/2} = 2.31$$

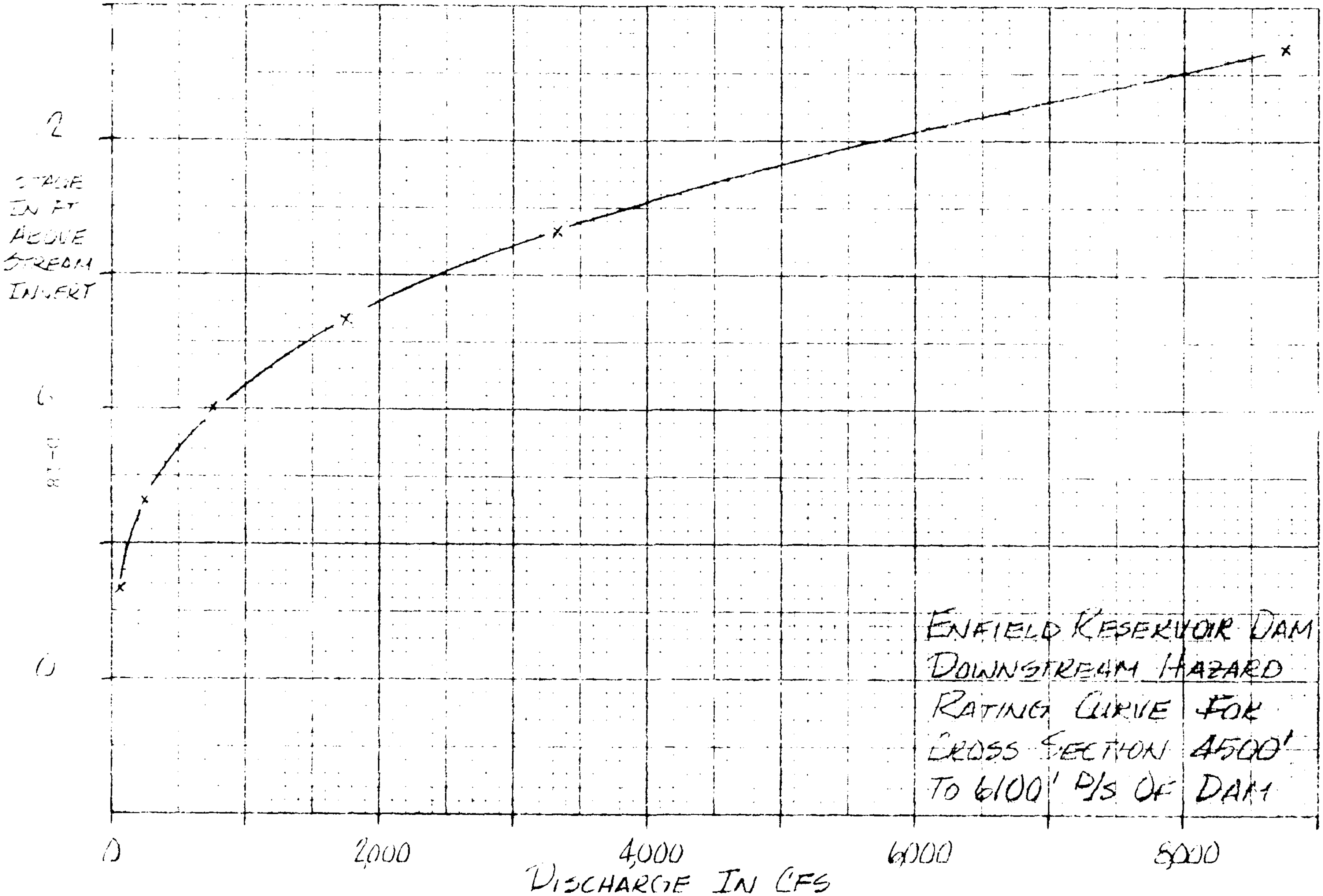
The trials below refer to the cross section on p. D-16.



1
5
1
8
40
0
40
60
DISTANCE IN FEET
ENFIELD RESERVOIR DAM
DOWNSTREAM HAZARD
TYPICAL CROSS SECTION
4500' TO 6100' D/S
OF DAM

Trial No.	Stage (ft.)	Discharge
1	2	$A = 1/2(2)(10+12) = 22\ ft^2$ $WP = 10 + 2(2.2) = 14.4\ ft$ $R = A/WP = 22/14.4 = 1.53\ ft$ $Q = 2.31(22)(1.53)^{2/3} = 67\ cfs$
2	4	$A = 22 + 2(12) + 1/2(2)^2(5) + 1/2(2)^2(8) = 72\ ft^2$ $WP = 14.4 + 2(5.1) + 2(8.1) = 40.8\ ft$ $R = 72/40.8 = 1.76\ ft$ $Q = 2.31(72)(1.76)^{2/3} = 242\ cfs$
3	6	$A = 22 + 4(12) + 1/2(4)^2(5) + 1/2(4)^2(8) = 174\ ft^2$ $WP = 14.4 + 4(5.1) + 4(8.1) = 67.2\ ft$ $R = 174/67.2 = 2.59\ ft$ $Q = 2.31(174)(2.59)^{2/3} = 758\ cfs$
4	8	$A = 22 + 6(12) + 1/2(6)^2(5) + 1/2(6)^2(8) = 328\ ft^2$ $WP = 14.4 + 6(5.1) + 6(8.1) = 93.6\ ft$ $R = 328/93.6 = 3.50\ ft$ $Q = 2.31(328)(3.50)^{2/3} = 1{,}746\ cfs$
5	10	$A = 22 + 8(12) + 1/2(8)^2(5) + 1/2(8)^2(8) = 534\ ft^2$ $WP = 14.4 + 8(5.1) + 8(8.1) = 120\ ft$ $R = 534/120 = 4.45\ ft$ $Q = 2.31(534)(4.45)^{2/3} = 3{,}334\ cfs$
6	14	$A = 22 + 12(12) + 1/2(12)^2(5) + 1/2(12)^2(8) = 1102\ ft^2$ $WP = 14.4 + 12(5.1) + 12(8.1) = 172.8\ ft$ $R = 1102/172.8 = 6.38\ ft$ $Q = 2.31(1102)(6.38)^{2/3} = 8{,}746\ cfs$

Use the above data to [illegible] discharge rating curve



ENFIELD RESERVOIR DAM
DOWNSTREAM HAZARD
RATING CURVE FOR
CROSS SECTION 4500'
TO 6100' D/S OF DAM
STAGE IN FT ABOVE STREAM INVERT
DISCHARGE IN CFS
0
2000
4000
6000
8000

BREACH ANALYSIS (CONT.)

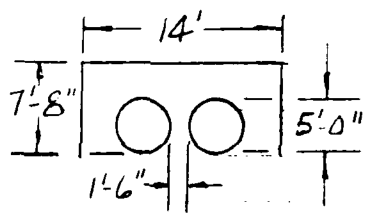
Referring to the rating curve on p. D-18 ...

@ $Q_A = 1{,}300$ cfs, stage = 7.2 feet.

@ $Q_B = 6{,}935$ cfs, stage = 12.8 feet

∴ an increase in stage due to breach of $12.8 - 7.2 = 5.6$ feet results. Three inhabited structures upstream of the double barrel culvert would be inundated, including one whose sill elevation is only 5.9 feet above the stream invert. Excessive property damage and loss of 3-5 lives is possible [illegible].

Analyze the single barrel culvert, located about 6100' downstream of the dam.



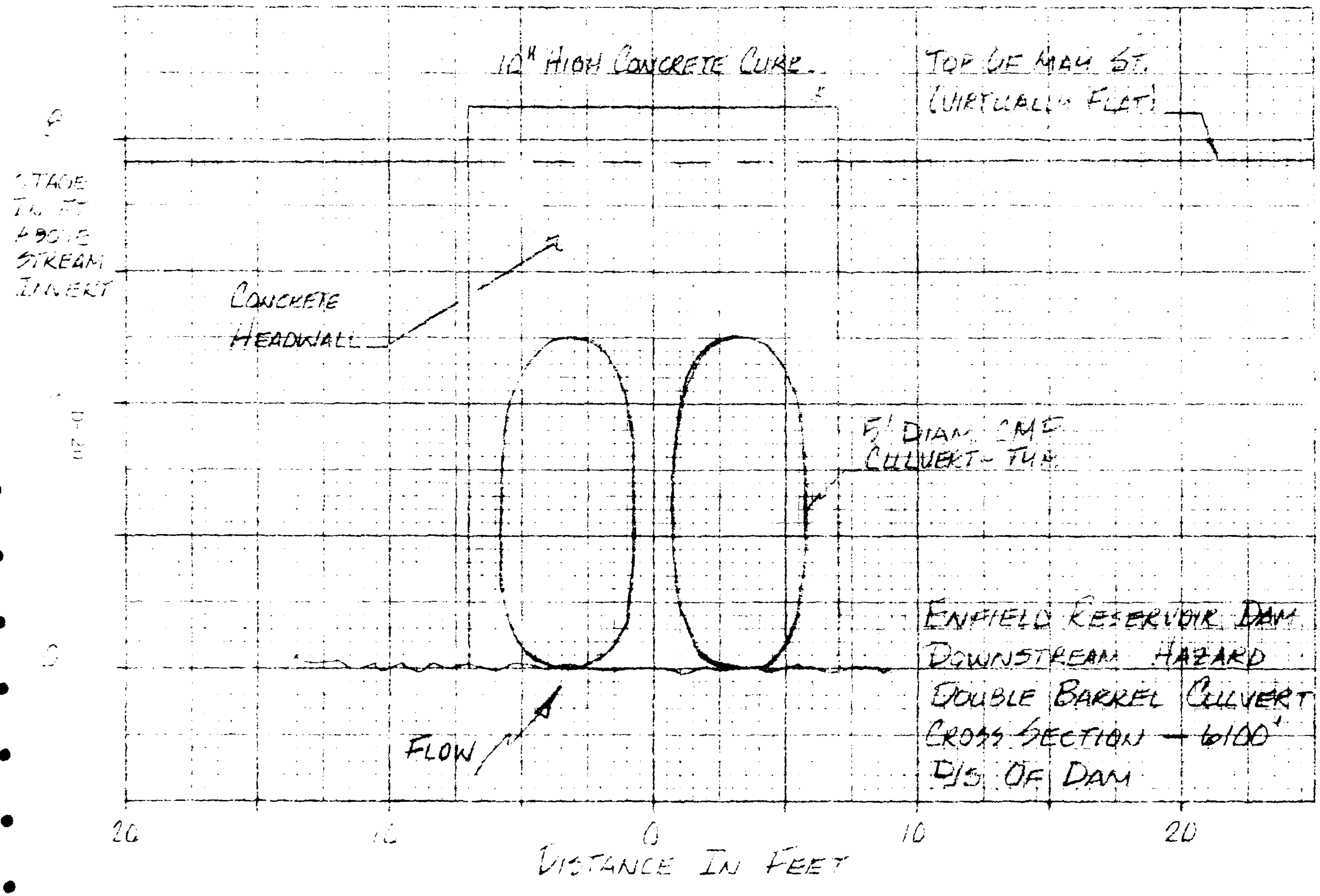
Note: Culvert is approximately 35 ft. long.

Use the orifice equation to calculate capacity of opening flowing full... $Q = Ca\sqrt{2gh}$
Upstream stage = 12.8 feet (see rating curve, p. D-18).
Assume downstream stage ≐ 7.0 feet, using the rating curve on p. D-18. (Antecedent $Q = 1300$ cfs)
$C = 0.72$*

$$Q = 0.72(31.3)\sqrt{2(32.2)(5.8)} = 547 \text{ cfs}$$

547 cfs << 6,935 cfs ∴ the culvert will not pass the total breach Q ...

* Estimated from Table 4-11, p. 4-27, Brater & King, Handbook of Hydraulics.



10" HIGH CONCRETE CURB
TOP OF MAIN ST. (VIRTUALLY FLAT)
STAGE IN FT ABOVE STREAM INVERT
CONCRETE HEADWALL
5' DIAM. CMP CULVERT - TYP.
FLOW
ENFIELD RESERVOIR DAM
DOWNSTREAM HAZARD
DOUBLE BARREL CULVERT
CROSS SECTION — 6100'
D/S OF DAM
20
10
0
10
20
DISTANCE IN FEET

D-20

Use the Manning Equation to rate flow through the double barrel culvert up to a stage of 5 feet. At stages between 5 feet and 7 feet, 5 inches, pressure flow would occur through the culvert. Above 7 feet 8 inches, weir flow over May St. and pressure flow through the culvert result.

$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$ $\quad n = 0.025$, $S = 0.006$

$$K = \frac{1.49}{n} S^{1/2} = \frac{1.49}{0.025} (0.006)^{1/2} = 4.62$$

Weir flow: $Q = CLH^{3/2}$, $C = 2.6$ ∇

The trials below refer to the cross section on p. D-20.

Trial No.	Stage (ft)	Discharge
1	2.5	$A = \frac{1}{2}\left(\pi (5)^2/4\right)(2) = 19.6\ ft^2$ $WP = \frac{1}{2}\left(2\pi(2.5)\right)(2) = 15.7\ ft$ $R = A/WP = 19.6/15.7 = 1.25\ ft$ $Q = 4.62(19.6)(1.25)^{2/3} = 105\ cfs$
2	6	$Q = Ca\sqrt{2gh} = 0.72(39.3)\sqrt{2g(0)} = 0\ cfs$
3	8.5	$Q = Ca\sqrt{2gh} + CL^{*}H^{3/2}$ $Q = 0.72(39.3)\sqrt{2g(8.5-7.67)}$ $+ 2.6(95-14)(0.54)^{3/2} = 421\ cfs$

* L, length of weir (roadway), varies depending on stage of flow through cross section shown on p. D- [illegible].

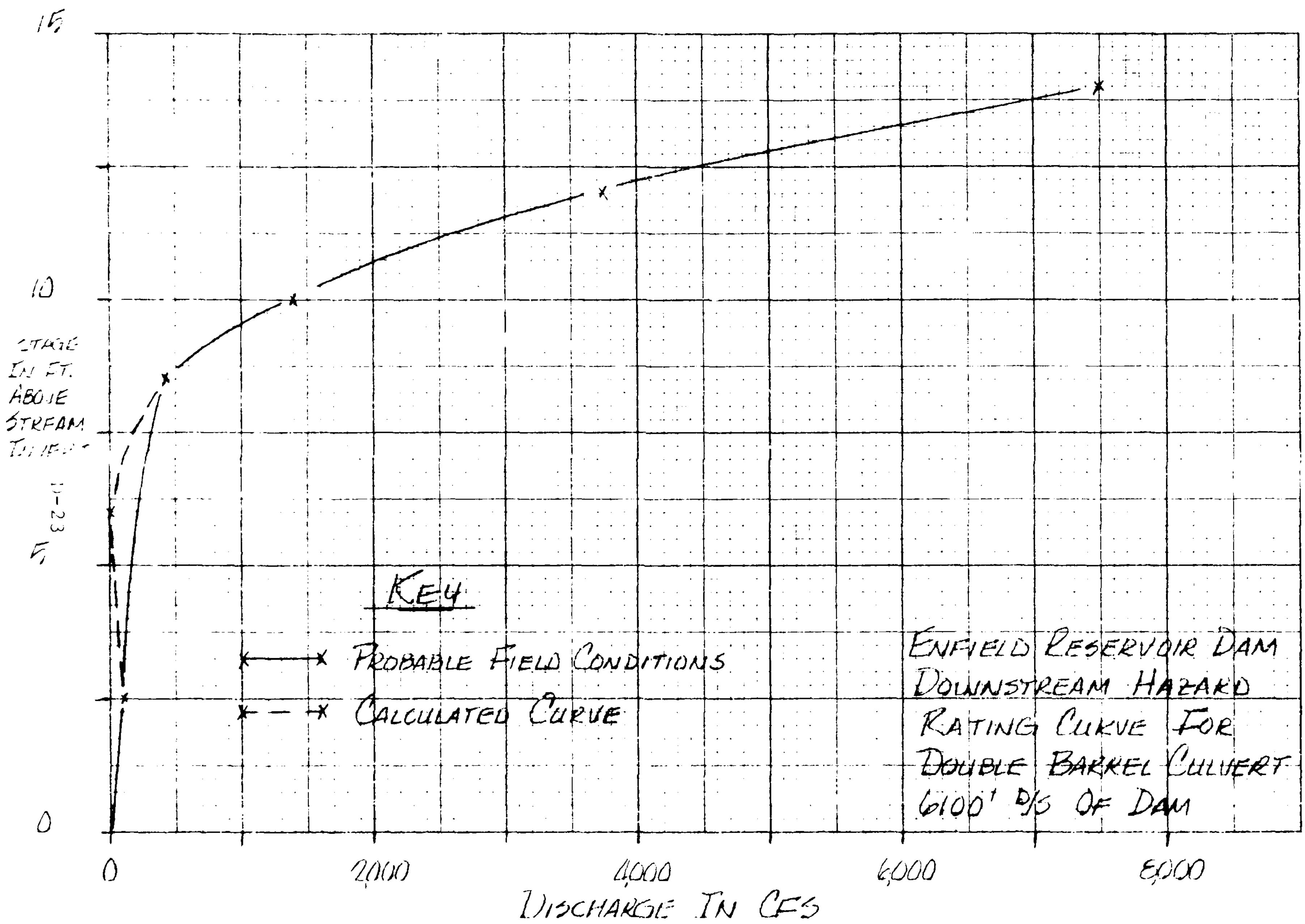
∇ Estimated from table [illegible], p. [illegible], Brater & King, Handbook of Hydraulics.

Note: Invert of double barrel culvert = stream invert.

BREACH ANALYSIS (CONT.)

Trial No.	[illegible], ft	Discharge
4	10	$Q = 0.7(39.2)\sqrt{2g(10-7.2)} + 2.6(116-14)(2.34)^{3/2} + 2.6(14)(2.34 - 10/12)^{3/2} = 1,397$ cfs
5	12	$Q = 0.7([illegible])\sqrt{2g(12-7.2)} + 2.6(142-14)(4.34)^{3/2} + 2.6(14)(4.34 - 10/12)^{3/2} = 3,145$ cfs
6	14	$Q = 0.7([illegible]3)\sqrt{2g(14-7.2)} + 2.6(169-14)(6.34)^{3/2} + 2.6(14)(6.34 - 10/12)^{3/2} = 7,196$ cfs

Use the above data to develop a discharge rating curve...


15
10
5
0
STAGE IN FT. ABOVE STREAM THREAD
0
2000
4000
6000
8000
DISCHARGE IN CFS
KEY
PROBABLE FIELD CONDITIONS
CALCULATED CURVE
ENFIELD RESERVOIR DAM
DOWNSTREAM HAZARD
RATING CURVE FOR
DOUBLE BARREL CULVERT
6100' D/S OF DAM

BREACH ANALYSIS (CONT.)

Referring to the rating curve on p. D-23...

@ Q_A = 1,3[illegible] cfs, stage = 9.9 feet

@ Q_D = 6,935 cfs, stage = 13.8 feet

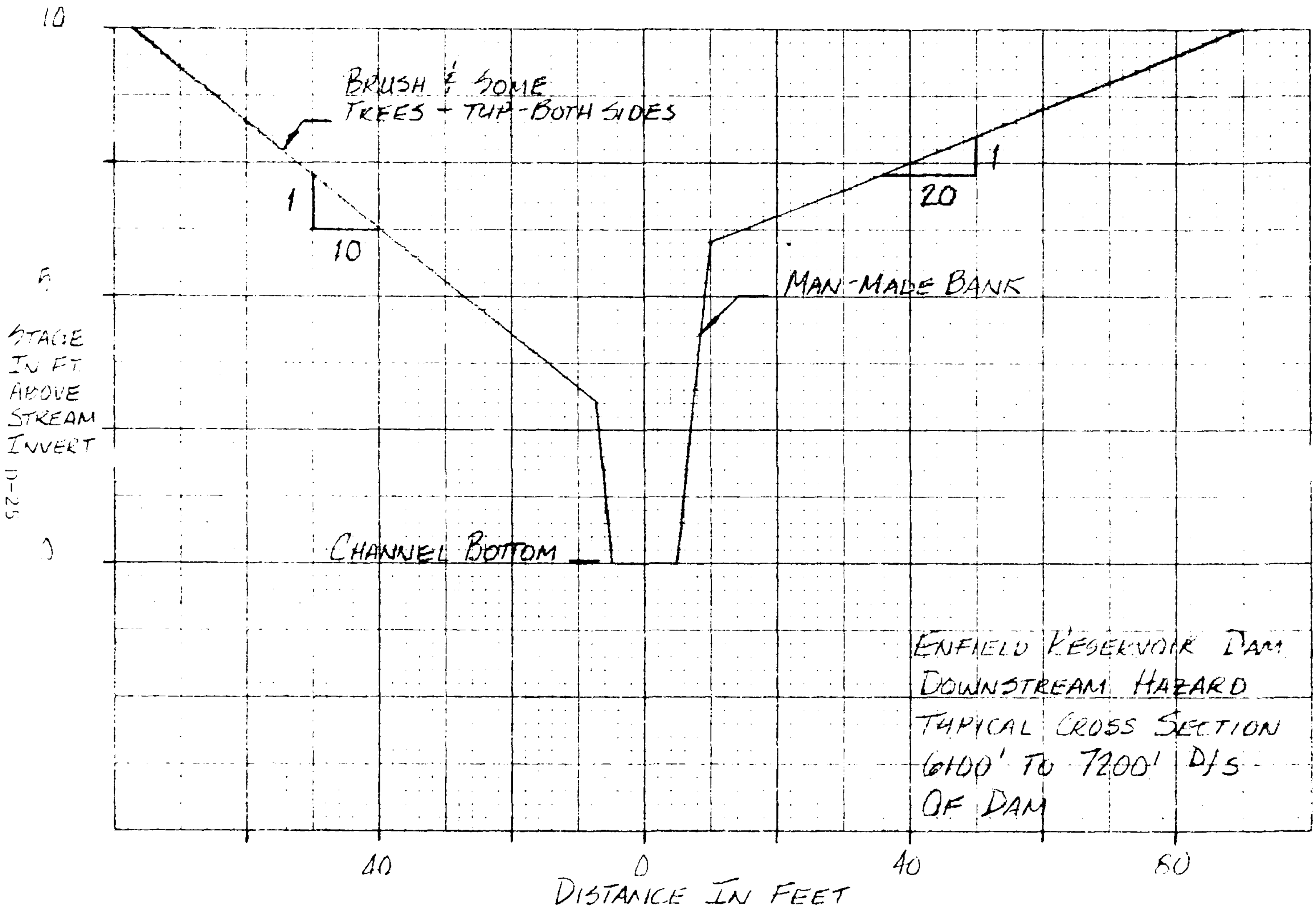
An increase in stage of 13.8 − 9.9 = 3.9 feet results. May St. would be inundated by about 3.1 feet of water during non-breach [illegible] conditions. After the breach, May St. would be inundated about 7.0 (3.9+3.1) feet of water. Excessive damage to May St. is a likely result.

Use a typical cross section of the reach extending from May St. to Route 4. Apply the Manning Equation to this cross section to rate flow...

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \qquad n = 0.05,\ S = 0.01$$

$$K = \frac{1.49}{n} (S)^{1/2} = \frac{1.49}{0.05} (0.01)^{1/2} = 2.98$$

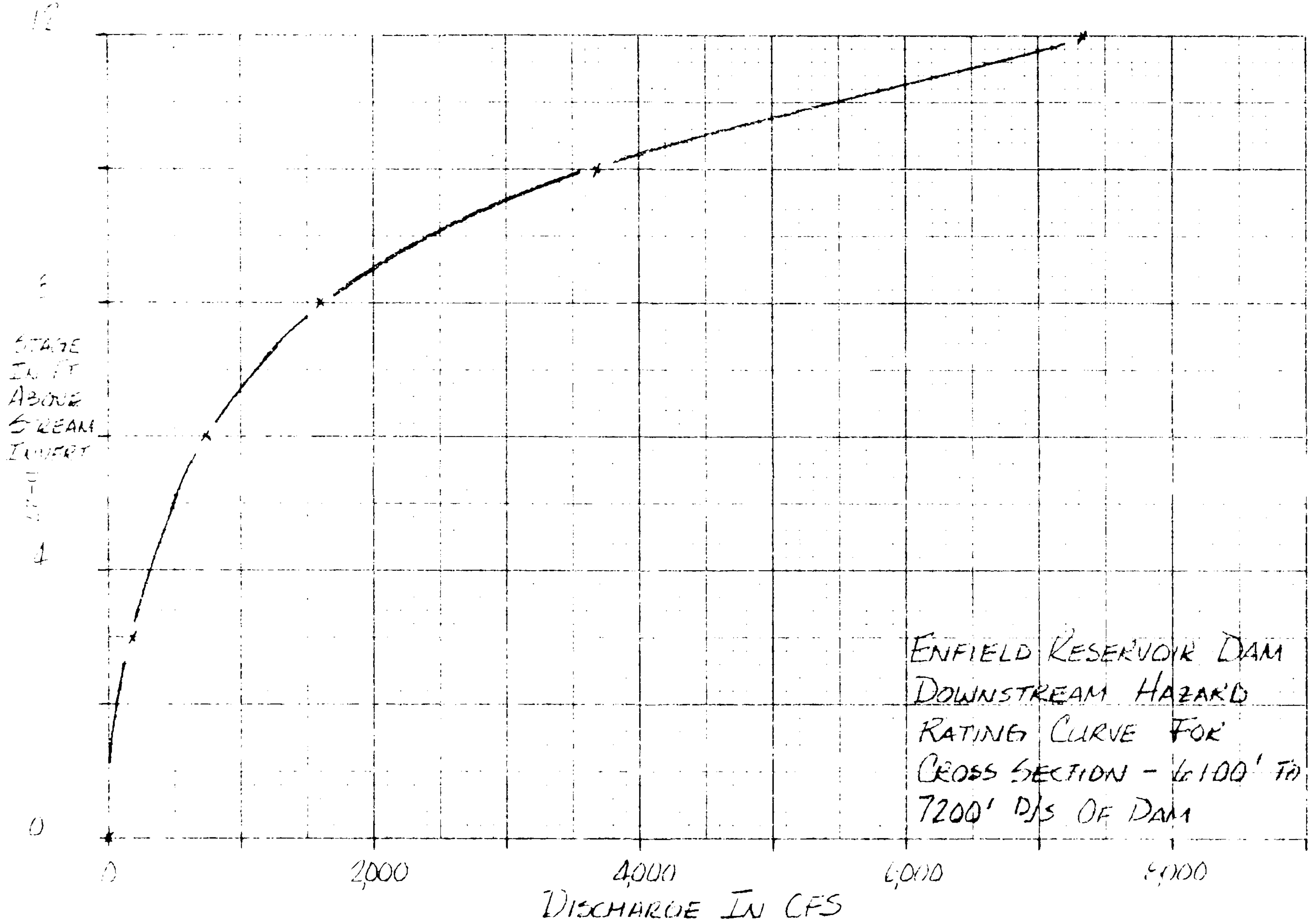
The trial calculations for the cross section on p. D- .


10
5
0
STAGE
IN FT
ABOVE
STREAM
INVERT
BRUSH & SOME
TREES – TYP-BOTH SIDES
1
10
20
MAN-MADE BANK
CHANNEL BOTTOM
ENFIELD RESERVOIR DAM
DOWNSTREAM HAZARD
TYPICAL CROSS SECTION
6100' TO 7200' D/S
OF DAM
40
0
40
60
DISTANCE IN FEET

BREACH ANALYSIS (CONT.)

Trial No.	Stage (ft)	Discharge
1	3	$A = \tfrac{1}{2}(3)(10+15) = 37.5\ ft^2$ $WP = 10 + 2(3.9) = 17.8\ ft$ $R = 37.5/17.8 = 2.11\ ft$ $Q = 2.98(37.5)(2.11)^{2/3} = 184\ cfs$
2	6	$A = 37.5 + \tfrac{1}{2}(2.5)(3) + (15)(3) + \tfrac{1}{2}(3)^2(10) = 131.3\ ft^2$ $WP = 17.8 + 3.9 + 3(10) = 51.7\ ft$ $R = 131.3/51.7 = 2.54\ ft$ $Q = 2.98(131.3)(2.54)^{2/3} = 728\ cfs$
3	8	$A = 131.3 + \tfrac{1}{2}(2)^2(20) + \tfrac{1}{2}(2)^2(10) + 47.5(2) = 286.3\ ft^2$ $WP = 51.7 + 2(20) + 2(10) = 111.7\ ft$ $R = 286.3/111.7 = 2.56\ ft$ $Q = 2.98(286.3)(2.56)^{2/3} = 1{,}596\ cfs$
4	10	$A = 131.3 + \tfrac{1}{2}(4)^2(20) + \tfrac{1}{2}(4)^2(10) + 47.5(4) = 561.3\ ft^2$ $WP = 111.7 + 2(20) + 2(10) = 171.7\ ft$ $R = 561.3/171.7 = 3.27\ ft$ $Q = 2.98(561.3)(3.27)^{2/3} = 3{,}682\ cfs$
5	12	$A = 131.3 + \tfrac{1}{2}(6)^2(20) + \tfrac{1}{2}(6)^2(10) + 47.5(6) = 956.3\ ft^2$ $WP = 171.7 + 2(20) + 2(10) = 231.7\ ft$ $R = 956.3/231.7 = 4.13\ ft$ $Q = 2.98(956.3)(4.13)^{2/3} = 7{,}329\ cfs$

Use the curve data to develop a discharge rating curve...



ENFIELD RESERVOIR DAM
DOWNSTREAM HAZARD
RATING CURVE FOR
CROSS SECTION - 6100' TO
7200' D/S OF DAM
STAGE IN FT ABOVE STREAM INVERT
12
8
4
0
0
2000
4000
6000
8000
DISCHARGE IN CFS

BREACH ANALYSIS (CONT.)

Referring to the rating curve on p. D-27...

@ Q_A = 1,300 cfs, stage = 7.4 feet

@ Q_B = 6,9[illegible] cfs, stage = 11.7 feet

∴ an increase in stage due to breach of 11.7 - 7.4 = 4.3 feet results. Two inhabited structures located along this reach would be flooded by about 3 feet of water after a breach. Appreciable property damage would probably result.

The potential for property damage and loss of life due to a breach of Enfield Reservoir Dam may be summarized as follows:

Five inhabited structures would be flooded, one with about 7 feet of water. Main St. would be inundated by about 6 feet of water when the flood wave reaches the downstream [illegible] about 600' downstream of the dam. Extensive property damage and loss of 3-6 lives is possible.

AD-A156 470 NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS ENFIELD RESERVOIR DAM. (U) CORPS OF ENGINEERS WALTHAM MA NEW ENGLAND DIV APR 79 2/2

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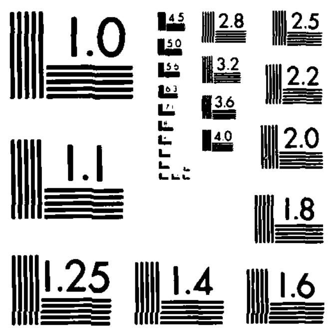


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Low Level Outlet: Capacity

Assume: Pool elevation = 950.4 (top of dam)
Pipe invert elevation = 928.0
12-in. diam. cast iron pipe, 100-ft. section

Use: Orifice equation, $Q = Ca\sqrt{2gh}$
$a \equiv$ cross sectional pipe area $= 0.79\ ft^2$
$h \equiv$ head differential $= 950.4 - (928.0 + {}^{12}\!/_{12}/2) = 21.9\ ft$
$C = ?$

Find: C, coefficient of discharge

$$C = C_p / A_p / \sqrt{2g}\ , \quad C_p^{*} = A_p \sqrt{\frac{2g}{1 + K_L + K_f L_p}}$$

$K_L \equiv$ entrance loss $= 0.5$ ▽

$K_F \equiv$ friction loss $= 0.042$ •

$n \equiv$ roughness coefficient $= 0.015$ (75 yr. old pipe)

$A_p \equiv$ area of pipe $= 0.79\ ft^2$

$L_p \equiv$ length of pipe $= 100\ ft$

$C_p \equiv$ coefficient of discharge incorporating A_p & $2g$

$C \equiv$ coefficient of discharge

* From equation 3-12, p. 3-24, Soil Conservation Service Field Engineering Manual.

▽ Figure D-1, p. 639, Schwab, Frevert, ..., Soil and Water Conservation Engineering.

• Table D.1, p. 641, Schwab, Frevert, ..., Soil and Water Conservation Engineering.

LOW LEVEL OUTLET CAPACITY (CONT.)

$$C_p = A_p \sqrt{\frac{2g}{1 + K_L + K_f L_p}} = 0.79 \sqrt{\frac{64.4}{1 + 0.5 + 0.042(100)}}$$

$$C_p = 2.66$$

$$C = C_p / A_p / \sqrt{2g} = 2.66 / 0.79 / \sqrt{2(32.2)}$$

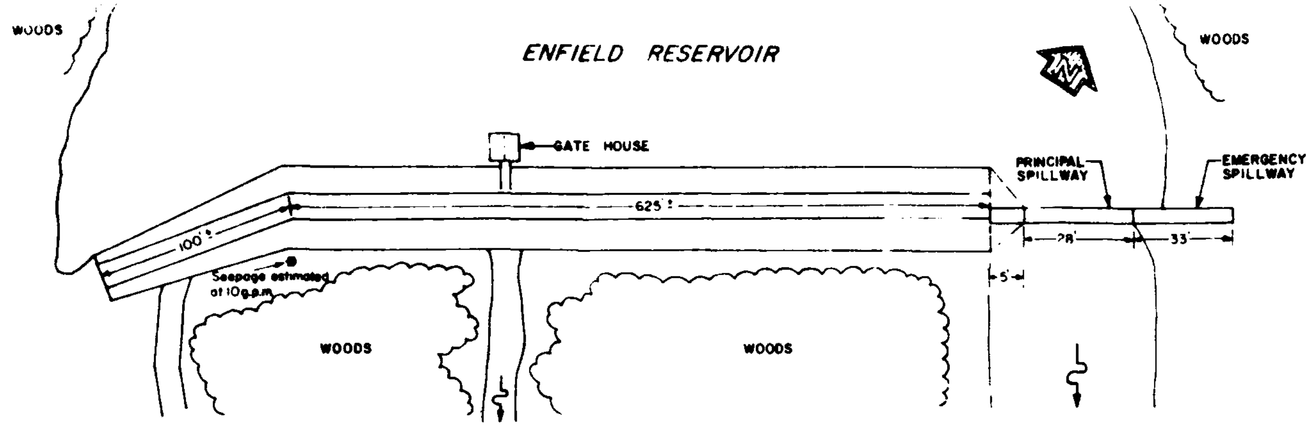
$$C = 0.42$$

$$Q = Ca\sqrt{2gh} \quad *$$

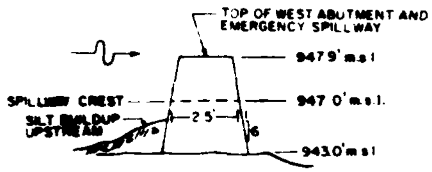
$$Q = 0.42(0.79)\sqrt{2g(21.9)} = \underline{12 \text{ cfs}}$$

APPENDIX E

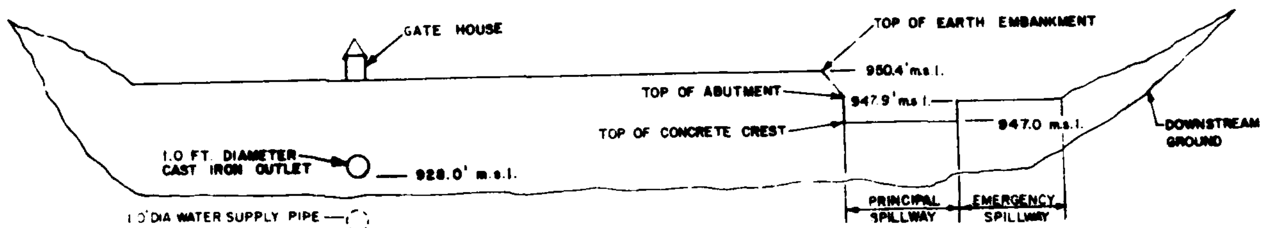
INFORMATION AS
CONTAINED IN THE NATIONAL
INVENTORY OF DAMS



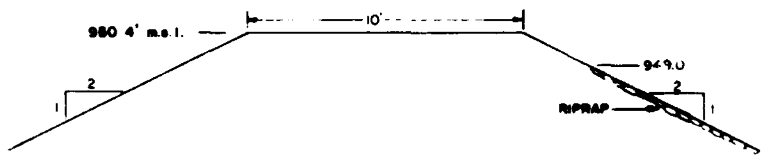
PLAN



SPILLWAY SECTION



ELEVATION



EARTH EMBANKMENT SECTION

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NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

ENFIELD RESERVOIR DAM

ENFIELD RESERVOIR NEW HAMPSHIRE

SCALE NOT TO SCALE
DATE APRIL, 1979

END

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