

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

AD-A154 405

DTIC ACCESSION NUMBER

H

LEVEL

PHOTOGRAPH THIS SHEET

1

INVENTORY

DAM-MA 00619

DOCUMENT IDENTIFICATION

Oct 1978

DISTRIBUTION STATEMENT A

Approved for public release
Distribution Unlimited

DISTRIBUTION STATEMENT

ACCESSION FOR

NTIS GRA&I

DTIC TAB

UNANNOUNCED

JUSTIFICATION

BY

DISTRIBUTION /

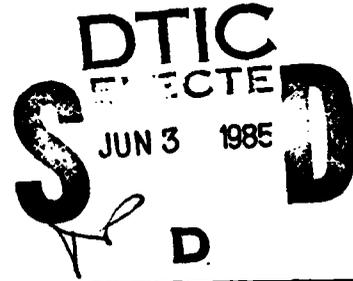
AVAILABILITY CODES

DIST

AVAIL AND/OR SPECIAL

A-1

DISTRIBUTION STAMP



DATE ACCESSIONED

DATE RETURNED

85 6 3 034

DATE RECEIVED IN DTIC

REGISTERED OR CERTIFIED NO.

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-DDAC

AD-A154 405

**BLACKSTONE RIVER BASIN
HOLDEN, MASSACHUSETTS**

**HOLDEN RESERVOIR NO. 2 DAM
MA 00619**

**PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM**



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

OCTOBER 1978

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MA 00619	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Holden Reservoir No. 2 Dam NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS		5. TYPE OF REPORT & PERIOD COVERED INSPECTION REPORT
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) U.S. ARMY CORPS OF ENGINEERS NEW ENGLAND DIVISION		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS DEPT. OF THE ARMY, CORPS OF ENGINEERS NEW ENGLAND DIVISION, NEDED 424 TRAPELO ROAD, WALTHAM, MA. 02254		12. REPORT DATE October 1978
		13. NUMBER OF PAGES 60
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) APPROVAL FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Cover program reads: Phase I Inspection Report, National Dam Inspection Program; however, the official title of the program is: National Program for Inspection of Non-Federal Dams; use cover date for date of report.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) DAMS, INSPECTION, DAM SAFETY, Blackstone River Basin Holden, Massachusetts Tatnuk Brook-Tributary of the Blackstone River		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The dam is about 530 ft. long and 48 ft. high. There are deficiencies which must be corrected to assure the continued performance of the dam. Generally the dam is in good condition. It has been classified as significant in the hazard category. It is recommended that the owner employ a qualified engineer to conduct a more detailed hydrologic and hydraulic study for this site.		

HOLDEN RESERVOIR NO. 2 DAM

MA 00619

BLACKSTONE RIVER BASIN
HOLDEN, MASSACHUSETTS

PHASE I - INSPECTION REPORT
NATIONAL DAM INSPECTION
PROGRAM

NATIONAL DAM INSPECTION
PROGRAM

PHASE I INSPECTION REPORT

BRIEF ASSESSMENT

Identification No.: MA00619

Name of Dam: Holden Reservoir No. 2

Town: Holden

County and State: Worcester County, Massachusetts

Stream: Tatnuck Brook - Tributary of the Blackstone
River

Date of Inspection: September 13, 1978

The dam at Holden Reservoir No. 2 is an earth-fill dam with a rubble masonry core and a cutoff trench in bedrock. The dam was constructed about 1900 for a water supply reservoir by the City of Worcester. The dam is about 530 feet long and 48 feet high above the original streambed. The spillway is a 40-foot-long, ungated ogee weir with a stilling basin. The spillway, which is located at the east abutment of the dam, has a crest elevation (El) of 718.0. The outlet conduit is a 30-inch diameter, cast-iron pipe. Discharge from the outlet conduit is to a stilling basin at the bottom of the spillway channel. The controls for the outlet and for two 30-inch intakes are located in the gate house located upstream of the dam, in the reservoir. The water from the reservoir is chlorinated at the chlorination building and pump station located downstream of the dam.

There are deficiencies which must be corrected to assure the continued performance of this dam. This conclusion is based on the visual inspection at the site, available engineering data, and review of operating and maintenance procedures. Generally, the dam is in good condition. According to the Corps of Engineers guidelines for the classification of hazard potential, the dam has been placed in the "significant" hazard category.

HOLDEN RESERVOIR NO. 2 DAM

The following are visible signs of distress which may indicate a potential hazard at the site: cracked and missing mortar in the walls of the spillway channel; cracking and slumping of grouted riprap near the gate house; settlement cracks in the vicinity of the central pier of the spillway bridge; efflorescence in the walls and in the stone bridge over the spillway; deterioration of the granite ogee weir; accumulation of soil and rock in the stilling basin; dense growth of vegetation in the downstream channel; and numerous animal burrows in the downstream face of the dam.

Hydraulic analyses indicate that the spillway can discharge a flow of 1,830 cfs (cubic feet per second) with the reservoir surface at El 724, which is the average elevation of the crest of the dam. An outflow test flood of 4,220 cfs (one-half the probable maximum flood (PMF)) at water surface El 724.2 will overtop the dam. The spillway can discharge 43 percent of the test outflow.

It is recommended that the Owner employ the services of a qualified consultant to conduct a more detailed hydrologic and hydraulic study for this site; evaluate the capacity of the spillway; and design repairs for the spillway and training walls. In addition the Owner should accomplish the following: repair the stone training wall and concrete floor of the spillway and channel; repair the bridge above the spillway; clear the accumulated soil in the stilling basin; clear the downstream channel; and fill in the animal burrows. The Owner should continue the program of maintenance inspections.

Repair of the spillway and training walls should be undertaken by the Owner within a year of receipt of

this Phase I Inspection Report. The remaining work should be implemented within two years. An alternative to these recommendations would be to lower the water level in the reservoir.



A handwritten signature in cursive script, appearing to read "Edward M. Greco".

Edward M. Greco, P.E.
Project Manager
Metcalf & Eddy, Inc.

Connecticut Registration
No. 08365

Approved by:

A handwritten signature in cursive script, appearing to read "Stephen L. Bishop".

Stephen L. Bishop, P.E.
Vice President
Metcalf & Eddy, Inc.



Massachusetts Registration
No. 19703

HOLDEN RESERVOIR NO. 2 DAM

This Phase I Inspection Report on Holden Reservoir No. 2 Dam has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the Recommended Guidelines for Safety Inspection of Dams, and with good engineering judgment and practice, and is hereby submitted for approval.

Richard F. Doherty

RICHARD F. DOHERTY, MEMBER
Water Control Branch
Engineering Division

Carney M. Terzian

CARNEY M. TERZIAN, MEMBER
Design Branch
Engineering Division

Joseph A. McElroy

JOSEPH A. MCELROY, CHAIRMAN
Chief, NED Materials Testing Lab.
Foundations & Materials Branch
Engineering Division

APPROVAL RECOMMENDED:

Joe B. Fryar

JOE B. FRYAR
Chief, Engineering Division

PREFACE

This report is prepared under guidance contained in Recommended Guidelines for Safety Inspection of Dams, for a Phase I Investigation. 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 hydrology 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 aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general conditions and the downstream damage potential.

HOLDEN RESERVOIR NO. 2 DAM

TABLE OF CONTENTS

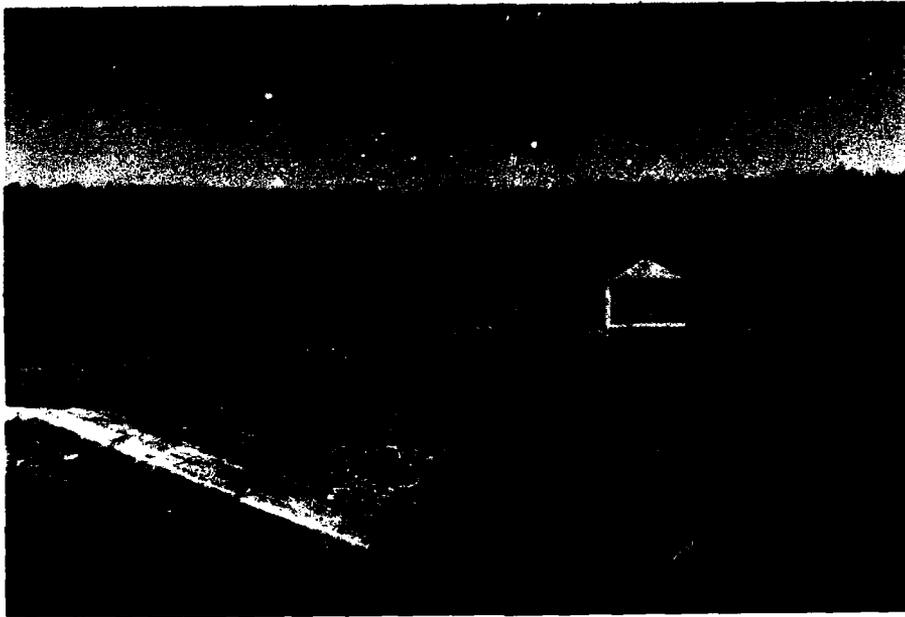
	<u>Page</u>
BRIEF ASSESSMENT	
PREFACE	
OVERVIEW PHOTO	
LOCATION MAP	
REPORT	
SECTION 1 - PROJECT INFORMATION	1
1.1 General	1
1.2 Description of Project	2
1.3 Pertinent Data	6
SECTION 2 - ENGINEERING DATA	10
2.1 General	10
2.2 Construction Records	10
2.3 Operating Records	10
2.4 Evaluation of Data	10
SECTION 3 - VISUAL INSPECTION	12
3.1 Findings	12
3.2 Evaluation	14
SECTION 4 - OPERATING PROCEDURES	15
4.1 Procedures	15
4.2 Maintenance of Dam	15
4.3 Maintenance of Operating Facilities	15
4.4 Description of Any Warning System in Effect	15
4.5 Evaluation	15
SECTION 5 - HYDRAULIC/HYDROLOGIC	16
5.1 Evaluation of Features	16

HOLDEN RESERVOIR NO. 2 DAM

TABLE OF CONTENTS (Continued)

	<u>Page</u>
SECTION 6 - STRUCTURAL STABILITY	18
6.1 Evaluation of Structural Stability	18
SECTION 7 - ASSESSMENT, RECOMMENDATIONS, AND REMEDIAL MEASURES	19
7.1 Dam Assessment	19
7.2 Recommendations	20
7.3 Remedial Measures	20
7.4 Alternatives	21
APPENDIXES	
APPENDIX A - PERIODIC INSPECTION CHECKLIST	
APPENDIX B - PLAN OF DAM AND PREVIOUS INSPECTION REPORTS	
APPENDIX C - PHOTOGRAPHS	
APPENDIX D - HYDROLOGIC AND HYDRAULIC COMPUTATIONS	
APPENDIX E - INFORMATION AS CONTAINED IN THE NATIONAL INVENTORY OF DAMS	

**OVERVIEW
HOLDEN RESERVOIR NO. 2
HOLDEN, MASSACHUSETTS**

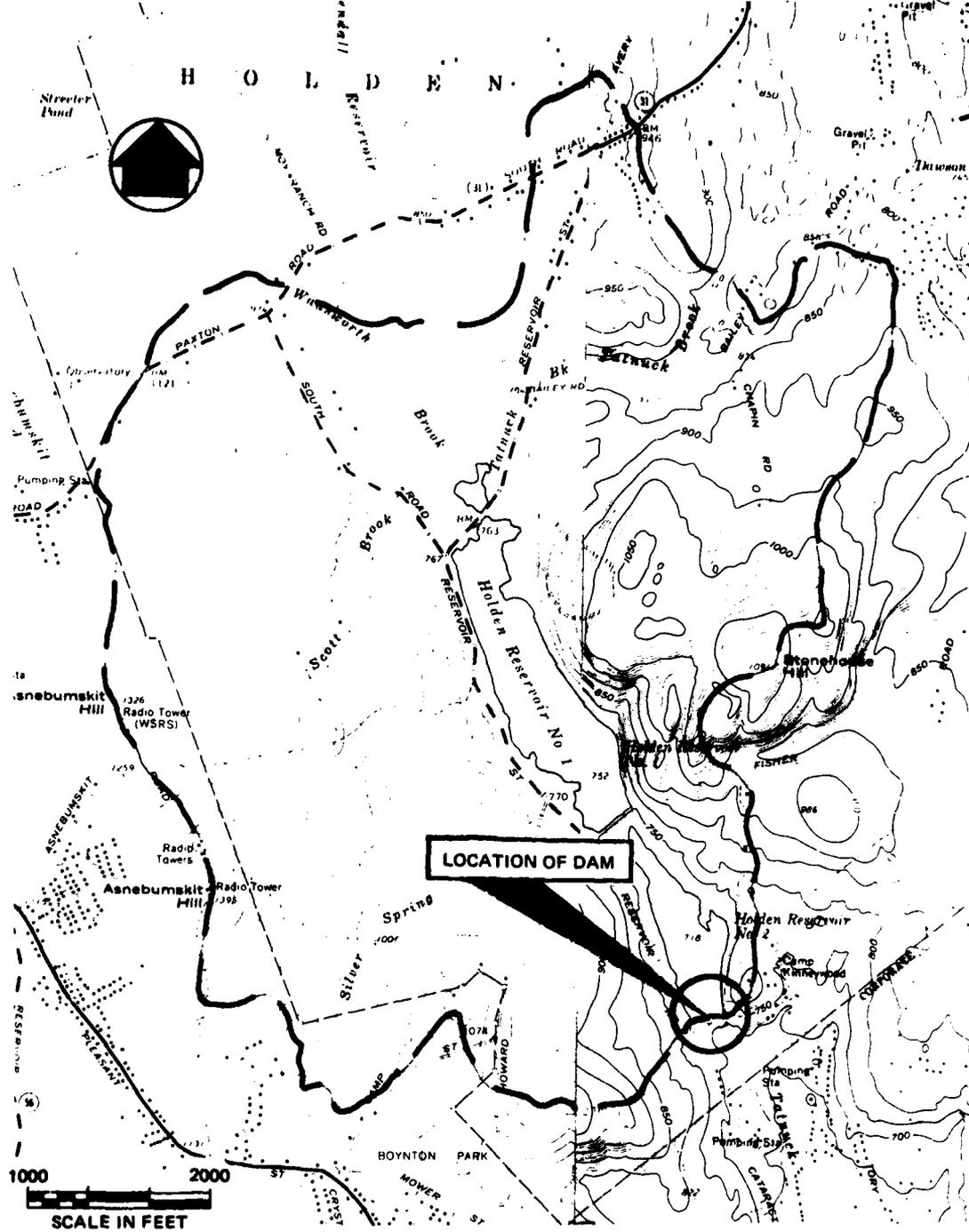


VIEW OF UPSTREAM FACE OF DAM

**Location and Direction of Photographs
Shown on Figure in Appendix B**

PAXTON QUADRANGLE
MASSACHUSETTS-WORCESTER CO.

WORCESTER NORTH QUADRANGLE
MASSACHUSETTS-WORCESTER CO.



LOCATION MAP - HOLDEN RESERVOIR NO. 2 DAM

NATIONAL DAM INSPECTION
PROGRAM

PHASE I INSPECTION REPORT

HOLDEN RESERVOIR NO. 2 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. Metcalf & Eddy, Inc. has been retained by the New England Division to inspect and report on selected dams in the State of Massachusetts. Authorization and notice to proceed was issued to Metcalf & Eddy, Inc. under a letter of July 28, 1978, from Ralph T. Garver, Colonel, Corps of Engineers. Contract No. DACW 33-78-C-0306 has been assigned by the Corps of Engineers for this work.
- b. Purpose
- (1) Perform technical inspection and evaluation of non-Federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-Federal interests.
 - (2) Encourage and assist the States to initiate quickly effective dam safety programs for non-Federal dams.
 - (3) Update, verify and complete the National Inventory of Dams.

HOLDEN RESERVOIR NO. 2 DAM

1.2 Description of Project

- a. Location. The dam at Holden Reservoir No. 2 is located on Tatnuck Brook, in the Town of Holden, Worcester County, Massachusetts (see Location Map).
- b. Description of Dam and Appurtenances. Holden Reservoir No. 2 Dam is an earthfill dam 530 feet long and 48 feet high (see Figures B-1, B-2, and B-3). The crest of the dam is 24 feet wide and covered with grass. The elevation of the crest varies from 722.8 on the upstream side to 724.2 on the downstream side. The dam ties into natural ground at the abutments. The embankment is constructed with a rubble masonry core and puddled fill on either side. The core wall extends about 5 feet into bedrock for most of the dam. The upstream and downstream sides of the embankment are constructed of selected materials with side slopes of 2:1 (horizontal to vertical). The upstream face of the dam is protected with riprap. The downstream area of the dam face was used as a spoil bank during dam construction. The access road to the dam and to the east side of the reservoir is on the spoil bank. The bank is covered with grass, and there is a row of trees growing along the south side of the road. The toe of the downstream slope is approximately at the tree line.

The spillway is an ogee weir located at the left (east) abutment. Figure B-3 indicates a cutoff wall into the bedrock upstream of the weir. The approach to the weir is paved with placed stone and bounded by 6-foot high mortared stone masonry training walls capped with granite slabs. The ogee section of the spillway is made of five granite blocks. Upstream and downstream of the weir, the floor of the spillway is paved with concrete. The crest of the granite weir, which is at El 718.0, is less than 1 foot above the concrete floor. The weir is 40 feet long. Flashboards can be added to the weir, as evidenced by the 10 holes drilled into the granite for pins. When not in use, the flashboards are stored in the gate house at the dam.

HOLDEN RESERVOIR NO. 2 DAM

The channel downstream of the ogee weir is also paved with concrete and bounded by mortared masonry side walls. At approximately 35 feet below the weir, a mortared stone masonry bridge spans the channel in two archways separated by a central pier. Each archway is 18 feet long and the bridge is 15 feet wide, upstream to downstream side. The channel slopes down as it passes underneath the bridge. At the upstream side, the maximum height from the floor of the channel to the crown of each arch is 4.3 feet. At the downstream side, this height increases to 7.4 feet.

About 80 feet below the weir, the side walls curve inward, reducing the width of the channel to 13.3 feet. The concrete channel slopes at about 6 percent and ends 180 feet below this point in a flat-bottomed stilling basin 24 feet long. The upstream end of the basin is 26 feet wide and, according to Figure B-1, there is a second cutoff wall there. The basin drops vertically about 2.5 feet below the floor of the channel. The downstream end is a curved mortared masonry wall. Water overflowing the basin flows down a stepped stone cascade weir on the downstream side of the wall and into a second concrete paved channel. This channel is bounded by a high mortared stone masonry retaining wall on the right and by the natural slope on the left side. The concrete pavement ends at about 70 feet from the cascade and the stream channel continues downstream bounded by a dry stone masonry retaining wall on the right.

The outlet works at Holden Reservoir No. 2 include two 30-inch diameter water supply intakes and a 30-inch diameter low-level outlet for draining the reservoir. Flow through each conduit is controlled by hand-operated sluice gates located inside a gate house. The gate house has a brick superstructure on a granite block foundation and is located in the reservoir. Access to the gate house from the dam is by a single span steel service bridge with a deck of wood planks. The bridge is secured into the granite abutments with anchor bolts.

HOLDEN RESERVOIR NO. 2 DAM

The inlet to the low-level outlet is submerged in the reservoir. The pipe is a total of 617 feet long, and according to the drawing (Figure B-1), the intake extends 100 feet into the reservoir and the outlet discharges into the stilling basin at El 670.2. The two water supply conduits originate in a screened intake well beneath the gate house. The pipes are in the same rubble bedding in the bedrock as the outlet pipe, at El 680.0 (see Figure B-3). Seepage collars extend from the bedding up into the embankment fill.

The 30-inch supply pipes change to 40-inch pipes beneath the access road. There is a lower brick gate house at the toe of the dam, adjacent to the stilling basin. This houses the valve which controls flow from the 40-inch lines to the chlorination building downstream.

A fourth 30-inch pipe serves as a direct connection from Holden Reservoir No. 1 (upstream of Holden Reservoir No. 2) to the chlorinators and pumping stations downstream. This pipe passes beneath the dam on the right side of the gate house.

- c. Size Classification. The dam at Holden Reservoir No. 2 is classified in the "intermediate" category since it is 48 feet high, with a maximum storage capacity of 1,091 acre-feet.
- d. Hazard Classification. Holden Reservoir No. 2 is situated in a sparsely developed rural area northwest of the City of Worcester. Failure of the dam would result in flooding in the Tatnuck Brook valley, which is mostly woodland, and possible damage to the Worcester pumping and chlorination stations located downstream. The residences closest to Tatnuck Brook on Olean Street are at least 2,600 feet downstream of the dam, and are about 5 feet above the present stream bed. The damaging effect of a flood wave could affect no more than two residences in this area. For this reason, the dam has been placed in the "significant" hazard category.

HOLDEN RESERVOIR NO. 2 DAM

- e. Ownership. The reservoir and dam are owned by the Department of Public Works Operations-Water, City of Worcester, 20 East Worcester Street, Worcester, Massachusetts. Mr. Kenneth Starbard, Supervisor of Water Supply (telephone: 617-829-4811) granted permission to enter the property and inspect the dam.
- f. Operator. The Supervisor of Water Supply and his staff operate the outlets at the dam, as well as the pumping station appurtenant to the water supply system.
- g. Purpose of Dam. The purpose of the dam is to provide storage for the City of Worcester water supply. Holden Reservoir No. 2 is the distributing reservoir in the low service supply system. The four other reservoirs in the system are Quinapoxet, Pine Hill, Kendall and Holden Reservoir No. 1, all located in the Town of Holden.
- h. Design and Construction History. The only plans available for this dam are dated May 8, 1900. The dam, which was presumably built soon after that, is the oldest dam in the low service system. Generally the dam has remained in good condition since its construction. An inspection report prepared in 1942 by Worcester County refers to "slight seepage at the foot of the structure" with no further explanation. There is no mention of seepage or leaking in subsequent reports. A 1960 report stated that the spillway was in good condition and a minor crack in the "south" wall was not a dangerous situation. However, the inspector did recommend that the masonry walls be repointed. It was also recommended that all the mortar be removed from the rip-rap and replaced by rich concrete grout.
- i. Normal Operational Procedures. Water from Holden Reservoir No. 2 enters the chlorination station downstream of the dam, on Olean Street, and then the distribution system serving the City of Worcester. The operating procedure at this site is to retain the maximum possible storage in Holden Reservoir No. 2 in order to maintain the maximum pressure possible in the City system.

HOLDEN RESERVOIR NO. 2 DAM

Twenty-inch high flashboards are usually added to the weir in the springtime, after the ice melts. These are removed once the water level is below the crest.

1.3 Pertinent Data

- a. Drainage Area. The drainage area contributing directly to Holden Reservoir is approximately 3,258 acres (5.09 square miles). It includes sparsely developed, hilly woodlands with average slopes estimated at 6 percent. Residential development is limited to the vicinity of South Road at the north end of the basin. The entire watershed area is controlled by the Worcester Department of Public Works. Silver Spring Brook, Scott Brook, Wadsworth Brook and Tatnuck Brook all discharge directly into Holden Reservoir No. 1, which drains by open channel and by pipeline into Holden Reservoir No. 2. Water from Quinapoxet, Pine Hill, and Kendall Reservoirs, which are in a different watershed, is diverted to Holden No. 1 and No. 2 reservoirs.
- b. Discharge at the Dam Site. Normal discharge is over the ungated spillway. The spillway is 40 feet long, with the crest at El 718.0. Water flows down the 250-foot long concrete and mortared masonry channel into a flat-bottom stilling pool. The pool extends about 24 feet. At the downstream end, water flows over the curved stone masonry wall and down a stepped stone cascade into a second concrete channel. This channel, which is bounded on the west (right) by a high masonry retaining wall, ends about 70 feet below the stilling basin. The natural stream channel then passes through an area with trees and brush to a small pool and control dam. The stream joins Tatnuck Brook about 600 feet below this pool.

The spillway can discharge an estimated 1,830 cfs with the water surface at El 724.0, which is the average elevation of the crest of the dam. An outflow test flood of 4,220 cfs would overtop the dam by about 1.2 feet.

HOLDEN RESERVOIR NO. 2 DAM

With the reservoir at the same elevation as the crest of the dam, the spillway will discharge 43 percent of the test outflow.

Daily weir readings for Holden Reservoir No. 2 are available at the Worcester DPW offices. Those records indicate that the dam was not overtopped during the 1938 or 1955 floods.

c. Elevation (feet above Mean Sea Level (MSL)).

The elevation of the crest of the spillway was established as a benchmark at El. 718.0. This elevation was estimated from a U. S. Geological Survey topographic map.

- (1) Top dam: 722.8 on upstream side,
724.2 on downstream side
- (2) Test flood pool: 725.2
- (3) Design surcharge (original design):
Unknown
- (4) Full flood control pool: Not applicable
(N/A)
- (5) Recreation pool: N/A
- (6) Spillway crest: 718.0
- (7) Upstream portal invert diversion tunnel:
N/A
- (8) Stream bed at dam (original stream bed):
675.8
- (9) Maximum tailwater: None

d. Reservoir

- (1) Length of maximum pool: 2,500 feet
- (2) Length of recreation pool: N/A
- (3) Length of flood control pool: N/A

e. Storage (acre-feet)

- (1) Test flood surcharge (Net): 350 at El
725.2

HOLDEN RESERVOIR NO. 2 DAM

- (2) Top of dam: 1,091
- (3) Flood control pool: N/A
- (4) Recreation pool: N/A
- (5) Spillway crest: 797 (without flashboards)

f. Reservoir Surface (acres)

- *(1) Top dam: 49
- *(2) Maximum pool: 49
- (3) Flood-control pool: N/A
- (4) Recreation pool: N/A
- (5) Spillway crest: 49

g. Dam

- (1) Type: earthfill
- (2) Length: 530 feet
- (3) Height: 48 feet
- (4) Top width: 24 feet
- (5) Side slopes: Upstream: 2:1
Downstream: 2:1
- (6) Zoning: Rubble core, puddled fill, and selected fill
- (7) Impervious core: Rubble core
- (8) Cutoff: Rubble core keyed into bedrock
- (9) Grout curtain: Unknown

*Based on the assumption that the surface area will not significantly increase with changes in reservoir elevation from 718.0 to 724.0.

HOLDEN RESERVOIR NO. 2 DAM

1. Spillway

- (1) Type: Ogee weir - provisions for 20-inch high flashboards
- (2) Length of weir: 40 feet
- (3) Crest elevation: 718
- (4) Gates: None
- (5) Upstream channel: Mortared stone pavement, then concrete slab. Mortared stone masonry training walls, capped with granite
- (6) Downstream channel: Concrete channel with vertical mortared stone masonry walls; maximum 40 feet wide, 3 feet deep. Channel is 250 feet long, ends in concrete stilling basin. Beyond basin, concrete paved channel changes to natural stream channel bounded on the right by a dry stone masonry retaining wall.

- j. Regulating Outlets. The regulating outlet at the dam is a 30-inch diameter cast-iron pipe. The pipe is shown on the drawing (Figure B-1) to be 617 feet long, with the invert at El 680.0. The inlet to the conduit is located on the bottom of the reservoir. The outlet is shown at the right sidewall of the stilling basin. Flow is controlled by a sluice gate in the gate house, upstream of the dam. The gate is operated by a handwheel inside the gate house. Hydraulic calculations indicate that the outlet has the capacity to discharge 100.4 cfs.

SECTION 2

ENGINEERING DATA

- 2.1 General. Three plans are available of the dam at Holden Reservoir No. 2. These plans are dated May 8, 1900 and show the embankment, spillway and outlet conduits. There are no specifications or computations available from the Owner, State, or County offices relative to the design and construction of the dam. The remaining data available for this evaluation were visual observations made during the inspection, review of previous inspection reports, and conversations with City, State, and County personnel.

We acknowledge the assistance and cooperation of personnel of the Massachusetts Department of Public Works: Messrs. Willis Regan and Raymond Rochford, and of the Massachusetts Department of Environmental Quality Engineering, Division of Waterways: Messrs. John J. Hannon and Joseph Iagallo.

Also, we acknowledge the cooperation and assistance of personnel from the Worcester County Engineer's Office: Messrs. John O'Toole, Joseph Brazauskas, and Mr. Wallace Lindquist - recently retired from county service.

Mr. Kenneth Starbard, and personnel from the Worcester Department of Public Works Operations-Water, provided information on the construction, history, and operation of the dam.

- 2.2 Construction Records. There are no construction records available.
- 2.3 Operating Records. Operating records for the entire water supply system are kept at the Department of Public Works office in Worcester. These are daily reports of rainfall, water level, storage volume, and depth of flow over weir.
- 2.4 Evaluation
- a. Availability. Other than hydrologic and hydraulic data referred to in Section 2.3,

HOLDEN RESERVOIR NO. 2 DAM

there is very little engineering data available for this dam. The Department of Public Works file is incomplete.

- b. Adequacy. The lack of in-depth engineering data did not allow for a definitive review. Therefore the adequacy of this dam could not be assessed from the standpoint of reviewing design and construction data, but is based primarily on visual inspection, past performance history and engineering judgment.
- c. Validity. The available information is considered valid.

SECTION 3
VISUAL INSPECTION

3.1 Findings

- a. General. The Phase I Inspection of the dam at Holden Reservoir No. 2 was performed on September 13, 1978. A copy of the inspection checklist is in Appendix A. Previous inspections of this dam have been made by others since 1924. A partial listing of these inspections is in Appendix B. A copy of the 1973 inspection report by the Massachusetts Department of Public Works is also included in Appendix B.
- b. Dam. The earth embankment of the dam is in generally good condition. The crest and downstream slope are clear of brush and trees. Numerous animal burrows were observed at the downstream toe of the dam, in the spoil bank area. The grouted riprap on the upstream slope is in fair condition. Some of the riprap is missing and there are weeds growing through cracks in the grout. The condition of the riprap is poorest in the vicinity on the service bridge to the gate house. Here, settlement and slumping of the slope is evident by the large cracks in the grout, parallel to the axis of the dam.
- c. Appurtenant Structures. The spillway is in good to fair condition. Stone walls in the approach and downstream channel show a significant amount of efflorescence. Some mortar is missing between the stones. The floor of the approach channel has some weeds growing up through cracks in the mortar. The concrete slabs on the floor of the channel are in fair condition. Some of the slabs are cracked. Weeds are generally growing in the construction joints and at the base of the sidewalls.

The granite ogee weir is showing signs of deterioration. One section of the weir has been patched with mortar that is beginning

HOLDEN RESERVOIR NO. 2 DAM

to spall. Elsewhere the granite has been chipped at the crest. The weir is stained with rust from the flashboard pins.

The bridge over the spillway shows heavy efflorescence, particularly under the archways. The mortar is crumbling between the stones and often missing altogether in some places. Settlement of the central pier is evident by the diagonal cracks appearing on the upstream face of the bridge and by other cracks in the concrete floor around the pier. There is another large crack in the mortar on the downstream face of the bridge, at the right spillway wall. The decorative capwall on the bridge has been displaced on the upstream side. An entire section of this wall was knocked off the downstream side by a vehicle. Pieces of the wall are still lying on the floor of the downstream channel. There are areas of erosion on the earth slopes at the bridge abutments.

The basin at the toe of the spillway channel shows an accumulation of soil and rocks, particularly at the upstream end. There is a 6-inch diameter cast-iron pipe extending through the cascade weir from the basin. There was no flow in this pipe, and its function is unknown. There is a 30-inch diameter opening in the right side wall, below the cascade. This would appear to be the outlet for the low-level conduit, but the pipe is blocked off about 5 feet back into the wall.

Trees overhang the natural stream channel, and weeds are growing on the floor below the basin and lower concrete channel.

The gate house in the reservoir is in good condition, with only minor cracking in the brick work. The three hand-operated sluice gates are reportedly in good operating condition. The screened intake is kept clear at all times.

The service bridge to the gate house is in fair condition. The granite abutments and steel girders are in good condition, but the

HOLDEN RESERVOIR NO. 2 DAM

bearings are badly rusted on the bridge, and the expansion joints at the dam side of the bridge are missing. The concrete slab at the approach to the bridge shows minor cracks.

The exterior of the lower gate house is fairly well maintained, although the steps at the entrance are generally overgrown with weeds. The interior was not inspected.

- d. Reservoir Area. Since Holden Reservoir No. 2 is used for a public drinking water supply, development near the reservoir is prohibited by the City of Worcester. A private camp is located on the far side of the hill just east of the reservoir, but outside the drainage area. There are no residences on Reservoir Road, which is the only other road near Holden Reservoir No. 2.
 - e. Downstream Channel. The channel passes through an overgrown, wooded area until it reaches a clearing and diversion pond. This is in the area of the chlorinators and pumping station operated by the City of Worcester. After that, the stream joins Tatnuck Brook, about 1,700 feet below the dam, and it continues through sparsely developed woodland to Cook Pond, in Worcester.
- 3.2 Evaluation. The dam at Holden Reservoir No. 2 appears to be in good condition. The slightly deteriorating state of the spillway channel and side walls indicates that this area requires more adequate maintenance. Recommended measures to improve these conditions are stated in Section 7.3.

SECTION 4
OPERATING PROCEDURES

- 4.1 Procedures. The storage in Holden Reservoir No. 2 is carefully controlled by the Department of Public Works as it is a significant element in the public water supply system for the City of Worcester. Water leaving this reservoir, either by gravity or pumping, passes through the chlorination building before entering the City distribution system.

Daily records of operating procedures are maintained by the Worcester Department of Public Works.

- 4.2 Maintenance of Dam. The Supervisor of Water Supply for the Worcester Department of Public Works retains a permanent staff for routine maintenance of the dam and related facilities. The work generally consists of mowing the grass on the dam, removing brush and debris from firelanes, brooks, and the spillway channel, and clearing dead wood from the watershed area.

- 4.3 Maintenance of Operating Facilities. The screens at the gate house are checked daily and cleaned as necessary.

- 4.4 Description of Any Warning System in Effect. There are no warning systems in effect at this dam. The Supervisor does not recall any occasion when the low-level outlet at the dam was opened in advance of a storm warning. The water level in the reservoir is carefully regulated daily.

- 4.5 Evaluation. An effective operating program has been developed to ensure a constant supply of water to the City of Worcester. Maintenance of the dam and watershed is regularly scheduled, however, more attention should be paid to the maintenance of appurtenances - particularly the spillway. In addition, the need for an emergency warning procedure is evident, considering that the dam is in the "significant" hazard category. Recommendations for a more thorough maintenance program and a warning system are included in Section 7.3.

HOLDEN RESERVOIR NO. 2 DAM

SECTION 5
HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

- a. Design Data. The probable maximum flood (PMF) rate was determined to be 1,900 cfs per square mile. This calculation is based on an average drainage area slope of 6.0 percent, the pond-plus-swamp area to drainage area ratio of 6.6 percent (reflecting Holden Reservoir No. 1), and the U.S. Army Corps of Engineers' Flow Rates (dated December 1977). Applying one-half the PMF rate to the 5.09 square miles of drainage area results in a calculated peak flood flow of 4,900 cfs as the inflow test flood. By adjusting the inflow test flood for surcharge storage, the maximum discharge rate was established as 4,220 cfs (829 cfs per square mile) with the water surface at El 725.2.

During peak outflow, approximately 1,800 cfs would pass over the crest of the dam, with a maximum velocity of about 5 feet per second and a depth of 0.8 feet under critical flow conditions. The spillway has the capacity to discharge 1,830 cfs with the reservoir surface at El 724, which is the elevation of the crest of the dam. This discharge rate is equivalent to 43 percent of the test outflow.

- b. Experience Data. The daily operating records for the 1938 and 1955 floods were reviewed at the Department of Public Works office. These indicated that the dam was not overtopped in either storm.
- c. Visual Observations. At the time of the inspection the water level was 1.3 feet below the crest of the spillway, and there were no flashboards in place. The minor amounts of debris in the spillway channel should be removed. The concrete slabs lining the floor of the channel are slightly dislocated and appear to be undermined in areas.

HOLDEN RESERVOIR NO. 2 DAM

- d. Overtopping Potential. The hydraulic computations indicate that the dam would be overtopped during the peak test flood. The depth above the minimum crest elevation would be 1.4 feet, with a unit flow of 4.2 cfs per foot.

If the dam failed, the initial outflow would be up to 20,000 cfs, producing an initial wave height of 8.5 feet at a velocity of 9 feet per second at a location 2,000 feet downstream from the dam. In the event of complete failure, the reservoir could drain in 1.3 hours.

Failure of the dam would result in flooding in the Tatnuck Brook valley, which is mostly woodland. There are two nearby residences on Olean Street located adjacent to Tatnuck Brook about 2,600 feet downstream from the dam. The damage by a flood wave would affect no more than these two residences.

SECTION 6

STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

- a. Visual Observations. The evaluation of the stability of Holden Reservoir No. 2 is based on the visual inspection conducted on September 13, 1978, and on a review of the available drawings and operating records. As discussed in Section 3, Visual Inspection, the embankment appears to be in good condition. However, the significant number of animal burrows on the downstream slope require attention.
- b. Design and Construction Data. The available drawings, included in Appendix B, indicate a core wall extending the length of the dam. The core wall extends at least 5 feet into ledge, and up to 16 feet in the vicinity of the outlet conduits. The cross-hatched pattern on the plans suggests a rubble masonry core, presumably grouted. The core was backfilled on either side with puddled material and then covered with some other unidentified "selected" material on the upstream and downstream slopes. There is no other information available on the type, shear strength, and permeability of the soil and/or rock materials of the embankment.
- c. Operating Records. There is no evidence that instrumentation of any type was ever installed in Holden Reservoir No. 2 Dam. The performance of this dam under prior loading can only be inferred by physical evidence at the site.
- d. Post-Construction Changes. There are no as-built drawings available for Holden Reservoir No. 2 Dam.
- e. Seismic Stability. The dam is located in Seismic Zone No. 2 and in accordance with Phase I "Recommended Guidelines" does not warrant seismic analyses.

HOLDEN RESERVOIR NO. 2 DAM

SECTION 7

ASSESSMENT, RECOMMENDATIONS, AND REMEDIAL MEASURES

7.1 Dam Assessment

- a. Condition. Based upon a review of available drawings, the visual inspection at the site, and a review of the maintenance and operating procedures, minor deficiencies in the dam should be corrected to assure the continued performance of the dam at Holden Reservoir No. 2. Generally, the dam is considered to be in good condition. However, several signs of distress were noted at the site: cracked and missing mortar in the walls of the spillway channel; settlement cracks and slumping in the grouted riprap in the area of the gate house; the significant amount of efflorescence in the walls and in the stone bridge over the spillway; deteriorating granite and concrete patchwork on the ogee weir; slight erosion of the earth slopes at the bridge abutments; dense vegetation in the downstream channel; and innumerable animal burrows in the downstream slope of the dam.

Hydraulic analyses indicate that the spillway can discharge a flow of 1,830 cfs when the reservoir is at El 724.0, which is the average elevation of the crest of the dam. This flow rate is only 43 percent of the test outflow. An outflow test flood of 4,220 cfs (one-half the probable maximum flood) will overtop the lowest point on the dam crest by 1.4 feet.

- b. Adequacy. The lack of in-depth engineering data did not allow for a definitive review. Therefore the adequacy of this dam could not be assessed from the standpoint of reviewing design and construction data, but is based primarily on visual inspection, past performance history and engineering judgment.
- c. Urgency. The recommendations and remedial measures outlined below should be implemented by the Owner within two years after receipt

HOLDEN RESERVOIR NO. 2 DAM

of this Phase I Inspection Report. However, repair of the training walls and floor of the spillway should be undertaken within one year.

- d. Need for Additional Investigations. Additional investigations to further assess the adequacy of the dam are outlined below in Section 7.2, Recommendations.

7.2 Recommendations. In view of the concerns over the continued performance of the dam it is recommended that the Owner employ a qualified consultant:

- a. to conduct a more detailed hydrologic and hydraulic investigation at the site;
- b. to design repairs for the spillway and training walls.

The recommendations on repairs and maintenance procedures are outlined below under Section 7.3, Remedial Measures.

7.3 Remedial Measures

- a. Operating and Maintenance Procedures. The grounds and embankment of the dam are well maintained. However, it is recommended that the Owner add the following items to the maintenance program:
 - (1) repair the stone masonry side walls to the spillway, and resurface the floor of the channel
 - (2) repair the stone work on the bridge spanning the spillway
 - (3) repair or replace the granite weir on the spillway
 - (4) clear the accumulated soil and rock from the stilling basin
 - (5) fill in the animal burrows on the downstream face of the dam
 - (6) clear the bushes and weeds from the downstream channel

HOLDEN RESERVOIR NO. 2 DAM

- (7) all repairs and maintenance should be undertaken in accordance with all applicable State regulations,
- (8) institute a definite plan for surveillance and a warning system during periods of unusually heavy rains and/or runoff,
- (9) technical inspections of this dam should be conducted on an bi-annual basis.

7.4 Alternatives. An alternative to implementing the recommendations and the maintenance procedures itemized above would be to lower the reservoir.

HOLDEN RESERVOIR NO. 2 DAM

APPENDIX A

PERIODIC INSPECTION
CHECKLIST

HOLDEN RESERVOIR NO. 2 DAM

PERIODIC INSPECTION

PARTY ORGANIZATION

PROJECT Holden Reservoir No 2

DATE 9/13/78

TIME 8:00 a.m.

WEATHER Sunny, 60°F

W.S. ELEV. 716.7 U.S. — DN.M.

Benchmark elevation 718.0
established at spillway crest

PARTY:

- | | |
|-------------------------|-----------|
| 1. <u>Ed Greco</u> | 6. _____ |
| 2. <u>Sue Pierce</u> | 7. _____ |
| 3. <u>Lyle Branagan</u> | 8. _____ |
| 4. <u>Dan Bornstein</u> | 9. _____ |
| 5. _____ | 10. _____ |

	PROJECT FEATURE	INSPECTED BY	REMARKS
1.	<u>Dam</u>	<u>E. Greco / S. Pierce</u>	
2.	<u>Spillway</u>	<u>L. Branagan / D. Bornstein</u>	
3.	_____	_____	_____
4.	_____	_____	_____
5.	_____	_____	_____
6.	_____	_____	_____
7.	_____	_____	_____
8.	_____	_____	_____
9.	_____	_____	_____
10.	_____	_____	_____

PERIODIC INSPECTION CHECK LIST

PROJECT Holden No. 2 DATE 9/13/78
 PROJECT FEATURE Dam NAME E. Greco
 DISCIPLINE Geotechnical NAME S. Pierce

Note: d/s = downstream; u/s = upstream

AREA EVALUATED	CONDITIONS
<u>DAM EMBANKMENT</u>	
Crest Elevation	varies 722.8 on upstream side, to 724.2 on downstream side
Current Pool Elevation	716.7
Maximum Impoundment to Date	unknown
Surface Cracks	none visible
Pavement Condition	grass on crest
Movement or Settlement of Crest	relatively flat
Lateral Movement	no apparent movement
Vertical Alignment	relatively flat
Horizontal Alignment	relatively straight
Condition at Abutment and at Concrete Structures	rock at right abutment bridge and spillway at left abutment
Indications of Movement of Structural Items on Slopes	none - steps leading to inlet structure in good condition
Trespassing on Slopes	series of chipmunk holes at d/s toe, center of dam
Sloughing or Erosion of Slopes or Abutments	mowed grass on d/s slopes
Rock Slope Protection - Riprap Failures	grouted riprap on u/s face, some riprap missing; weeds; slumping, cracking, settlement of grout at bridge abutment
Unusual Movement or Cracking at or near Toes	none visible
Unusual Embankment or Downstream Seepage	no seepage visible
Piping or Boils	none visible
Foundation Drainage Features	none
Toe Drains	none
Instrumentation System	none

PERIODIC INSPECTION CHECK LIST

PROJECT Holden #2

DATE 9/13/78

PROJECT FEATURE Intake Structure

NAME D. Bornstein

DISCIPLINE Structural / Hydraulic

NAME L. Branagan

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - INTAKE CHANNEL AND INTAKE STRUCTURE</u>	
a. Approach Channel	not visible (see drawings, Appendix B)
Slope Conditions	unknown
Bottom Conditions	unknown
Rock Slides or Falls	n/a
Log Boom	n/a
Debris	unknown
Condition of Concrete Lining	n/a
Drains or Weep Holes	n/a
b. Intake Structure	
Condition of Concrete	
Stop Logs and Slots	

PERIODIC INSPECTION CHECK LIST

PROJECT Holden #2 DATE 9/13/78
 PROJECT FEATURE Outlet works - gate house NAME D. Bornstein
 DISCIPLINE structural/hydraulic NAME L. Branagan

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - CONTROL TOWER</u>	
a. Concrete and Structural	Brick superstructure - granite foundation walls
General Condition	good
Condition of Joints	-
Spalling	-
Visible Reinforcing	-
Rusting or Staining of Concrete	no concrete
Any Seepage or Efflorescence	none
Joint Alignment	-
Unusual Seepage or Leaks in Gate	none visible
Cracks	minor cracking in brick; hairline cracks in base of bricks
Rusting or Corrosion of Steel	-
b. Mechanical and Electrical	3 hand-operated sluice gates
Air Vents	none
Float Wells	n/a
Crane Hoist	n/a
Elevator	n/a
Hydraulic System	n/a
Service Gates	screened intake 2 - 30" intakes 1 - 30" mud pipe
Emergency Gates	none
Lightning Protection System	none
Emergency Power System	none
Wiring and Lighting System in Gate Chamber	none

PERIODIC INSPECTION CHECK LIST

PROJECT Holden #2 DATE 9-13-78
 PROJECT FEATURE Bridge to Gate House NAME D. Bornstein
 DISCIPLINE Structural NAME _____

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - SERVICE BRIDGE</u>	Single span, wood plank deck built up on riveted steel (iron?) girders
a. Super Structure	
Bearings	badly rusted
Anchor Bolts	ties into granite block at intake structure
Bridge Seat	missing (possibly sheet lead)
Longitudinal Members	steel girders
Under Side of Deck	wood deck - good condition
Secondary Bracing	angle irons
Deck	wood planks - good condition
Drainage System	none
Railings	18-inch-high pipe railings
Expansion Joints	missing and rusted out, dam side
Paint	good condition
b. Abutment and Piers	
General Condition of Concrete	no concrete - granite in good condition
Alignment of Abutment	slight misalignment in brick
Approach to Bridge	concrete slab, minor crack
Condition of Seat and Backwall	granite wall, good condition

PERIODIC INSPECTION CHECK LIST

PROJECT Holden #2

DATE 9/13/78

PROJECT FEATURE Lower Gate House

NAME D. Bornstein

DISCIPLINE structural /hydraulic

NAME L. Branagan

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - OUTLET STRUCTURE AND OUTLET CHANNEL</u>	Brick building houses valves for
General Condition of Concrete	2 - 40-inch outlet pipes
Rust or Staining	none
Spalling	none
Erosion or Cavitation	none
Visible Reinforcing	none
Any Seepage or Efflorescence	none
Condition at Joints	good to fair
Drain Holes	none
Channel	40-inch pipes discharge to chlorinator
Loose Rock or Trees Overhanging Channel	30-inch pipe discharges to spillway channel.
Condition of Discharge Channel	n/a
Channel	n/a

PERIODIC INSPECTION CHECK LIST

PROJECT Holden # 2
 PROJECT FEATURE Spillway
 DISCIPLINE Hydraulic / Structural

DATE 9/13/78
 NAME L. Branagan
 NAME D. Bornstein

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS</u>	stone masonry training walls, stone-paved channel (shales set perpendicular to bedding, then grouted) concrete slab on approach
a. Approach Channel	
General Condition	good to fair, some weeds, loose mortar, patch
Loose Rock Overhanging Channel	none
Trees Overhanging Channel	none
Floor of Approach Channel	stone and concrete
b. Weir and Training Walls	efflorescence, loose stone and mortar on walls granite ogée weir with concrete patch
General Condition of Concrete	concrete patch on weir is loose
Rust or Staining	rust from flashboard pins
Spalling	patch on weir is spalled
Any Visible Reinforcing	none
Any Seepage or Efflorescence	significant efflorescence
Drain Holes	none
c. Discharge Channel	concrete slabs
General Condition	good to poor - some cracking, weeds erosion from roadway at dis left abut.
Loose Rock Overhanging Channel	none
Trees Overhanging Channel	none
Floor of Channel	cracks, few pieces of slab missing
Other Obstructions	none

Outlet Works, (continued)

d. Bridge over discharge channel - double arch masonry bridge
diagonal shear cracks at abutment
settlement at center pier
heavy efflorescence under bridge ; mortar missing
capwall. u/s - displaced
d/s - partially missing

e. spillway channel - descends to stilling pool
accumulation of dirt and stone in pool
cascade step weir from stilling pool
* 30-inch pipe d/s of cascade stilling pool, right side
loose stones in lower channel
grouted stone wall for 70 feet
Changes to natural channel except on right
side which is stone masonry wall
Trees overhanging lower channel.

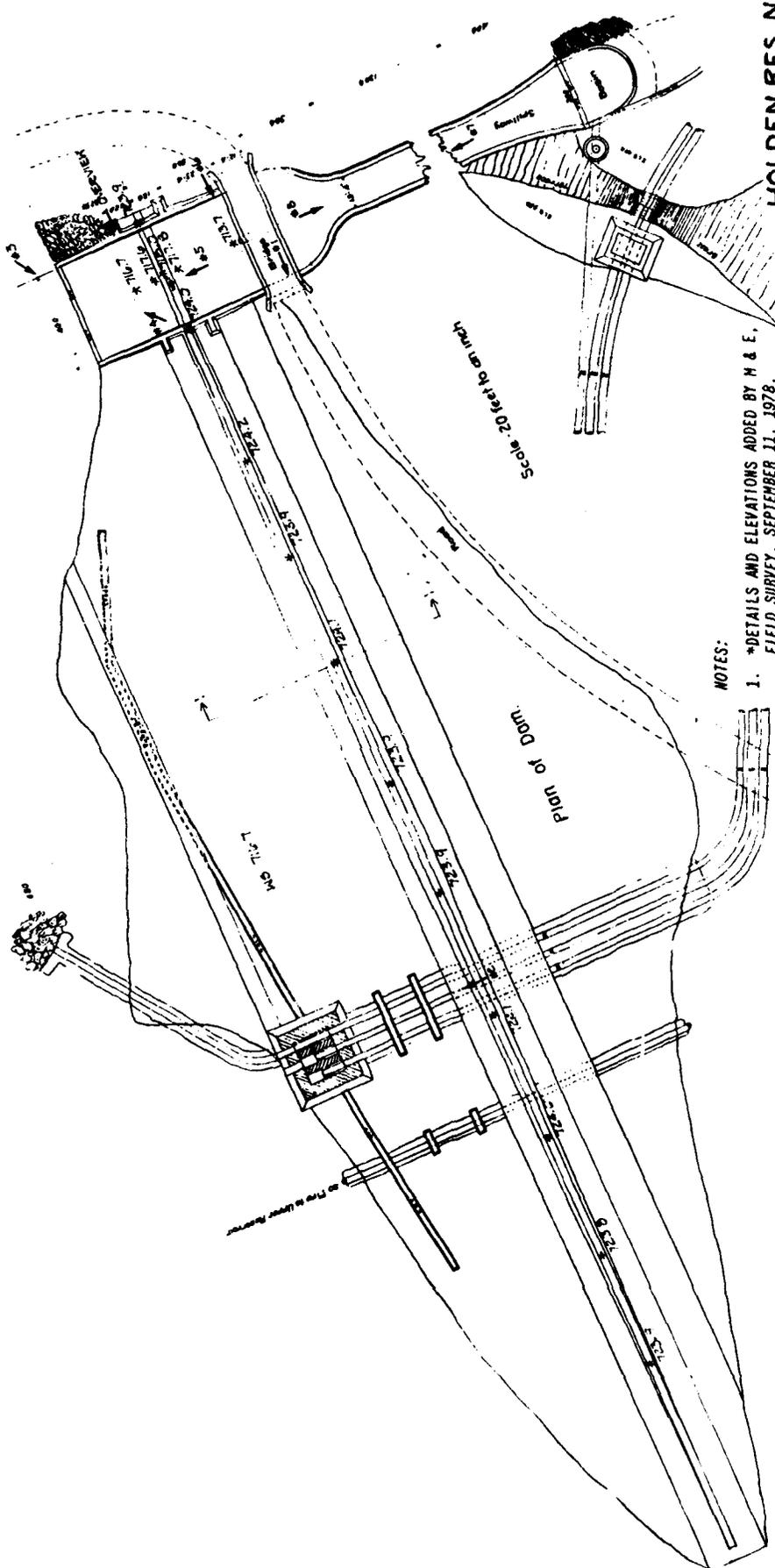
* 6-inch cast-iron pipe in stilling pool cascade face.

APPENDIX B

PLAN OF DAM AND PREVIOUS
INSPECTION REPORTS

	<u>Page</u>
Figures B-1, B-2, and B-3. Plans of Dam, dated May 8, 1900	B-1
Previous Inspections (Partial Listing)	B-4
Inspection Reports by Massachusetts Department of Public Works, May 21, 1973	B-6

HOLDEN RESERVOIR NO. 2 DAM



HOLDEN RES. NO. 2

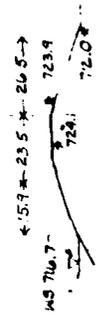
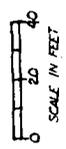
WORCESTER COUNTY COMMISSIONERS
 WORCESTER COUNTY ENGINEERING DEPARTMENT
 PLAN OF

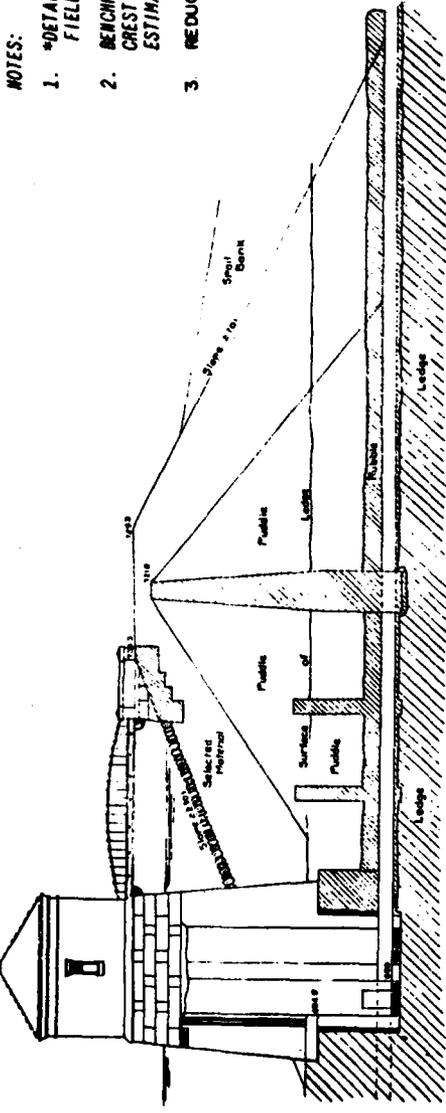
DAM
 APPROXIMATE BROOK
 FOR THE CITY OF WORCESTER
 HOLDEN, MASS.
 AS FILED AND APPROVED BY THE
 COUNTY COMMISSIONERS
 MAY 19 1900
 MARCH MEETING DOCKET 311
 SCALES AS NOTED

TRACED BY J. O. BROWN
 DRAWING CHECKED BY G. M. L. J. DAM NO. 21-02
 COUNTY ENGINEER

FIGURE 9-1

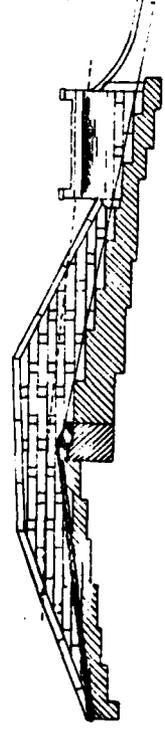
- NOTES:
- *DETAILS AND ELEVATIONS ADDED BY M & E, FIELD SURVEY, SEPTEMBER 11, 1978.
 - BENCHMARK ESTABLISHED AT EL. 718.0 AT THE CREST OF THE SPILLWAY. ELEVATION WAS ESTIMATED FROM A U.S.G.S. TOPOGRAPHIC MAP.
 - APPROXIMATE SCALE AFTER REDUCTION OF DRAWING:
 - H1 DENOTES NUMBER AND ORIENTATION OF PHOTOGRAPHS.





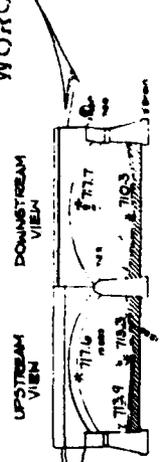
Section Through Gate House.

Scale 10 feet to an inch.



Section Through West Wall of Spillway

Scale 8 feet to an inch.



Bridge SECTION

Scale 8 feet to an inch.



Profile Through Spillway

Scale 20 feet to an inch.

NOTES:

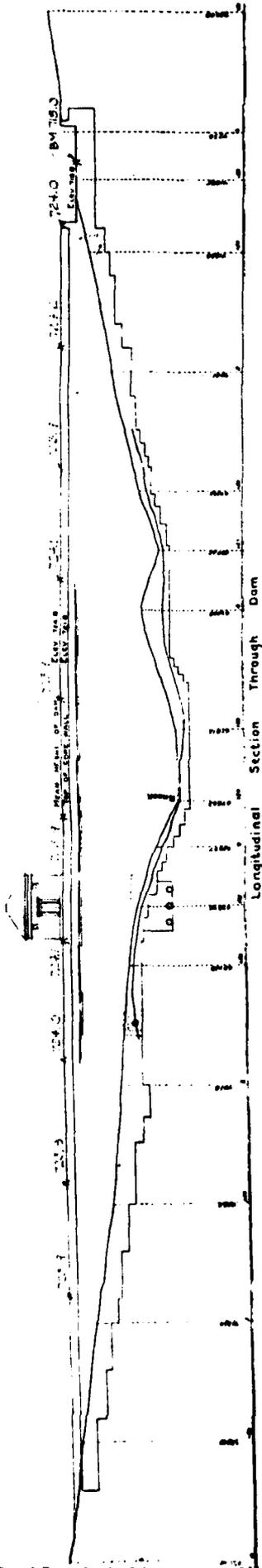
1. *DETAILS AND ELEVATIONS ADDED BY H & E. FIELD SURVEY, SEPTEMBER 11, 1978.
2. BENCHMARK ESTABLISHED AT EL. 718.0 AT THE CREST OF THE SPILLWAY. ELEVATION WAS ESTIMATED FROM A B.S.G.S. TOPOGRAPHIC MAP.
3. REDUCED APPROXIMATELY 80 %

Plan of
PROPOSED DAM ON TATNOCK BROOK
for
WORCESTER CITY WATER WORKS,
1900

HOLDEN RES. NO. 2

WORCESTER COUNTY COMMISSIONERS WORCESTER COUNTY ENGINEERING DEPARTMENT PL. 44, 02	
SCREEN DAM AND BRIDGE FOR THE CITY OF WORCESTER AS FILED AND APPROVED BY THE COUNTY COMMISSIONERS MAY 8, 1900	
DRAWN BY J. C. BROWN	CHECKED BY J. C. BROWN
TRACED BY J. C. BROWN	DAM NO 21-02
DRAWING CHECKED BY J. C. BROWN	COUNTY ENGINEER

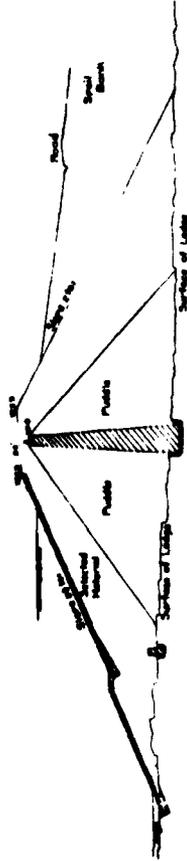
FIGURE B-2



Scale: 20 feet to an inch

NOTES:

1. *DETAILS AND ELEVATIONS ADDED BY M & E, FIELD SURVEY, SEPTEMBER 11, 1978.
2. BENCHMARK ESTABLISHED AT EL. 718.0 AT THE CREST OF THE SPILLWAY. ELEVATION WAS ESTIMATED FROM A U.S.G.S. TOPOGRAPHIC MAP.
3. PLAN REDUCED APPROXIMATELY 50 %.



Scale: 20 feet to an inch

Cty Engineers Office
Worcester, Mass

HOLDEN RES. NO. 2

WORCESTER COUNTY COMMISSIONERS
WORCESTER COUNTY ENGINEERING DEPARTMENT
PLAN OF

DAM IN
HOLDEN, MASS.

FOR THE CITY OF WORCESTER

AS FILED AND APPROVED BY THE

COUNTY COMMISSIONERS

MAY 8, 1900

MARCH MEETING DOCKET 311

SEALES AS NOTED

TRACED BY: *[Signature]* DAM NO. 21-02

TRACED CHECKED BY: *[Signature]*

[Signature] COUNTY ENGINEER

FIGURE B-3

21-02

Inspected: Nov. 18, 1947. E. Perry, Hardy & LOM
" Jan 7 1953 H. Spofford & Lloyd Starbuck
" May 25, 1960 LOM.

HOLDEN RESERVOIR No. 2 DAM

B-5

Recv. 1-30-74
DIV. of W.W.

FILE 2124

INSPECTION REPORT - DAMS AND RESERVOIRS

1. Location: City/Town Holden Dam No. 3-14-134-02

Name of Dam Holden Res. # 2 Inspected by POWER

Date of Inspection 5/21/73

2. Owner/s: per: Assessors _____ Prev. Inspection _____

Reg. of Deeds _____ Pers. Contact

1. CITY OF WOOD FRANCIS T. McGRATH CITY MANAGER
Name St. & No. City/Town State Tel. No.

2. _____
Name St. & No. City/Town State Tel. No.

3. _____
Name St. & No. City/Town State Tel. No.

3. Caretaker (if any) e.g. superintendent, plant manager, appointed by absentee owner, appointed by multi owners.

Name: _____ St. & No.: _____
City/Town: _____ State: _____ Tel.No.: _____

4. No. of Pictures taken None

5. Degree of Hazard: (if dam should fail completely)*

1. Minor _____ 2. Moderate _____
3. Severe 4. Disastrous _____

* This rating may change as land use changes (future development)

6. Outlet Control: Automatic _____ Manual
Operative yes; _____ No.

Comments: WATER LEVEL A SPILLWAY CONTROLLED BY FLASH

7. Upstream Face of Dam: Conditions:

1. Good 2. Minor Repairs _____
3. Major Repairs _____ 4. Urgent Repairs _____

Comments: completely clear of BRUSH or other Growth. CONDITION excellent

8. Downstream Face of Dam:

Condition: 1. Good ✓ 2. Minor Repairs _____
3. Major Repairs _____ 4. Urgent Repairs _____

Comments: Completely clear of BRUSH & TREES.

9. Emergency Spillway: NONE

Condition: 1. Good _____ 2. Minor Repairs _____
3. Major Repairs _____ 4. Urgent Repairs _____

Comments: THE EXISTING SPILLWAY APPEARS TO BE AMPLE.

10. Water Level at time of inspection: 2 ft. above ✓ below _____
top of dam _____ principal spillway ✓
other _____

11. Summary of Deficiencies Noted:

- Growth (Trees and Brush) on Embankment NONE
- Animal Burrows and Washouts NONE
- Damage to slopes or top of dam NONE
- Cracked or Damaged Masonry NONE
- Evidence of Seepage NONE NOTED
- Evidence of Piping NONE NOTED
- Erosion NONE
- Leaks NONE
- Trash and/or debris impeding flow NONE
- Clogged or blocked spillway NONE
- Other NO

12. Remarks & Recommendations: (Fully Explain)

This dam is in excellent condition & is well maintained by the City of Worcester. It is in need of no repairs at present.

13. Overall Condition:

- 1. Safe _____
- 2. Minor repairs needed _____
- 3. Conditionally safe - major repairs needed _____
- 4. Unsafe _____
- 5. Reservoir impoundment no longer exists (explain)
Recommend removal from inspection list _____

Boston Copy

DESCRIPTION OF DAM

DISTRICT 3

Submitted by T. POWERS Dam No. 3-14-134-02

Date 5/29/73 ~~City~~/Town Holden

Name of Dam Holden Res #2

1. Location: Topo Sheet No. 20D

Provide 8 1/2" x 11" in clear copy of topo map with location of Dam clearly indicated.

2. Year built: _____ Year/s of subsequent repairs _____

3. Purpose of Dam: Water Supply Recreational _____
Irrigation _____ Other _____

4. Drainage Area: 17.4 sq. mi. _____ acres

5. Normal Ponding Area: 50 acres; Ave. depth _____

Impoundment: _____ gals.; _____ acre ft.

6. No. and type of dwellings located adjacent to pond or reservoir
Nave i.e. summer homes, etc. _____

7. Dimensions of Dam: Length 630 Max. Height 20'±

Slopes: Upstream Face 3:1

Downstream Face 2:1

Width across top 22'

8. Classification of Dam by Material:

Earth Conc. Masonry _____ Stone Masonry

Timber _____ Rockfill Other _____

9. A. Description of present land usage downstream of dam:

15 % rural; 95 % urban.

B. Is there a storage area or flood plain downstream of dam which could accomodate the impoundment in the event of a complete dam failure? yes _____ no

10. Risk to life and property in event of complete failure.

No. of people 2000 ±
No. of homes 450 ±
No. of Businesses 25 ±
No. of industries NONE Type _____
No. of utilities 5 Type WATER, TEL, GAS
ELECT. POWER
Railroads NONE
Other dams 2
Other Massachusetts State College, 2 Public Schools

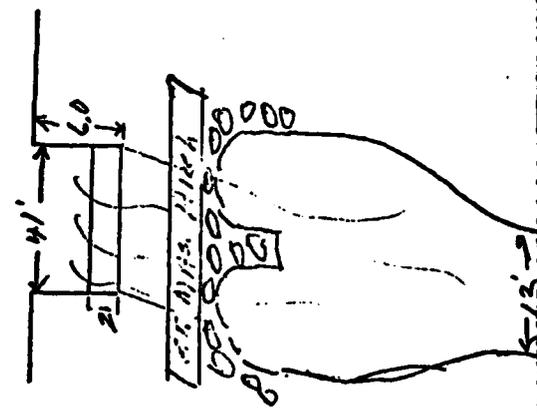
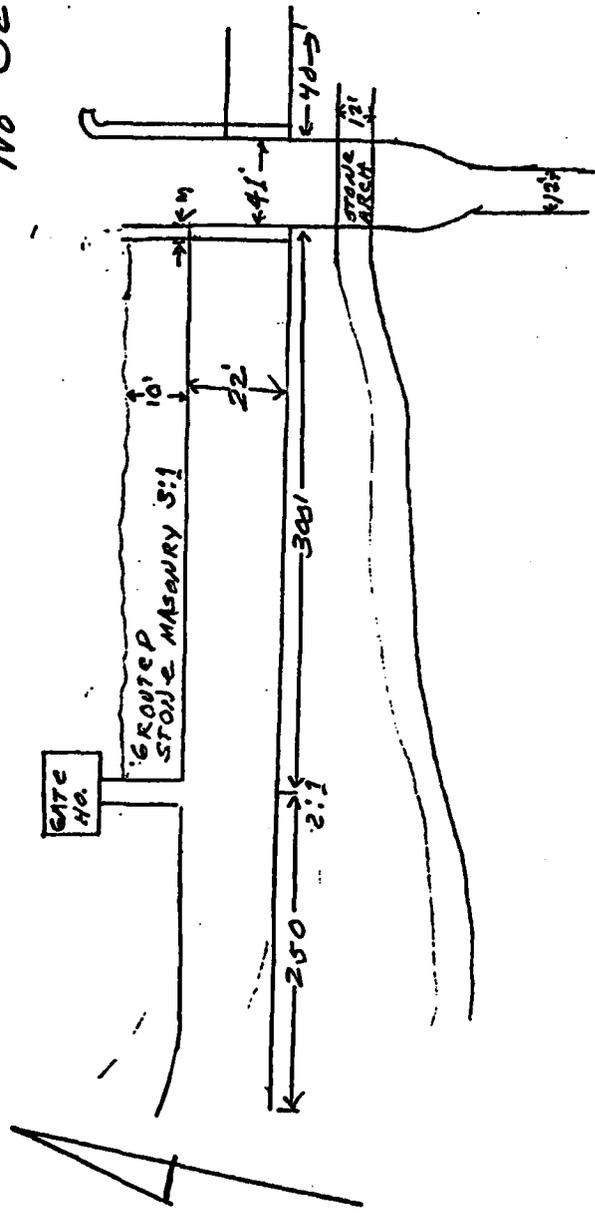
11. Attach Sketch of dam to this form showing section and plan on 8 1/2" x 11" sheet.

12. How to Locate:

*From Tutuok Square westward Northwesterly
1.5 mile on Olean St. to entrance of
Stone House Nursing Home Easterly side
of Olean St.*

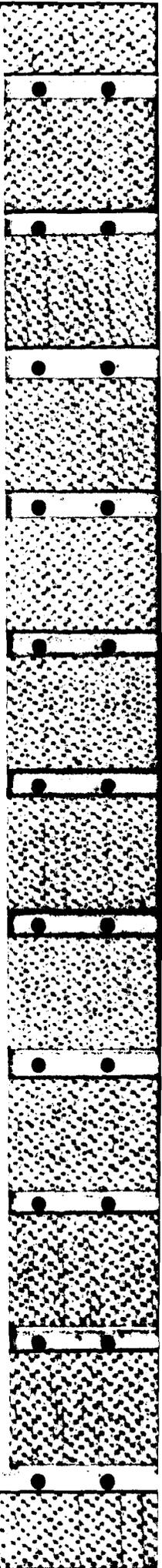
Holden
Dam # 3-14-134-02
Holden Res.
5/21/73

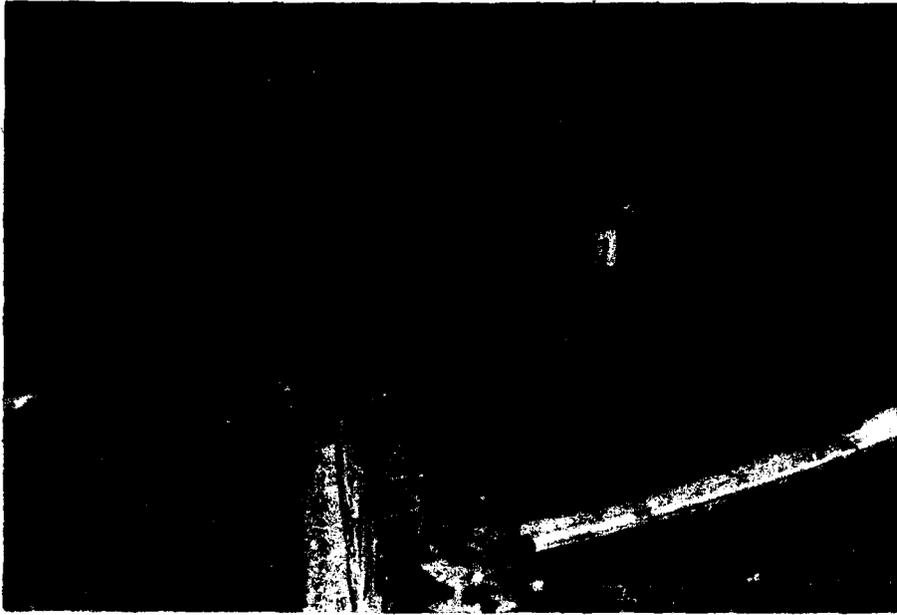
No Scale



APPENDIX C
PHOTOGRAPHS

HOLDEN RESERVOIR NO. 2 DAM



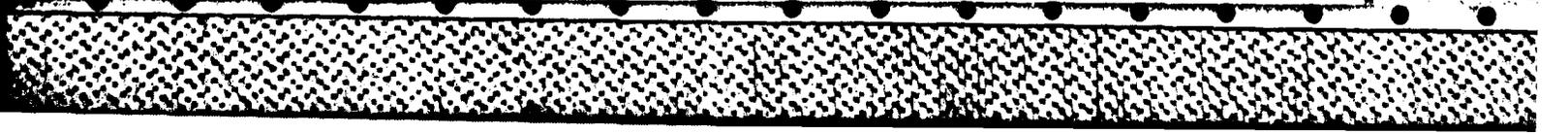
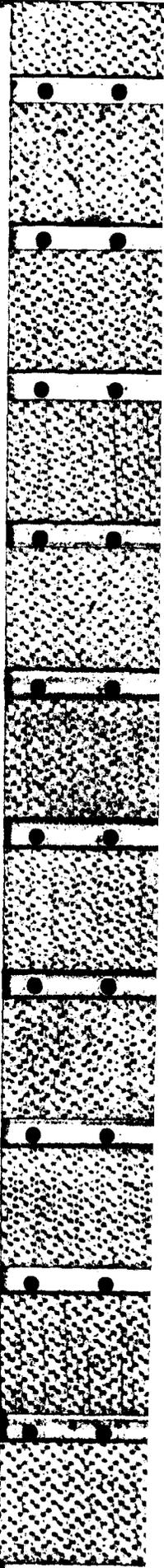


NO. 1 DOWNSTREAM FACE OF DAM



NO. 2 GATE HOUSE

C-1





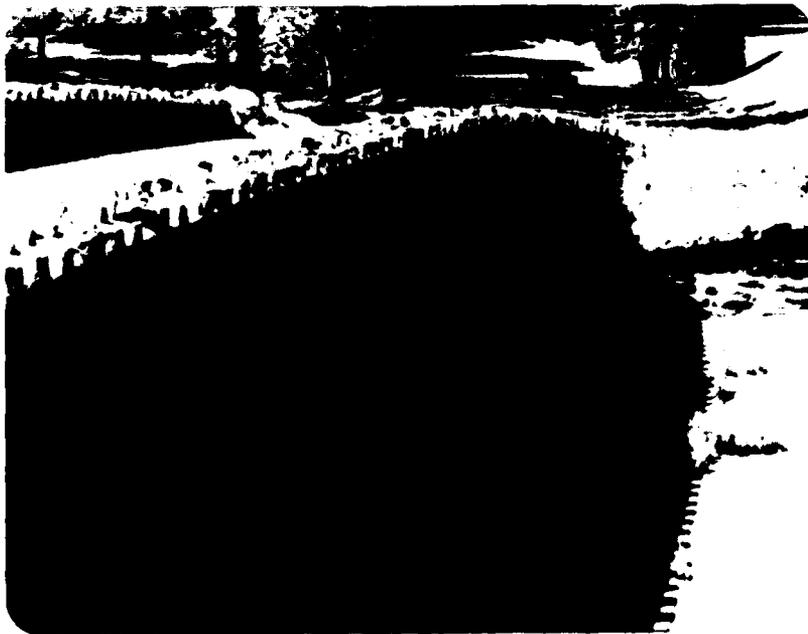
**NO. 3 UPSTREAM VIEW OF SPILLWAY, FROM
LEFT ABUTMENT**



NO. 4 LEFT WING WALL OF SPILLWAY



NO. 5 GRANITE WEIR AND FLOOR OF SPILLWAY



**NO. 6 BRIDGE OVER SPILLWAY CHANNEL;
VIEW TOWARD RIGHT ABUTMENT**



NO. 7 DOWNSTREAM CHANNEL OF SPILLWAY



**NO. 8 DOWNSTREAM CHANNEL OF SPILLWAY,
AND STILLING BASIN**

APPENDIX D
HYDROLOGIC AND HYDRAULIC
COMPUTATIONS

HOLDEN RESERVOIR NO. 2 DAM

I Test Flood, 100 year storm & Storage Functions

1- Total Drainage Area - 5.09 mi²

2- Pond(s) Area: 0.076 + 0.203 = 0.279
 Swamp(s) Area: = 0.06
Total Area Ponds & Swamps: 0.339

% Ponds & Swamps = $\frac{0.339}{5.09} = 6.6\%$

3- Tatnuck Brook - 4%± } Say Ave Slope = 6%
 Scott Brook - 7%±

4- Using C. of E. Curves for Peak Flow Rates & above guide values the Peak Flow Rate was estimated to be slightly higher than "Rolling" and taken at 1900 c.f.s./mi²
 Size Class: Intermed.; Hazard Pot.: Signif.; Spill. Des. Flood: 1/2 P.M.F. for
 Use: Test Flood = 1/2 P.M.F. - Dam size close to "Small"

5- Test Flood Inflow = $\frac{1}{2}(1900) 5.09 = 4900$ c.f.s.

6- Pond Storage

The pond area is 0.076 sq. mi. at elev. 718.
 Based on a const. area, storage increases at 49 ac. feet per foot of depth increase.
 At elev. 724 the storage above the weir crest is 394 acre feet.

7- Storage Functions are based on $Q_{out} = Q_{in} [1 - \frac{S_{out}}{R}]$

S_{out} = Storage Vol. in Reservoir related to final Q_{out} in terms of inches of rain over the drainage area.

S (in inches) = $12 D (\frac{0.076}{5.09}) = 0.18 D$; R = 6 hr rain in 6 hours

D = Storage Depth (above spillway) on reservoir, in feet

8- Storage Functions: (F_T) ; $D = 0$ @ Pond = 718

$F_T = 4900 - 516 S = 4900 - 93 D$

II Discharge Ratings

A - Spillway [Ref.: V.T. Chow "Open Channel Hydr." - pp 360-362]

40' wide - no gates or stoplogs

$$Q_s = 3.12 L H^{1.5} = 124.8 H^{1.5}$$

H	1	2	3	4	5	6	7	8	9
Q _s	125	353	648	998	1395	1834	2311	2824	3370
Pond El.	719	720	721	722	723	724	725	726	727

B - Crest Flow [Ref: Above - pp 52-53] $q_c = 2.55 H^{1.5}$

Crest Elev. varies from 723.8 to 724.2 - Use ave elev. @ 724

Total Length = 532 ft. $\therefore Q_c = 2.55(532) H^{1.5} = 1356.6 H^{1.5}$

H'	0.5	1.0	1.5	2.0
Q _c	480	1357	2492	3837
Pond El.	724.5	725	725.5	726

III Summary

A - Max. Crest Flow

$$h = 725.2 - 723.8 = 1.4', q_c = 4.2 \text{ cfs}$$

$$y_{\text{critical}} = 0.82', V_{\text{critical}} = 5.1 \text{ fps}$$

B - Spillway Capacity

With pond @ elev 724 (ave. crest elev.), spillway discharge = 530 c.f.s or 43% of Test Flood outflow

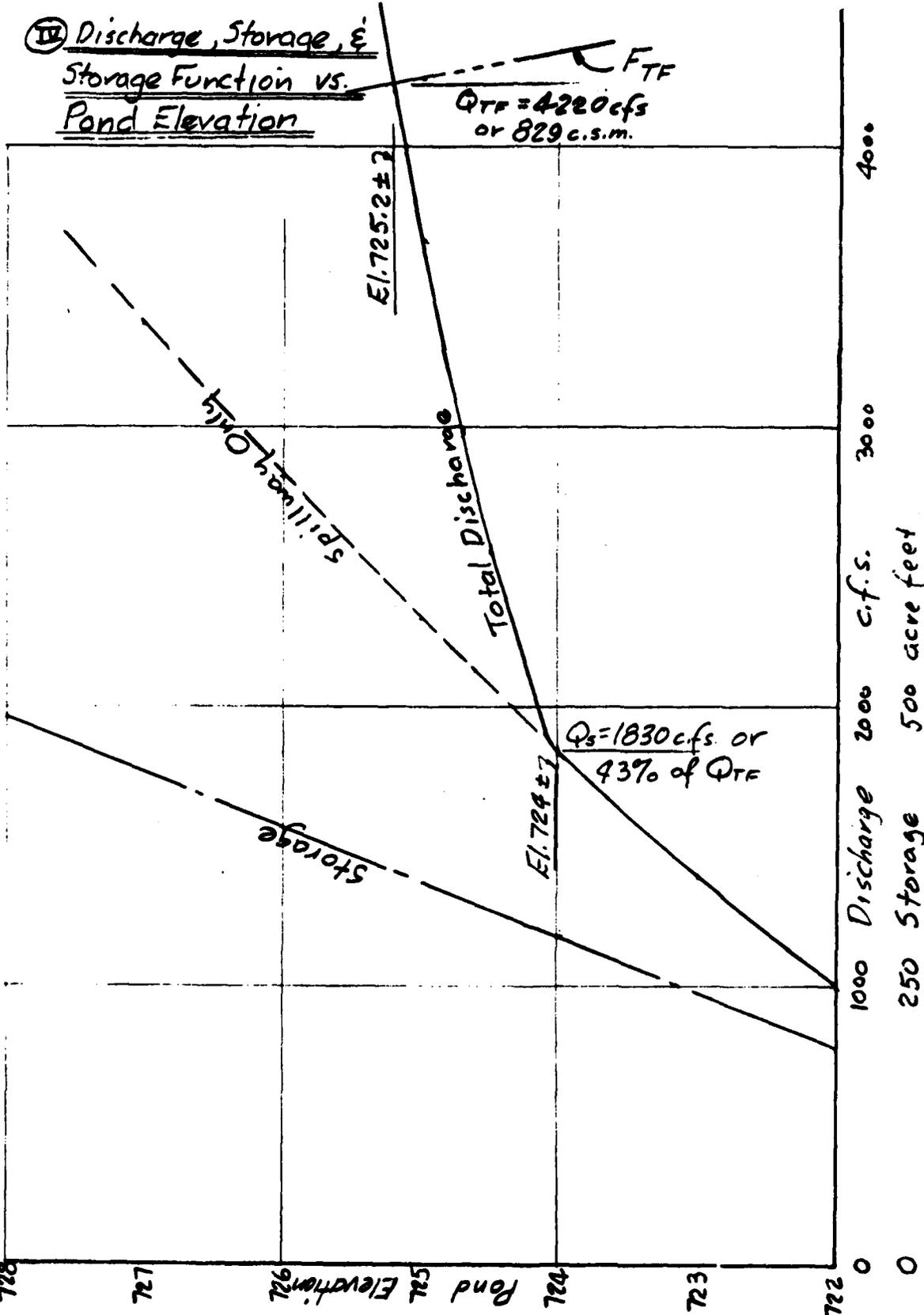
C - Lowlevel Outlet [Ref. Williams & Hazen "Hydr. Tables"]

30" ϕ - 617' long - w/gate; Head = $h_f + 3h_v$; C = 110

Nominal Head: $718 - 670.2 = 47.8'$; $Q_{LLO} = 100.2 \text{ cfs}$

$$\text{Time to Lower Pond 1 foot} = \frac{(49)(43560)}{150.4(3600)} = 5.9 \text{ hours or } 354 \text{ min.}$$

④ Discharge, Storage, & Storage Function vs. Pond Elevation



METCALF & EDDY, ENGINEERS

Ⓟ Failure of Dam

Peak Failure Flow:

Pond Elevation - 724 (Dam Crest ±)
 Toe Elevation - 695 (Top of "Ledge")

$Y_0 = 29'$

Dam Length Subject to Breaching = 192' (half ht.)

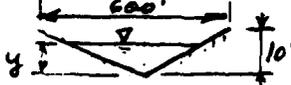
$W_0 = 40\% (192) = 76.8$

$Q_R = 1.68 W_0 (Y_0)^{1.5} = 1.68 (76.8) (29)^{1.5} = 20100 \text{ cfs.}$

Storage Volume Released:

Storage Above Spillway - 294 acre feet
 Storage Below Spillway - 797 " " (From Annual Report with no flash boards.)
 $S = \text{Total Storage} = 1091$

Channel Hydraulics:



$S = \frac{20}{1000} = 0.02, n = 0.06, V = 3.5 R^{2/3}$
 $R \approx \frac{1}{2} y, A = 30y^2$

Reach to 1st House:

$Q'_2 = 20100 \left[1 - \frac{2167(2400)}{1091(43560)} \right] = 17900$

$Vol_2 = \frac{2400(1920)}{43560} = 106, \bar{V} = \frac{2400(1920+2400)}{2(43560)} = 119$

$Q_2 = 20100 \left[1 - \frac{119}{1091} \right] = 17900 \text{ cfs}$

Depth $\approx 8'$, $\bar{V} \approx 9 \text{ fps}$

y	A	V	Q
4	480	5.55	2700
6	1080	7.3	7900
8	1920	8.8	17000
10	3000	10.2	30700
9	2430	9.5	23200
8.5	2167	9.2	19900

Time to Drain:

$\frac{43560 (1091)}{3600 (\frac{1}{2}) (20100)} = 1.3 \text{ Hours, or } 79 \text{ Minutes}$

APPENDIX E
INFORMATION AS CONTAINED IN THE
NATIONAL INVENTORY OF DAMS

HOLDEN RESERVOIR NO. 2 DAM

END

FILMED

7-85

DTIC