AD-A146 331 NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS 1/1
NAGOG POND DAM MA 001..(U) CORPS OF ENGINEERS WALTHAM
MA NEW ENGLAND DIV NOV 78

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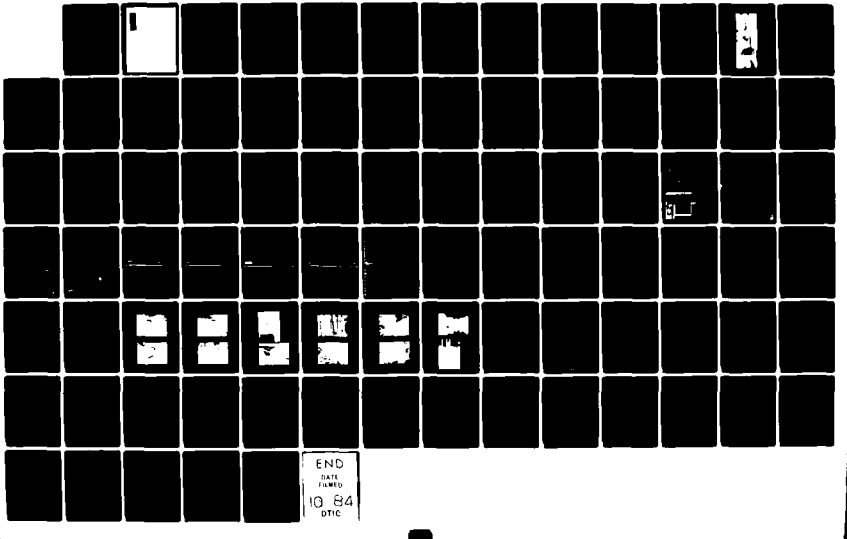

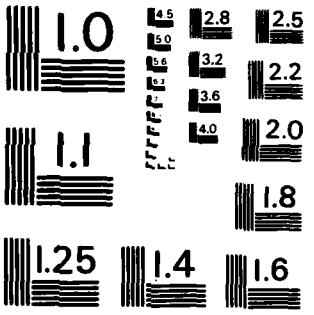

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Cover program reads: Phase I Inspection Report, National Dam Inspection Program; however, the official title of the program is: National Program for Inspection of Non-Federal Dams; use cover date for date of report.

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

DAMS, INSPECTION, DAM SAFETY,

Merrimack River Basin
Acton, Mass.

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

The dam is a concrete gravity section. It is recommended that the Nagog Pond Dam be reclassified from having a "high" hazard potential to having a "low" hazard potential, based on available information. Based on sized and hazard classification, the test flood for this dam is the 100-year flood. The dam is in good condition.

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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:

NEDED

JAN 9 1979

Honorable Edward J. King
Governor of the Commonwealth of
Massachusetts
State House
Boston, Massachusetts 02133

Dear Governor King:

I am forwarding to you a copy of the Nagog Pond Dam Phase I Inspection Report, which was prepared under the National Program for Inspection of Non-Federal Dams. This report is presented for your use and is based upon a visual inspection, a review of the past performance and a brief hydrological study of the dam. A brief assessment is included at the beginning of the report. I have approved the report and support the findings and recommendations described in Section 7 and ask that you keep me informed of the actions taken to implement them. This follow-up action is a vitally important part of this program.

A copy of this report has been forwarded to the Department of Environmental Quality Engineering, the cooperating agency for the Commonwealth of Massachusetts. In addition, a copy of the report has also been furnished the owner, the Town of Concord, Public Works Department, Keyes Road, Concord, Massachusetts 01742, ATTN: Mr. Harold W. Storrs, Superintendent of Public Works.

Copies of this report will be made available to the public, upon request, by this office under the Freedom of Information Act. In the case of this report the release date will be thirty days from the date of this letter.

I wish to take this opportunity to thank you and the Department of Environmental Quality Engineering for your cooperation in carrying out this program.

Sincerely yours,

JOHN P. CHANDLER
Colonel, Corps of Engineers
Division Engineer

Incl
As stated

MERRIMACK RIVER BASIN

ACTON, MASSACHUSETTS

NAGOG POND DAM

MA 00129

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

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

NOVEMBER 1978

PHASE I INVESTIGATION REPORT
NATIONAL DAM INSPECTION PROGRAM

Identification No.:	MA 00129
Name of Dam:	Nagog Pond
Town:	Acton
County:	Middlesex
State:	Massachusetts
Stream:	Nagog Brook
Date of Site Visit:	3 October 1978

BRIEF ASSESSMENT

Nagog Pond dam is located approximately two miles north of Acton center and impounds a water supply for the nearby Town of Concord. The dam is a concrete gravity section keyed into bedrock. The top of the dam is approximately 168 ft. long and 15 ft. high. This dam was constructed in 1909 to replace an existing dam which was of inadequate construction.

It is recommended that the Nagog Pond dam be reclassified from having a "high" hazard potential in the Corps of Engineers National Inventory of Dams to having a "low" hazard potential, based on available information.

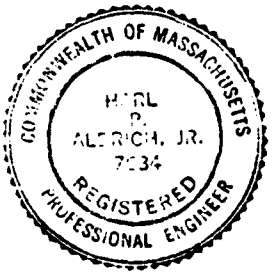
The dam is in good condition, based on a visual examination of the structure. Although some deficiencies were noted, there was no evidence of settlement, lateral movement or other signs of structural failure or other conditions which would warrant urgent remedial treatment.

Based on size and hazard classification in accordance with Corps of Engineers guidelines, the test flood for this dam is the 100-year flood. With the water level at top of dam, the spillway has a capacity of 60 cfs. Hydraulic analyses indicate the test flood outflow of 22 cfs (17.7 csm) can be passed with a freeboard of 0.76 ft. remaining.

The Town of Concord, owner of the dam, should implement the remedial measures, including repair of deteriorating concrete, making the reservoir drain operable, clearing brush and trees, regrading the discharge channel and other work as outlined in Section 7.3, within two years after receipt of this report.

HALEY & ALDRICH, INC.
by:

Harl Aldrich
President



This Phase I Inspection Report on Negog Pond 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 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, DC 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 Investigations are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the test flood is based on the estimated "probable maximum flood" for the region (greatest reasonably possible storm run-off), or a fraction 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.

The Phase I Investigation does not include an assessment

of the need for fences, gates, no-trespassing signs, repairs to existing fences and railings and other items which may be needed to minimize trespass and provide greater security for the facility and safety to the public. An evaluation of the project for compliance with OSHA rules and regulations is also excluded.

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TABLE OF CONTENTS (Continued)

1. Overview of outlet structure and upstream side of dam.

FILE NO. 4160 A22

DAM: Nagog Pond

IDENTIFICATION NO. MA 00129

LOCATION MAP
USGS QUADRANGLE
WESTFORD, MA.
APPROX. SCALE: 1"= 2000'

PHASE I INVESTIGATION REPORT
NATIONAL DAM INSPECTION PROGRAM
NAGOG POND DAM
MA 00129

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.

Haley & Aldrich, 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 were issued to Haley & Aldrich, Inc. under a letter dated 26 April 1978 from Colonel Ralph T. Garver, Corps of Engineers. Contract No. DACW33-78-C-0301 has been assigned by the Corps of Engineers for this work. Camp, Dresser & McKee, Inc. was retained as consultant to Haley & Aldrich, Inc. on the structural, mechanical/electrical and hydraulic/hydrologic aspects of the Investigation.

B. Purpose. The primary purposes of the National Dam Inspection Program are to:

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 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 PROJECT DESCRIPTION

A. Location. The Nagog Pond Dam is located approximately 2 miles north of the center of Acton, MA and 6.5 miles northwest of Concord, MA. The dam forms the outlet to Nagog Pond where Nagog Brook begins, as shown on the topographical location map, page viii.

B. Description of Dam and Appurtenances. The Nagog Pond dam is a concrete gravity section containing a sharp crested spillway with a steel weir plate. No earth embankments are associated with this structure. A gate house and outlet works are appurtenant to the dam. A plan sketch of the configuration of the dam is shown in Appendix C-1. A more detailed plan and profile of the dam are shown on a contract drawing, Appendix B-4.

The dam is approximately 15 ft. high and 168 ft. in length, consisting of unreinforced concrete embedded with granite taken out of an old dam. The foundation is reportedly keyed into bedrock which outcrops at the left abutement and several nearby locations. The top elevation of the dam is approximately 227.66 MSL, except for a 20-ft. wide section 0.5 ft. lower. The 10 ft. long spillway near the center of the dam is at El. 226.16, allowing 1.5 ft. of freeboard.

A brick gate house built on the dam protects controls for the 16-in. water supply pipeline and blowoff passing through the dam. Details of this structure are shown on a contract drawing, Appendix B-3. The intake for the supply pipeline extends 1700 ft. upstream of the dam. Left of the gate house, a 24-in. by 24-in. gated reservoir drain passes through the dam.

C. Size Classification. Nagog Pond dam has an estimated maximum storage of 3,140 acre-feet and a maximum height of 15 ft. Storage of 1,000 to 50,000 acre-feet and a height of 40 to 100 ft. classifies a dam in the "intermediate" size category, according to guidelines established by the Corps of Engineers. Although the height of Nagog Pond dam is much less than 40 ft., it is classified as an "intermediate" size dam by virture of its storage capacity.

D. Hazard Classification. Nagog Pond is currently classified as having a "high" hazard potential in the Corps of Engineers National Inventory of Dams. However, computations based on "Guidance For Estimating Downstream Dam Failure Hydrograph" included in Appendix D, demonstrate that this dam should be reclassified to a lower hazard classification.

In the reach of Nagog Brook from the dam to the concrete box culvert under Route 27, the brook is conveyed through a steep,

narrow natural channel. In the event of a dam failure, the channel itself would experience a moderate degree of erosion. However, there appears to be no structures that would even experience minor flooding. At Route 27, there would be sheet flow across the road for approximately 500 feet, but the road would still be passable. Approximately 800 ft. downstream of Route 27, Nagog Brook joins Nashoba Brook and 1000 ft. downstream of this point Conant Brook enters Nashoba Brook from the west. At this latter confluence an unattached outside structure could experience some minor flooding.

In the next 1000-ft. reach, between the confluence of Conant and Nashoba Brooks and the dam located approximately 100 ft. upstream of Brook Street, Nashoba Brook flows through an estimated 400 ft. wide flood plain for the majority of the distance. At this dam, the flows are conveyed by both the spillway and bypass channel that exists to the left of the spillway. In the event of a breach of the Nagog Pond Dam, it appears that the spillway in conjunction with the bypass channel could handle the flows.

At Brook Street, the brook is conveyed by two corrugated metal plate arches, and flows from a dam failure will not top the road. At this point, it again appears that no structures will be damaged by flooding. Downstream of Brook Street, Nashoba Brook winds in and out of culverts under the N.Y., N.H. & H Railroad Tracks. Again, the brook is surrounded by a wide flood plain through most of its course. This flood plain will dissipate the flows before they reach the ponding caused by the Concord Road Dam.

Therefore, since it appears that only minor flooding of one outside structure, minor sheet flow over a portion of Route 27 and no loss of life would result from a dam failure, it is recommended that Nagog Pond Dam be reclassified as having a "low" hazard potential.

E. Ownership. The name and address of the current owner is:

Town of Concord
Public Works Department
Keyes Road
Concord, MA 01742
Phone: (617) 369-2709

The dam was built by the Town of Concord in 1909 to replace an existing dam of which the ownership is unknown.

F. Operator. Mr. Harold W. Storrs, Superintendent of Public Works, Concord, Massachusetts, is ultimately responsible for operation and maintenance of the dam.

G. Purpose of Dam. The dam was constructed to impound a water supply for the nearby Town of Concord and continues to serve that purpose.

H. Design and Construction History. In 1909, the Town of Concord undertook the development of Nagog Pond as an additional water supply for the Town. This project included construction of the present Nagog Pond Dam. A detailed report on the project design and construction was submitted to the Town of Concord by the engineers, Metcalf & Eddy, Inc., Boston, MA and is included in Appendix B-5. The following is a brief summary of the construction sequence.

A 16-in. water supply pipeline from Nashawtuc Reservoir in Concord to an old existing dam at the Nagog Pond outlet was completed in September 1909. Subsequent excavation at the dam site revealed the old dam to be seriously leaking due to inadequate construction. It was decided to remove the old structure and construct a new dam and gate house founded on bedrock in its place. This work was performed by Henry Spinach Contracting Company, Waterbury, Connecticut from October 1909 through February 1910.

A temporary cofferdam was constructed across a narrow portion of Nagog Pond approximately 1300 ft. west of the dam. This shallow portion of the pond adjacent to the dam site was then drained to permit construction of the new dam and placement of intake pipeline. A 1300-ft. long section of the intake was supported on wooden piles less than 20 ft. in length driven through soft peat comprising the pond bottom in this shallow area. The remaining 400 ft. of the approximately 1700-ft. long intake pipeline was constructed by divers to extend into the deeper waters beyond the cofferdam.

I. Normal Operational Procedures. There is no established routine for the operation of this dam. The control works are operated for water supply purposes. The 16-in. water supply line from the gate house is usually open and flowing at all times. The reservoir drain is considered inoperable.

1.3 PERTINENT DATA

All record plans for Nagog Pond Dam are on mean high tidewater datum. To convert from mean high tidewater datum to mean sea level, add 10.16 feet to elevations on mean high tidewater datum. All elevations used herein were so converted to mean sea level (MSL) datum.

A. Drainage Area. The drainage area of Nagog Pond is approximately 794 acres (1.24 square miles) as shown on the map, Appendix D-1. The pond surface itself comprises an estimated 35 percent (275 acres) of the total drainage area. The watershed's topography is primarily rolling terrain and very densely forested with only minor development, the most significant being that along the 1/2 mile stretch of Route 2A (Great Road) within its limits. Nagog Pond is fed by runoff from the surrounding watershed and there are no discernible brooks tributary.

B. Discharge at Dam Site.

1. Outlet Works	16-inch water supply pipe and 24-inch sluice gate
2. Maximum known reservoir elevation at dam site	El. 227.32 on 9 March 1973 is highest known level in past 15 years
3. Ungated spillway capacity at top of dam	60 cfs at El. 227.66
4. Ungated spillway capacity at test flood pool elevation	22 cfs at El. 226.9
5. Gated spillway capacity at normal pool elevation	Not applicable
6. Gated spillway capacity at test flood pool elevation	Not applicable
7. Total spillway capacity at test flood pool elevation	22 cfs at El. 226.9
8. Total project discharge at test flood pool elevation	22 cfs at El. 226.9

C. Elevation (ft. above MSL)

1. Top dam	227.66
2. Test flood pool-design surcharge	226.9
3. Design surcharge - original design	Unknown
4. Full flood control pool	Not applicable
5. Recreation pool	226.16
6. Spillway crest	226.16
7. Upstream portal invert diversion tunnel	Not applicable
8. Streambed at centerline of dam	Approx. 213
9. Maximum tailwater	Unknown

D. Reservoir

1. Length of maximum pool	1.3 miles (Est.)
2. Length of recreation pool	1.3 miles (Est.)
3. Length of flood control pool	Not applicable

E. Storage (acre-feet)

1. Top of dam	3140
2. Test flood pool	2915
3. Flood control pool	Not applicable
4. Recreation pool	2698
5. Spillway crest	2698

F. Reservoir Surface (acres)

1. Top of dam	308
2. Test flood pool	296
3. Flood control pool	Not applicable
4. Recreation pool	281
5. Spillway crest	281

G. Dam

1. Type	Concrete gravity section dam
2. Length	168 ft.
3. Height	15 ft.
4. Top Width	4 ft. nominal
5. Side Slopes	1H:12V upstream 3H:12V downstream
6. Zoning	Not applicable
7. Impervious core	Concrete dam
8. Cutoff	Dam keyed into bedrock
9. Grout curtain	Unknown

H. Diversion and Regulating Facilities. Not Applicable.

I. Spillway

1. Type	Sharp crested with steel weir plate
2. Length of weir	10 ft.
3. Crest elevation	226.16
4. Gates	None
5. U/S Channel	Unknown
6. D/S Channel	Approx. 1.5 percent

J. Regulating Outlets. The intake for the reservoir drain is an underwater fieldstone channel extending to the dam. A 24-in. square sluice gate is mounted on the upstream face of the dam with the top of the operating rod underwater. A 24-in. square opening through the dam conveys the water which is outletted at the downstream face of the dam into the spillway discharge channel. The invert of the drain is at El. 215.16. The drain is presently inoperable.

Water is taken from the reservoir for water supply by a 16-in. intake pipeline and a 12-in. intake pipeline. Both intake pipelines outlet in the gate house, as shown on the contract drawing in Appendix B-3. The 16-in. pipeline has a 16-in. gate valve at its outlet into the main chamber, while the 12-in. pipe has two outlets, one to the main chamber and the other to the blowoff chamber. Both outlets for the 12-in. intake line have gate valves, but an operator was only observed over the outlet to the blowoff chamber.

A 12-in. gate valve controls the flow of water from the main chamber to the blowoff chamber. The 16-in. water supply pipeline from the main chamber is not gated. The blowoff chamber outlets through a 12-in. and an 8-in. spool pieces to the downstream side of the dam and the spillway channel. Each of the spool pieces have gate valves on the blowoff chamber side. Invert elevation of the blowoffs are approximately El. 215.7.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN RECORDS

Contract drawings of proposed construction and an engineering report to the Town of Concord prepared by Metcalf & Eddy, Inc., Boston, MA constitute the available design data.

2.2 CONSTRUCTION RECORDS

The sequence of construction activities is documented in the engineering report prepared by Metcalf & Eddy.

2.3 OPERATION RECORDS

Operation records in the form of periodically measured reservoir water levels and inspection reports by the Commonwealth of Massachusetts are available.

2.4 EVALUATION

A. Availability. A detailed list of all engineering data available for use in preparing this report is included in Appendix B-1. Selected documents from the listing are also included in Appendix B.

B. Adequacy. The available engineering data, when used in combination with the visual examination described in Section 3, were sufficient for the purposes of this report.

C. Validity. The information contained in the engineering data may be generally considered valid. Details on the contract drawings are shown as designed and were found to vary slightly but not significantly from those actually constructed.

SECTION 3 - VISUAL EXAMINATION

3.1 FINDINGS

A. General. The Phase I visual examination of the Nagog Pond dam was conducted on 3 October 1978.

In general, the project was found to be in good condition. Some deficiencies which require correction were noted.

A visual inspection check list is included in Appendix A and selected photographs of the project are given in Appendix C. A "Site Sketch Plan", Appendix C-1, shows the direction of view for each photograph.

B. Dam. The dam is a concrete gravity section founded on bedrock, extending from a bedrock abutment on the left, Photo No. 2, to an abutment which is probably bedrock on the right, Photo No. 3. There is no earth embankment associated with this structure. On the upstream side of the dam, shown in Photo No. 1, the ground slopes gently down to the pond starting from a level approximately 0.5 to 1.0 ft. below the crest of the dam. The somewhat riprapped slope is covered by brush, weeds and maple saplings which are as much as 10 to 12 ft. in height. The downstream side of the dam, Photos No. 2, 3 and 4, slopes gently from a level 4 to 8 ft. below the crest of the dam and is wooded.

The dam, including spillway and highwater spillway, Photo No. 5 and 6, is generally in good condition. The structure is in good alignment and there is no observed indication of lateral movement. One portion of the crest of the dam was observed to have a longitudinal slope but this was construed to have been a construction error or expediency rather than settlement, as no adjacent cracking was observed. The dam is reported to have been constructed on bedrock. No major seepage or other serious defect was observed.

The concrete surface of the dam has been patched in the past, especially on the crest of the dam. A number of these patches are becoming loose. Other areas are starting to spall. There is deterioration of surface concrete to the left and right sides of the spillway on the upstream face as well as on the upstream side of the weir plate. An example of such deterioration is shown in Photo No. 7. The weir plate is corroded, especially on the right side. Concrete immediately downstream of the weir plate does not appear to be well bonded to the main dam. The downstream face of the spillway and the

dam exhibits cracks and efflorescence.

C. Appurtenant Structures. The gate structure, shown in Photo No. 1, is generally in good condition but does need repairs. Slate shingles are missing from the roof. The wooden trim is almost devoid of paint. The brick masonry appears in good condition. The parge coat, just below the base of the brick masonry is not bonded to the underlying material and has spalled off in local areas. The concrete substructure has local eroded areas, some concrete cracking and efflorescence present.

The gate valves within the gate house appear to be maintained and operable. They are currently chained to prevent vandal damage, as shown in Photo No. 8. Two of the gate valve operators are loose, braced by timbers and are apparently located over valve boxes. The blowoff outlets on the downstream face of the dam on the right side of the discharge channel are partially blocked by earth, Photo No. 9.

The reservoir drain sluice gate is completely buried with debris on the upstream side, Photo No. 10. Although the top of the corroded gate operating rod is visible underwater, the gate is considered inoperative. The drain outlet at the downstream face of the dam on the left side of the discharge channel is partially blocked by earth and debris, Photo No. 11.

None of the gates for this structure were operated.

The pond is quite shallow in the area several hundred feet upstream of the dam, Photo No. 12. Consequently, the intake for the water supply pipe is located about 1700 ft. from the gate house in the deeper waters of the pond.

D. Reservoir Area. The area around Nagog Pond is generally wooded on rolling terrain. While the slope on the south side is steep, there is little possibility that landslides into the reservoir would cause waves which would overtop the dam. No conditions which might result in a sudden increase in sediment load into the reservoir were noted.

E. Downstream Channel. The discharge channel has fieldstone walls in the immediate vicinity of the dam. Approximately 20 to 25 ft. downstream of the dam, the walls have collapsed and the channel is blocked by debris. The natural channel of Nagog Brook is narrow, rock lined and winding, Photo No. 13.

3.2 EVALUATION

The dam and spillway are in need of surface repairs to arrest the deterioration of the structures. The gate house needs repairs to prevent further deterioration. The area adjacent to the dam and the downstream channel should be cleared to allow the free flow of flood waters. The reservoir drain gate should be rebuilt to allow its use in an emergency. However, based on the visual examination, there appears to be no significant potential for the failure of the dam and/or spillway at this time.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

In general, there are no established operational procedures, maintenance programs or formal warning systems in effect for this dam.

4.2 MAINTENANCE OF DAM

There are no established written procedures to assure periodic inspection and maintenance of the dam.

4.3 MAINTENANCE OF OPERATING FACILITIES

The operation of the facility is based on the demand and supply of water rather than any formal established operational procedures. The gate house and discharge channel do not receive regular maintenance, and the outlet drain is not operational.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

There is no formal warning system or emergency preparedness plan in effect for this structure.

4.5 EVALUATION

A periodic observation and maintenance program should be established to examine the dam, control its deterioration, insure operability of all gates, and control tree and brush growth adjacent to the structure and within the downstream channel.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

A. Design Data. A set of plans entitled "Nagog Pond Supply, Outlet Of Nagog Pond" bearing the date of October 1909 were the basis for the construction of this facility. The reservoir was constructed in order to augment the Town of Concord's water supply and was designed for a safe yield of 1 MGD. No hydraulic nor hydrologic design data was found. The recommended test flood for the size (intermediate) and hazard potential (low) classifications of this dam is in the range of the 100-year frequency to the 1/2 PMF. Since the value of maximum storage is near the lower value designated for dams of "intermediate" size, the recommended test flood for Nagog Pond Dam is the 100-year flood.

B. Experience Data. The "SCS-TP-149, Method for Estimating Volume and Rate of Runoff in Small Watersheds" was used as a guide for determining the inflow hydrograph into Nagog Pond for the 100-year storm. The peak inflow was calculated to be 420 cfs. However, because the water surface area comprises approximately 35 percent of the total drainage area, flood routing was deemed necessary and using the method for flood routing presented in "Water Supply and Wastewater Disposal" by Fair and Geyer, resulted in a peak outflow of 22 cfs at a pond water surface elevation of 226.9 ft. above MSL, approximately 0.76 ft. below the top of the dam.

C. Visual Observations. The inspection revealed that no apparent major modifications have been made to the dam since its original construction in 1909, except for patching of the spillway sides and the top of the dam.

The channel downstream of the dam is approximately 3 ft. in width, 5 ft. in depth, with vertical side slopes. The left side of the channel is rock lined, whereas the right side is earthen. Nagog Brook winds through a dense forest (primarily coniferous trees) at an estimated 1.4 percent slope and reaches Nashoba Brook approximately 800 ft. downstream of Route 27.

Nashoba Brook continues via a natural channel and is conveyed through the Brook Street Dam via a 40-ft. wide spillway and a 13-ft. wide bypass channel. Approximately 100 ft. downstream of this dam, the brook flows through two C.M. Plate Arches under Brook Street. After this point, Nashoba Brook continues to be conveyed through a series of culverts and sections of natural channel surrounded for the most part by a wide flood plain and is eventually inundated by the ponding area caused by the Concord Road Dam.

D. Overtopping Potential. As stated previously, based on the size (intermediate) and hazard (low) classifications published in the Guidelines, the test flood is the 100-year storm. A rating curve for the Nagog Pond Dam spillway was developed, and demonstrated that the spillway is capable of handling approximately 60 cfs at El. 227.66, the elevation at the top of the dam. Since the value of the test flood is 22 cfs with a maximum pool elevation of 226.16, it is evident that the spillway can pass the test flood without overtopping the dam. These values were calculated given that the outlet structures were closed during the storm.

E. Evaluation. As discussed in detail in Section 1.2D, the spillway is capable of handling the 100-year flood flows. A failure of the dam would result in flows which would cause sheet flow over Route 27 for a distance of approximately 500 feet and possible minor flooding of an outside structure located on the right bank of the brook. Otherwise, it appears that no damage would be caused. Therefore, it appears that a breach of the dam would not result in any appreciable downstream damage.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

A. Visual Observations. There was no observed movement, distress or concrete condition during the 3 October 1978 site examination which would indicate structural instability.

B. Design and Construction Data. Proposed construction plans, dated 1909, and a general report on the project are available. Based on the general dimensions shown on the plans, the general foundation description (rock) given in the report and the observed elevation of ground surface adjacent to the structure, the structure is considered stable.

C. Operating Records. There is a survey pin at the top of the dam left of the gate house, but no records are known to exist which would indicate the magnitude and nature of any past structural movements. The reservoir water level is periodically measured and recorded.

D. Post-Construction Changes. Based on a comparison of the 1909 proposed construction drawings with the observations made during the October 1978 site examination, no major post-construction changes are apparent.

E. Seismic Stability. This dam is located in Seismic Zone No. 2 and in accordance with Recommended Phase I guidelines, does not warrant seismic analysis.

SECTION 7 - ASSESSMENT, RECOMMENDATIONS AND REMEDIAL MEASURES

7.1 DAM ASSESSMENT

A. Condition. The visual examination of the dam, spillway and gate house indicates that the structures are in good condition. The indicated deficiencies are primarily surface conditions. There are no visual signs of failure or conditions which would warrant urgent remedial treatment.

The spillway was determined to be capable of passing the test flood, a 100-year flood, without overtopping the dam. The spillway is capable of handling a flow of approximately 60 cfs while the test flood caused a flow of only 22 cfs over the spillway.

B. Adequacy of Information. There is sufficient information available to evaluate the structures. The information is in the form of contract drawings of the proposed facility and a report to the town on the construction. It should be noted, however, that the reference to the foundation material (rock) is minimal.

C. Urgency. The remedial measures outlined in 7.3 should be undertaken by the Owner within two years after receipt of this report.

D. Need for Additional Investigation. Additional investigation is not believed to be necessary at this time.

7.2 RECOMMENDATIONS

Not applicable.

7.3 REMEDIAL MEASURES

A. Alternatives. Not applicable.

B. Operating and Maintenance Procedures. The following remedial work should be undertaken by the Town of Concord, owner of the dam, to correct deficiencies noted during the visual examination:

1. Remove all deteriorated concrete from the surfaces of the dam, spillway and gate house and resurface the areas with concrete or mortar well bonded to the underlying concrete.

2. Restore the roof, paint the wood trim, and replace the parge coat just below the brick masonry on the gate house.

3. Remove the corrosion from the weir plate and coat the plate with a resistant material such as an epoxy.

4. Reconstruct the reservoir drain to make it operational and accessible during high reservoir levels.

5. Firmly attach the loose and timber braced gate operators within the gate house to the floor or other rigid support.

6. Clear the brush and trees on the upstream side of the dam, adjacent to the dam and within the spillway to minimize root encroachment into cracks in the masonry and fieldstone discharge channel walls.

7. Regrade the discharge channel to remove the partial blockage of the reservoir drain outlet, the partial blockage of the blowoff outlets and the partial blockage of the channel approximately 20 feet downstream of the spillway.

Although the dam is currently in good condition, it is considered important that the owner prepare an operations and maintenance manual for the dam. The manual should include provisions for biennial technical inspection of the dam and for surveillance of the dam during periods of heavy precipitation and high reservoir water levels. The procedures should delineate the routine maintenance work to be done on the dam to ensure satisfactory operation and to minimize deterioration of the facility.

APPENDIX A
INSPECTION TEAM ORGANIZATION AND CHECK LIST

VISUAL INSPECTION PARTY ORGANIZATION

NATIONAL DAM INSPECTION PROGRAM

Dam: Nagog Pond

Date: 3 October 1978

Time: 1145-1530

Weather: Cloudy and Cool (50's F.)

Water Surface Elevation Upstream: El. 224.3 MSL

Stream Flow: None

Inspection Party:

Harl P. Aldrich, Jr. Haley & Aldrich, Inc.	- Soils/Geology
Roger H. Wood Camp, Dresser & Mckee, Inc.	- Structural/Mechanical
Charles E. Fuller Camp, Dresser & Mckee, Inc.	- Hydraulic/Hydrologic

Present During Inspection:

Edward Shaw, Department of Public Works, Concord, MA
Richard A. Brown, Haley & Aldrich, Inc.
Donna L.B. D'Amore, Camp, Dresser & Mckee, Inc.

VISUAL INSPECTION CHECK LIST
NATIONAL DAM INSPECTION PROGRAM

DAM: Nagog Pond DATE: 3 Oct. '78

AREA EVALUATED	CONDITION
DAM AND SPILLWAY	
1. Approach Channel	
a. General Condition	Spillway at pond
b. Obstructions	Brush and grass
c. Log Boom	None
2. Weir	
a. Flashboards	None
b. Weir El.	226.16 MSL
c. Vegetation	Brush and grass both sides
d. Seepage or Efflorescence	Efflorescence downstream on each side of weir
e. Rust or Stains	None observed
f. Cracks	None noted
g. Condition of Joints	Good
h. Spalls, Voids or Erosion	Deterioration left side of upstream face
i. Visible Reinforcement	None observed
j. General Structural Condition	The general condition is good except for deterioration on upstream face of dam. On the left side of weir, corroded weir plate and hollow sound of concrete just downstream of weir plate
3. Discharge Channel	
a. Apron	None observed
b. Stilling Basin	None observed
c. Channel Floor	Natural ground
d. Vegetation	Trees, brush, and grass
e. Seepage	Channel bottom is moist
f. Obstructions	Young trees, brush, debris and partial blockage (fill) approx. 20 ft. from spillway.
g. General Structural Condition	Channel walls are fieldstone in fair condition. Channel needs cleaning
4. Dam	
a. Vegetation	Brush & trees each face of dam
b. Seepage or Efflorescence	Efflorescence various locations downstream face

VISUAL INSPECTION CHECK LIST
NATIONAL DAM INSPECTION PROGRAM

DAM: Nagog Pond DATE: 3 Oct. '78

AREA EVALUATED	CONDITION
c. Rust or Stains	None noted
d. Cracks	Minor cracking
e. Condition of Joints	Good
f. Spalls, Voids or Erosion	Spalls and patched spalls which are now loose present. Local areas with deteriorated concrete
g. Visible Reinforcement	None observed
h. General Structural Condition	The general condition is good to fair, the deteriorated and spalled concrete should be repaired
OUTLET WORKS - RESERVOIR DRAIN	
1. Inlet	
a. Obstructions	Minor debris
b. Channel	Field stone channel underwater
c. Structure	None
d. Screens	None
e. Stop Logs	None
f. Gates	24" x 24" sluice gate - Top of operator underwater
2. Control Facility	
a. Structure	None - part of dam
b. Screens	None
c. Stop Logs	None
d. Gates	See Item 1f
e. Conduit	24" x 24" opening in dam
f. Seepage or Leaks	Not visible
3. Outlet	
a. Structure	None
b. Erosion or Cavitation	Top of outlet eroded or spalled
c. Obstructions	Outlet partially blocked by earth
d. Seepage or Leaks	Not visible
4. Mechanical and Electrical	Not applicable

VISUAL INSPECTION CHECK LIST
NATIONAL DAM INSPECTION PROGRAM

DAM: Nagog Pond DATE: 3 Oct '78

AREA EVALUATED	CONDITION
OUTLET WORKS - GATE HOUSE AND WATER SUPPLY INTAKES	
1. Inlet	Underwater pipes - not visible
2. Control Facility	
a. Structure	Slate shingles missing from roof Brick in good condition. Parge coat on upper fndn. loose. Erosion of concrete substructure. Ext. surface, some cracks & efflorescence, wood trim needs paint.
b. Screens	Not observed
c. Stop Logs	None noted
d. Gates	One 16" gate valve loose & braced One 12" gate valve loose & braced Two 12" gate valves One 8" gate valve Plan calls for another 12" gate valve but operator not observed.
e. Conduit	Not applicable
f. Seepage or Leaks	Not visible
3. Outlet	
a. Structure	Blowoffs through opening in dam; 16" pipeline
b. Erosion or Cavitation	Not visible
c. Obstructions	Partially blocked blowoff outlet by earth and brush downstream
d. Seepage or Leaks	Not visible
4. Mechanical and Electrical	Not applicable

APPENDIX B

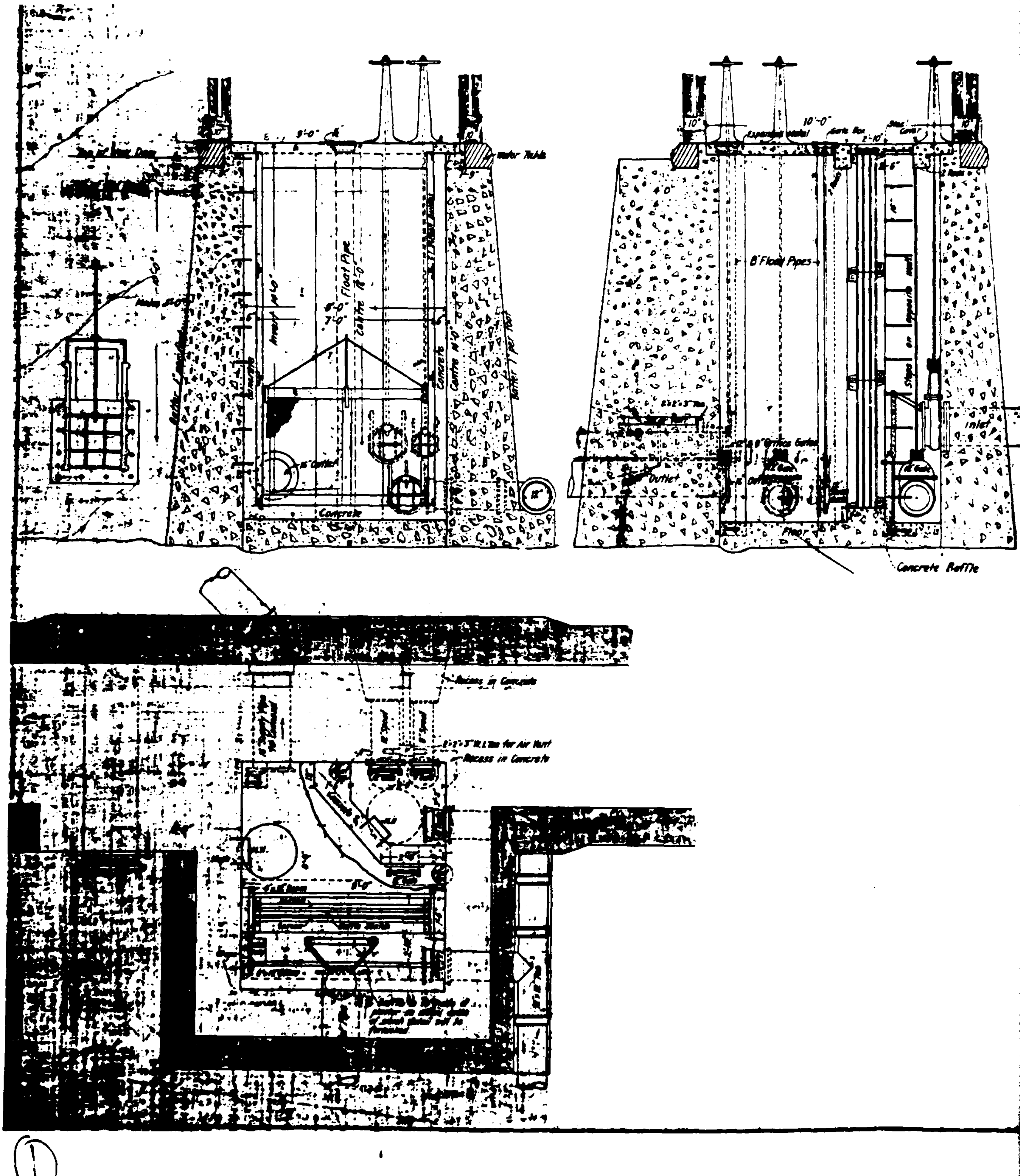
LIST OF AVAILABLE DOCUMENTS AND PRIOR INSPECTION REPORTS

LIST OF AVAILABLE DOCUMENTS
NAGOG POND DAM

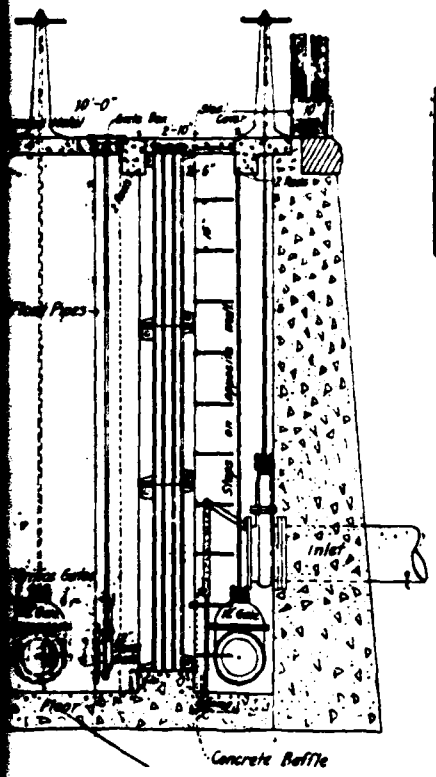
DOCUMENT	CONTENTS	LOCATION
"Details of Screen and Iron Work for High Service", Drawing C-299, Metcalf & Eddy, Boston, MA, August 1908	Details	Town of Concord, Public Works Department, Keyes Road, Concord, MA 01742
"Venturi Meter Chamber and Pipe Connecting on 16" Supply Pipe from Nagog Pond", Metcalf & Eddy, Boston, MA, 1 July 1909	Section plan and elevations	Town of Concord, Public Works Department, Keyes Road, Concord, MA 01742
"Steel Trap Doors for Gate House", Metcalf & Eddy, Drawing C-354, Boston, MA, 9 August 1909	Plan, section and details	Town of Concord, Public Works Department, Keyes Road, Concord, MA 01742
"Reconstruction of Dam at Outlet of Nagog Pond", Drawing C-356, Metcalf & Eddy, Boston, MA, 28 September 1909	Elevations, sections and plan	Town of Concord, Public Works Department, Keyes Road, Concord, MA 01742
"Gate House In Dam at Outlet of Nagog Pond", Drawing C-357, Metcalf & Eddy, Boston, MA, 30 September 1909	Details and side elevation	Town of Concord, Public Works Department, and Appendix B-3
"Proposed Concrete Dam at Outlet of Nagog Pond", Drawing C-358, Metcalf & Eddy, Boston, MA, 29 October 1909	Elevation, plan and section	Town of Concord, Public Works Department, and Appendix B-4
Engineers' Report Upon the Nagog Pond Extension, Concord Town Report, pp. 55-65, Metcalf & Eddy, Boston, MA, 14 February 1910	Report on the general design and detailed construction progress at Nagog Pond Dam	Town of Concord, Public Works Department, Keyes Road, Concord, MA 01742 and Appendix B-5

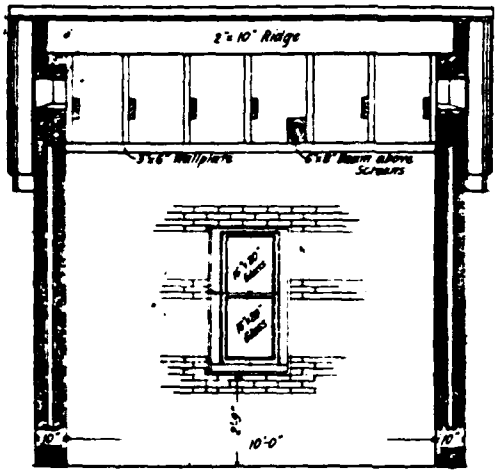
LIST OF AVAILABLE DOCUMENTS
NAGOG POND DAM
(continued)

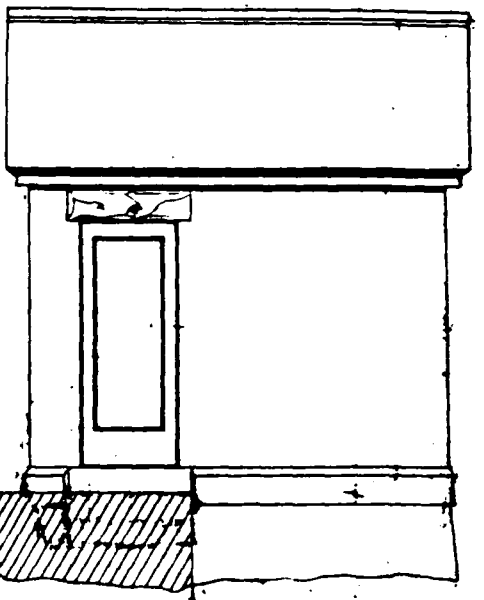
DOCUMENT	CONTENTS	LOCATION
Inspection Report dated 6 August 1973	Most recent State inspection report and description of dam on file	Massachusetts Department of Environmental Quality Engineering, 10[illegible] Nashua Street, Boston, MA 02114 and Appendix B-11


Float Pipe
Concrete
Water Table
8" Float Pipes
Inlet
Outlet
Floor
Concrete Baffle
Recess in Concrete

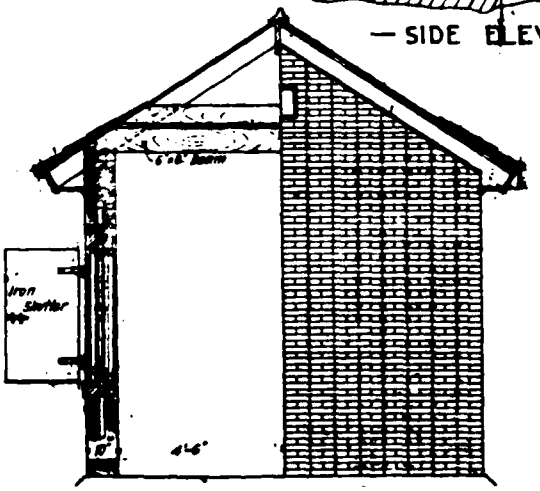
C-357







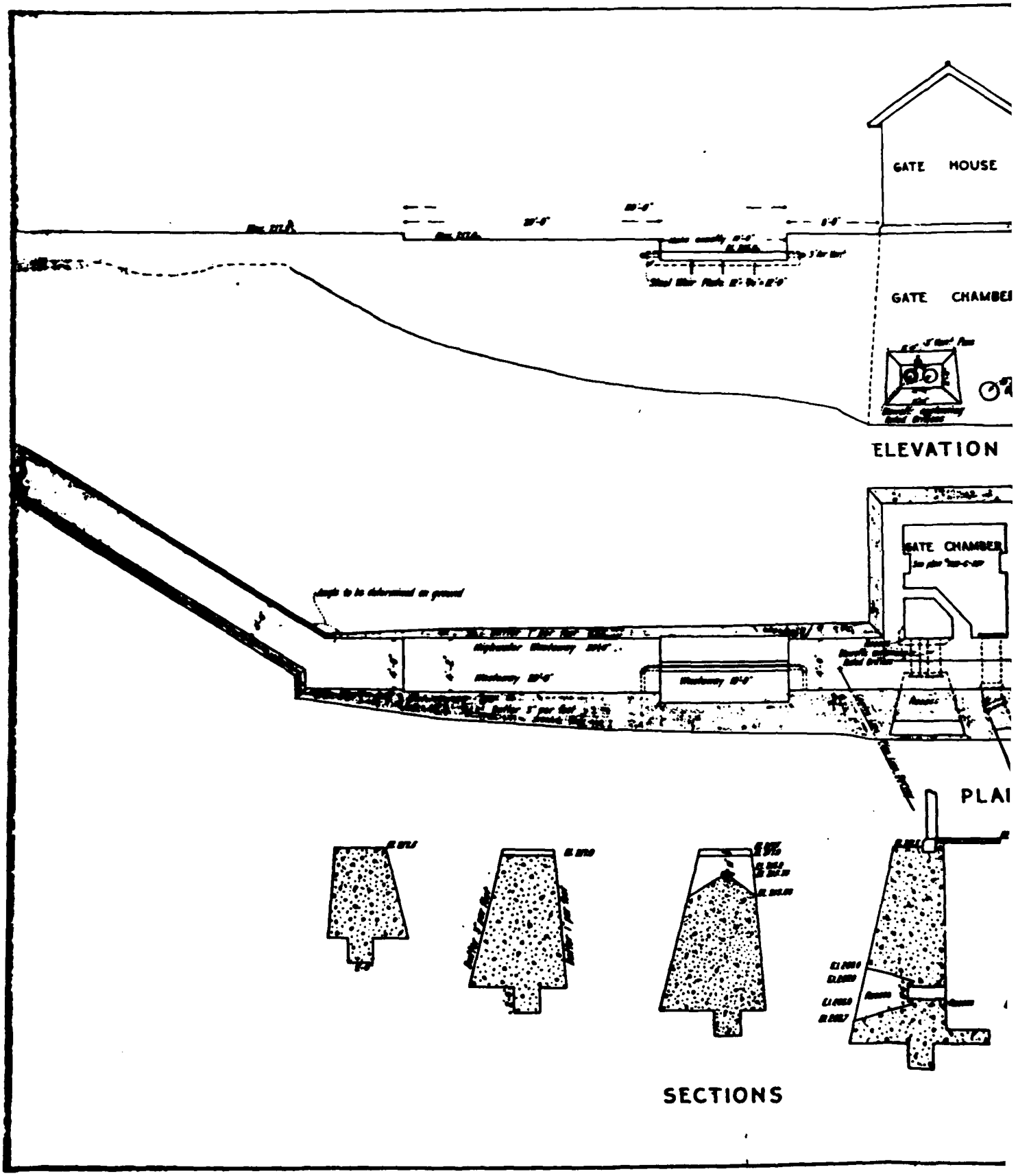
— SIDE ELEVATION —



CONCORD · WATER · WORKS
CONCORD — MASS

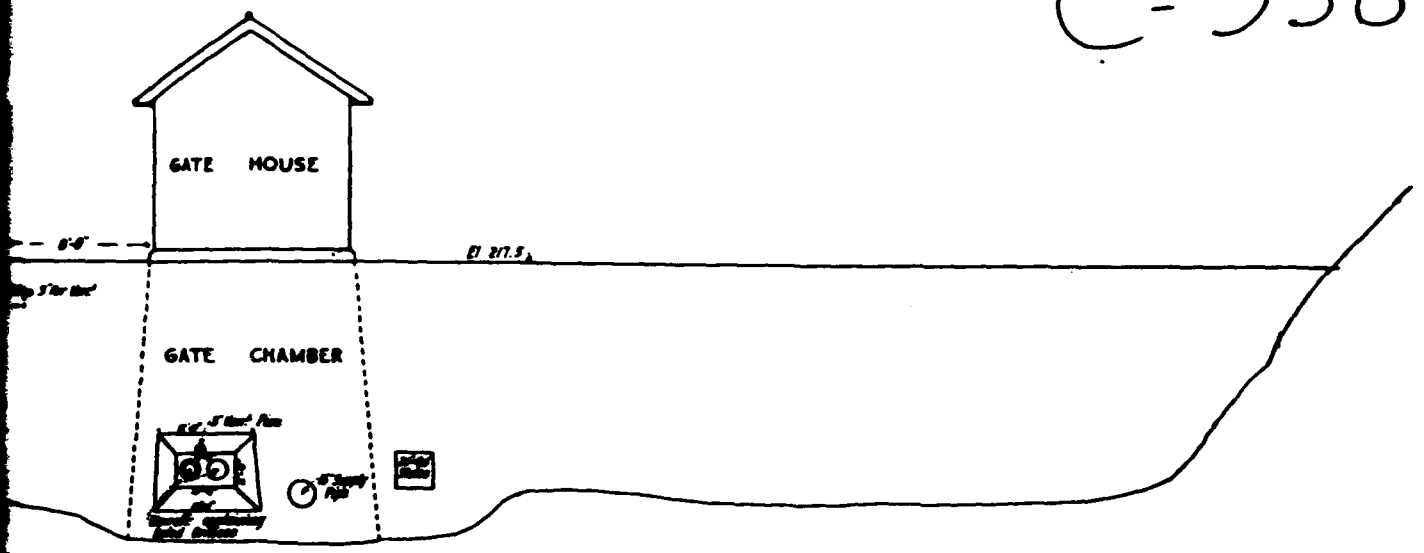
NAGOG POND SUPPLY
GATE HOUSE IN DAM
—AT—
OUTLET OF NAGOG POND

B-3

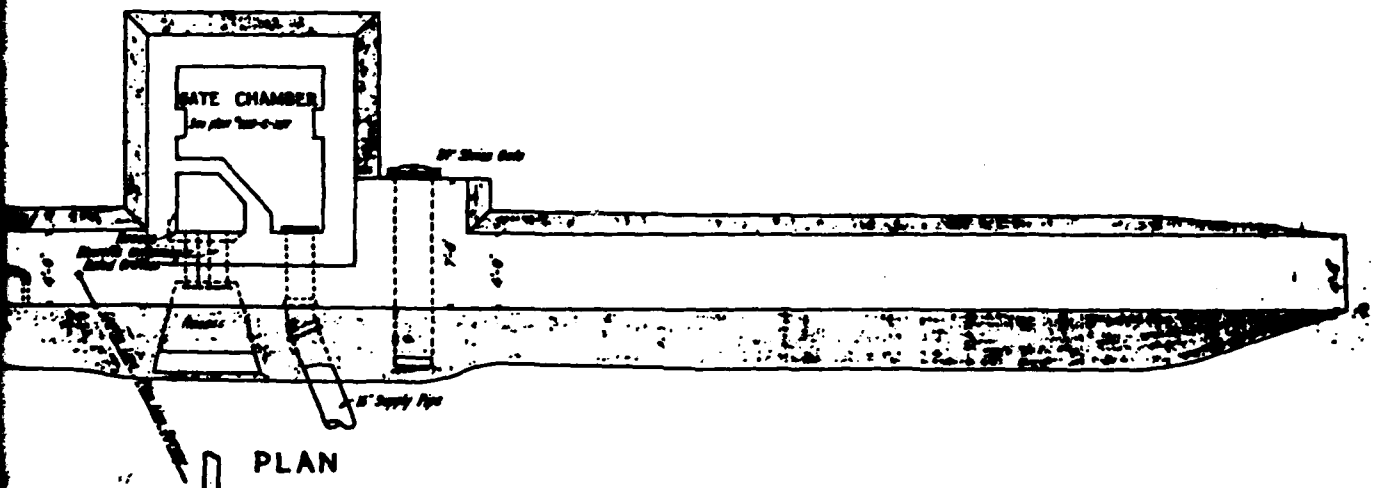

GATE HOUSE
GATE CHAMBE
ELEVATION
GATE CHAMBER
PLA
SECTIONS

(1)

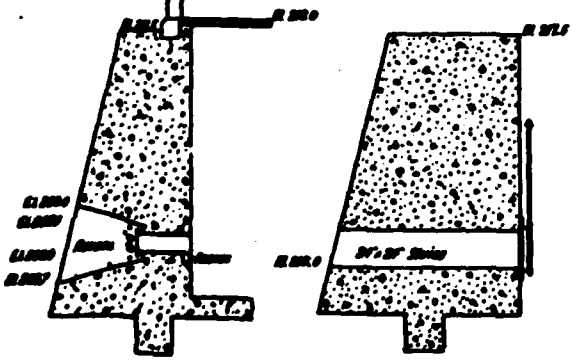
C-358



ELEVATION



PLAN



CONCORD WATER WORKS
CONCORD — MASS.

NAGOG POND SUPPLY
PROPOSED CONCRETE DAM
—AT—
OUTLET OF NAGOG POND

OCT. 29, 1909 SCALE, 1 IN. = 1 FT.

METCALF & EDDY
CONSULTING ENGINEERS
BOSTON — MASS.

B-4 (2)

Annual Report of

Water and Sewer Commissioners

of the Town of
Concord, Massachusetts
for the year ending
January 31
1910

Concord, Mass.
Thomas Todd Co., Printers
1910

B-5

ENGINEERS' REPORT UPON THE NAGOG POND EXTENSION

BOSTON, February 14, 1910.

Messrs. William Wheeler, Elmer E. Shattuck, Thomas Hollis, Water and Sewer Commissioners of the Town of Concord, Mass.

GENTLEMEN: We submit to you our report upon the construction of the works incident to the development of an additional water supply from Nagog Pond.

While some work remains to be done, such as the construction of the gatehouse superstructure, the removal of the coffer-dam, and some cleaning up at the outlet dam and along the pipe line, the works are substantially complete, and water is now being drawn from Nagog Pond for the supply of the Town.

Nagog Pond Supply

It may be of interest to the citizens of Concord to record here a few of the physical facts relating to the new Nagog Pond supply, without going into a lengthy discussion as to the reasons for the adoption of this source of water supply. As to the latter, suffice it to say that upon comparison with other possible sources it proved to be the most economical and desirable.

The water, which is much like that from Sandy Pond in character, is excellent in quality. The pond lends itself exceedingly well to water supply purposes, on account of its large storage capacity, its rocky or sandy shore and bottom, and its substantial depth, all of which tend to check if not prevent organic growths that might otherwise be troublesome.

In this respect, the bay near the outlet dam differs from the main body of the pond, inasmuch as it is shallow and has a deep deposit of peat (in some places eighteen feet or more in depth) over a considerable portion of it. The character of the bay and the danger of its chance pollution made it desirable to extend the intake pipe a distance of approximately 1,700 feet from the outlet dam, 1,300 feet through the bay past the island, or Breezy Point, so called, and about 400 feet out into deep water in the lake, at considerably increased cost to the Town. This will also result in giving water of somewhat better quality and lower temperature than could have been obtained at the outlet dam.

The pond lies at a distance of approximately 6½ miles from the center of the Town of Concord, and 3.9 miles from the Massachusetts Reformatory. Connecting with the end of the 16-inch high service pipe at its junction with the 12-inch pipe running from the Acton Road up to Annursnack Reservoir, the Nagog Pond pipe line follows the Acton Road toward Groton to a point near the crossing of the New York, New Haven & Hartford R. R. and Nashoba Brook, from which point the line runs through private lands, a distance of approximately 1½ miles to the dam.

The outlet dam at Nagog Pond lies at an elevation of 216.16 feet above mean high tidewater, as appears in the elevations given in the writers' report upon the construction of the high service system. It is about 5 feet 3½ inches below the top of the flashboard at the outlet of Sandy Pond, and 3 feet 2 inches above the overflow of Nashawtuc Reservoir. Owing to this difference in water level between Nagog Pond and Sandy Pond, and to the small fall available for overcoming the friction of the water flowing in the pipe from Nagog Pond to Nashawtuc Reservoir, it was necessary to lay a pipe of comparatively large diameter (16 inches), and to place a check valve upon this new pipe line to prevent water from flowing from Sandy Pond through the pipe system back into Nagog Pond at times of abnormally small consumption in the Town of Concord, as well as at such times as the high service pressure may be put upon the entire pipe system.

Available Storage in Nagog Pond

The available storage in Nagog Pond is shown below. The area of water surface at high-water mark, corresponding to the crest of the outlet dam, was found to be about 287 acres, or 0.45 of a square mile by planimeter measurements from the map of Nagog Pond prepared by and lodged with the Massachusetts Harbor and Land Commissioners in Boston, plotted to a scale of 1 to 4,000. The length of shore line at this elevation is approximately 4.2 miles. In default of definite information concerning the slope of the ground from the shore out under the pond, a bottom slope of approximately one in seven has been assumed, and upon this basis the storage capacity of the pond has been computed. Broadly speaking, this computation indicates that a year's supply of water for the Town of Concord is stored within the upper 22 inches of the pond, and that a volume equivalent to from five to six years' consumption is contained in the upper 10 feet of storage below the crest of the dam at the outlet of Nagog Pond.

Estimated Areas and Volumes of Water in Nagog Pond for Each Foot in Depth below the Crest of the Outlet Dam

Elevation 216.16

Depth in Feet below Crest of Dam.	Approximate Area of Water Surface in Acres.	Gallons of Water Stored.
0	287.8	0
1	283.8	93,000,000
2	280.8	91,900,000
3	276.8	90,800,000
4	272.8	89,600,000
5	269.8	88,500,000
6	266.8	87,300,000
7	263.8	86,300,000
8	259.8	85,100,000
9	255.8	83,900,000
10	252.8	82,800,000
Grand Total,		879,100,000

Present annual consumption, approximately 165,000,000 gallons.

The total area of the watershed or catchment area above the dam at the outlet of Nagog Pond is estimated at 1.52 square miles.

Plans and Takings

Surveys and plans were made for the taking of the necessary rights of way for pipe lines, and access thereto, and for the taking of lands under and bordering upon the pond, adjacent to the intake, for the preservation of the purity of the water supply. The areas of land taken in fee, or in which rights were taken, were as follows:

Total area for pipe line,	5.610 acres
Total area for access,	2.058 "
Total area bordering upon pond,	41.950 "
Grand total,	49.618 acres

Area under the water of Nagog Pond, at elevation 216.16, corresponding to the crest of the new dam which is at the same elevation as the old dam, 287.33 acres

Plans were also prepared for the location of the pipe line within or along the Massachusetts State Highway (or Acton Road, so called), and formal permit was obtained from the Highway Commission, under date of June 9, 1909, to locate the pipe line as proposed. The originals of these plans, together with the construction plans, numbering in all something over twenty, are now on file at the office of your engineers, and copies of the more important of them have been furnished to your Superintendent for your files, that the record of this construction work may be complete.

Water Power Diversion

Report has already been made to you of the effect upon riparian owners of this diversion. As yet no settlements have been effected. Suffice it to say at this time that the amount

of the damage resulting is, in the opinion of the writers, nominal and trifling, for the two important reasons that the percentage of the total watershed diverted from the riparian owners is small in amount, varying from only three to about eight per cent., and the fall available at the privileges affected is small, in two cases out of three being below the limit of practical economical development.

Construction Work

Substantially the entire work was built by contract after competitive bidding.

Cast Iron Pipe and Specials. The bids received upon the cast iron pipe and specials are shown in Appendix I. Contract was awarded on April 10, 1909, to the United States Cast Iron Pipe & Foundry Company, the lowest bidder, at $23.35 per net ton for pipe, and 2½ cents per pound for the specials, delivered in Acton. The flexible joint, or so-called ball and socket joint pipe, used in the lake intake, requiring special machinery, was purchased of the same firm at an additional cost of $10 per ton. The total cost of pipe, after credit for pipe cracked in transit, was $29,279.47.

Distribution of Cast Iron Pipe. Invitations were sent to eight or ten persons in Concord, Acton, and Bedford, who it was thought might be interested in the carting and distributing of the 1,200 tons of pipe. Shipment of the pipe began before the contractor for the pipe laying was upon the ground, and it therefore became necessary for the Town to make independent arrangements for the handling of the pipe for the contractor, in order to save demurrage charges and to expedite the work as far as possible. The making of arrangements with the property owners along the pipe line for the distribution of the pipe and for access to the pipe line was a very important consideration in the award of this contract. Contract for this work was finally awarded to Mr. George E. Greenough, of Acton Center, who submitted the most advantageous bid.

Valves. Bids were received, upon June 7, 1909, for

furnishing the necessary valves, as shown in Appendix II, and contract was awarded to the lowest bidder, the Rensselaer Manufacturing Company.

Order was subsequently placed with the Coffin Valve Company for certain sluice gates required in the dam, not contemplated in the original contract, and for which the patterns of this company were believed to be particularly advantageous.

The total contract of the Rensselaer Manufacturing Company amounted to $810.07; that of the Coffin Valve Company, for a 16-inch check valve and the sluice gates, to $348.

Other Small Contracts. The contract for manhole frames and covers was awarded to the Sessions Foundry Company, of Bristol, Conn., which furnished similar castings for the high service work during 1908, and which was the lowest bidder. The total payment under this contract was $58.32.

Contract for the cast iron screen guides required in the gatehouse at Nagog Pond outlet was awarded to the Waterville (Me.) Iron Works, the lowest bidder, at 3 cents per pound; in total amount, $38.12.

Order for the copper screens was placed with the Morss & Whyte Company, the lowest bidders; price, $40.

Contract for the steel covers and trap-doors required for the gatehouse was awarded the Robb-Mumford Boiler Company, the lowest bidders, on August 19, 1909, at a price of $70.

Three bids were received upon a special weir plate of ¼-inch steel, 12 feet long. The order was given to the lowest bidder, L. M. Ham & Company, whose price was $18.

Order was placed with the Builders Iron Foundry, of Providence, R. I., May 28, 1909, for one 12-inch by 4-inch and one 6-inch by 2-inch Venturi meter, with type M indicator recorder and necessary charts and special planimeter, for measuring the water consumption from Nagog Pond. These meters were installed in a meter house built of concrete masonary and located for accessibility adjacent to the State Highway, near its crossing of the New York, New Haven

Hartford Railroad, at such a point as to admit not only of their present use, but of their future use in case at any time hereafter the Town of Acton should desire to take water from this pipe line, under suitable agreement with the Town of Concord.

The cast iron pipe and specials were all inspected at the foundry by Mr. William R. Conard, of Burlington, N. J., at a total cost of $261.20.

Contract for Laying Pipe. The construction of the new works was advertised in *Engineering News*, *Engineering Record*, and *Engineering-Contracting*, and in response to these advertisements twelve bids were received, on May 20, 1909, as shown in Appendix III. Contract was awarded, June 2, 1909, to the lowest bidder, the Henry Spinach Contracting Company, of Waterbury, Conn., after examination of the references and bond offered.

The contract contemplated and provided for the completion of the pipe line on August 1, and of the entire work on September 15, 1909, as there was urgent need of the new water supply on account of the anticipated shortage of water in Sandy Pond.

Pipe laying began June 8, 1909, and was completed up to the outlet dam September 14, 1909.

From the outlet of Nagog Pond the contractor was given the right, under the contract, to lay the submerged intake pipe into the pond (a distance of approximately 1,700 feet) either by diver or by building a cofferdam across the arm of the lake between the island and the main land, about 1,300 feet distant from the dam, to drain this portion of the pond before laying the pipe therein, and thereafter to lay the 400 feet more or less of intake pipe remaining out into the lake by means of a diver. Considerable time was lost by the contractor in an effort to sublet this work, but finally he was obliged to execute the work himself. Lumber for the cofferdam was not received upon the ground until August 31, 1909, and the coffer-dam was begun September 15, 1909, and completed just one month later. The submerged portion of

the intake (that is, running out into the main body of the lake), which was built with the aid of a diver, was begun on October 18 and completed on November 2, although an apron of masonry at the outer end of this intake pipe was not finished until November 7, 1909. That portion of the intake lying within the arm of the pond intercepted by the coffer-dam which had been built was begun on November 14, 1909, and substantially completed February 1, 1910. Owing to the presence of a peat bog in this arm of the pond, it was necessary to lay the intake pipe upon piles (twenty feet more or less in length) driven by hand and capped with timber, which resulted in further delay. Moreover, the soft character of the foundation made it advantageous to the contractor to postpone this work until after the completion of the work upon the dam, in order that he might have frozen ground upon which to work and to transport the pipe, and the contractor had great difficulty in getting and holding labor for this work. This delay resulted in considerable increase in cost of labor, through the added cost of conducting such work in extremely cold winter weather, which was offset, however, in large measure by the saving in cost of transporting, distributing, and laying the pipe upon such a difficult foundation.

The delay had the further serious disadvantage that it necessitated the making of temporary arrangements by the Town for the use of the Nagog Pond water. These were made by the Water and Sewer Commissioners, independently of this contract, and a temporary 10-inch Wyckoff wooden stave pipe line 1,400 feet in length was built from the coffer-dam to the dam at the outlet of Nagog Pond, and served to supply the Town for several months, during which the supply would otherwise have been interrupted. The additional expense to the Town involved in this temporary pipe line was $1,145.31, including pay roll items.

The new 16-inch cast iron pipe was utilized for the partial supply of the Town from September 15 to November 7. Upon November 7 the drainage of the arm of the lake below the coffer-dam began, and water was diverted from the pipe

until the completion of the wooden pipe line above referred to on November 18, 1909.

Masonry Dam. When excavations upon the site of the old dam were completed, the structure was found so constructed as to be totally inadequate to the needs of the service, and to account fully for the serious leakage of water through it. It was necessary, therefore, to make contract for the construction of a new dam to replace the old, which should be water-tight. Accordingly, contract was awarded, on October 27, 1909, to the Henry Spinach Company, which held the contract for the pipe laying, upon terms which were advantageous to both parties. Excavation began October 17, 1909, and the old dam was removed in a period of eleven days. The excavation was carried down to a suitable foundation upon rock for the new structure, forms were erected on November 17, and the work of depositing the Portland cement concrete, of which the new dam was built, began November 24, the last batch of concrete being put in place February 9, 1910. The granite which was taken out of the old dam, and which was found to be sound and suitable for use, was imbedded in the concrete of the new structure in order to reduce the cost of the latter as far as possible. The new dam is 4 feet in width at the top, with batters of 1 inch per foot on the upstream face and 3 inches per foot on the downstream face; 18 feet high at the deepest point, with a bottom thickness corresponding thereto of 10 feet. The additional cost of the work resulting from the necessity of rebuilding the dam at the outlet of the pond was approximately $4,500.

The gatehouse was built in connection with the construction of the dam, the superstructure alone remaining to be completed at the date of writing.

The finishing of the embankment and cleaning up about the dam and the removal of the coffer-dam will have to be done after the frost has left the ground in the spring.

Cost of the Work. In Appendix IV is shown a tabulation of the number of feet of pipe laid. The expenditures to date and the total cost of the works incidental to obtaining an additional supply of water from Nagog Pond, exclusive of

the cost of lands and rights of way, are estimated as follows:

Expenditures to January 31, 1910,	$57,339.76	
January estimate for Spinach contract,	2,708.13	
Sundry bills, February 1,	43.21	
		$60,091.10

Approximate estimated cost of completion:

Amount retained under Spinach contract,	$3,761.80	
Gatehouse,	750.00	
Stone bounds,	125.00	
Engineering,	700.00	
Miscellaneous items,	260.00	
		5,600.00
Total cost, exclusive of lands and rights of way and damages, say approximately,		$66,000.00

It may be of interest to note that, as in the case of the high service work, the contractor has suffered a loss not only of his own time, but in the actual cost to him of the execution of this work.

The delay in the final execution of this work and the additional cost to the Town of the temporary wooden stave pipe line made necessary thereby, are a source of regret, but in spite of this delay the difference between the prices quoted by the lowest bidder and those of the second bidder upon this work, shown in Appendix III, amply justify the acceptance of the lowest bid and the award of the contract to the Henry Spinach Contracting Company, and the writers take pleasure in calling attention to the fact that in spite of vexatious delays and of an apparent loss in the early stages of the work of upwards of $5,000, the contractor showed much determination and grit in pushing the work through, and has built the works in a substantial manner.

The work was executed under the direction of one of the writers' principal engineers, Mr. William T. Barnes, and the immediate supervision of the resident engineer, Mr. P. H. Mosher, assisted by Mr. J. Arthur Lockhart, to whose fidelity and zeal the success of the work is in large measure due.

Respectfully submitted,

METCALF & EDDY.

OK FILE

INSPECTION REPORT - DAMS AND RESERVOIRS

(1.) Location: ~~City~~/Town ACTON DAM NO. 4-9-2-5

Name of Dam NAGOG POND DAM Inspected by A. Z. PIZAN & F. H. PARE

Date of Inspection 8-6-'73

(2.) Owners: per: Ass. ✓ Prev. Inspection

Reg. of Deeds Pers. Contact

1. TOWN OF CONCORD, PUBL. WKS. BLDG, CONCORD MASS. - 01742 369-7526
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.

SUPT. NAT. RES., PUBL. WKS. BLDG, CONCORD, MASS. - 01742 369-7526
Name St. & No. ~~City~~/Town State Tel. No.

(4.) No. of Pictures taken 2

(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: OUTLET CONTROLLED BY 16" SUPPLY PIPE IN PUMP HOUSE

(7.) Current Use of Dam: Condition:

1. Good ✓ 2. Minor Repairs

3. Major Repairs 4. Urgent Repairs

Comments:

DAM NO. 4-9-2-5

(8) Downstream Face of Dam: Condition: 1. Good ✓ 2 Minor Repairs_____
3. Major Repairs____ Urgent Repairs_

Comments:_____

(9) Emergency Spillway: Condition: 1. Good ✓ 2. Minor Repairs_____
3. Major Repairs____ 4. Urgent Repairs___

Comments:_____

(10) Water level @ time of inspection _____ ft. above 0.5' below_____
top of dam_____Principal spillway ✓
other_____

(11) Summary of Deficiencies Noted:

Growth (Trees and Brush) on Embankment ✓

Animal Burrows and Washouts_____

Damage to slopes or top of dam_____

Cracked or Damaged Masonry_____

Evidence of Seepage_____

Evidence of Piping_____

Erosion_____

Leaks_____

[illegible] Debris Impeding Flow [illegible]

[illegible] Blocked Spillway [illegible]

[illegible]

4-9-2-5

(12) Remarks & Recommendations: (Fully Explain)

DAM IS IN GOOD CONDITION.

(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_____

DESCRIPTION OF DAM
DISTRICT #4

Submitted by FRANCIS H. PARÉ & ADAM J. PIZAN Dam No. 4-9-25
Date 8-6-73 City/Town NORTH ACTON 01720
Name of Dam NAGOG POND DAM

1. Location: Topo Sheet No. 25C
Provide 8½" x 11" in clear copy of topo map with location of Dam clearly indicated.

2. Year built: 1925 Year/s of subsequent repairs NONE VISIBLE

3. Purpose of Dam: Water Supply ✓. Recreational ____
Irrigation ____. Other ____

4. Drainage Area: 1 SQ. MI. 640 ACRES.

5. Normal Ponding Area: 300 acres; Ave. Depth 10'
impoundment: 1 BIL. gals; 3,000 acre ft.

6. No. and type of dwellings located adjacent to pond or reservoir ____
i.e. summer homes etc. NONE

7. Dimensions of Dam: Length 85' Max. Height 15'
Slopes: Upstream Face VERT
Downstream Face "
Width across top 5'

8. Classifications of Dam by Materials:
Earth ____. Conc. Masonary ✓. Stone Masonary ____
Timber ____. Rockfill ____. Other ____

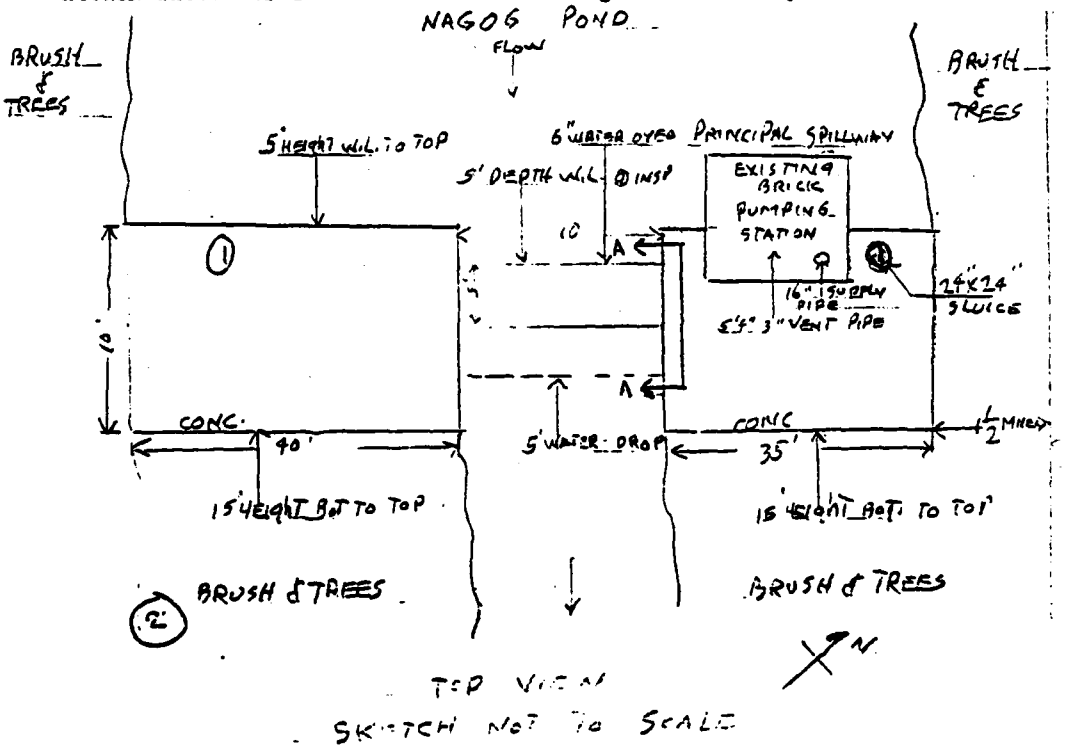
9. A. Description of present land usage downstream of dam: 90 % rural;
10 % urban
B. Is there a storage area or flood plain downstream of dam: which could accommodate the impoundment in the event of a complete dam failure
no ✓. yes ____.

DAM NO. 4-9-2-5

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

No. of people NONE.
No. of homes "
No. of businesses "
No. of industries " Type
No. of utilities NONE Type
Railroads "
Other dams "
Other

11.
Attach sketch of dam to this form showing section and plan 8½"X11" Sheet.

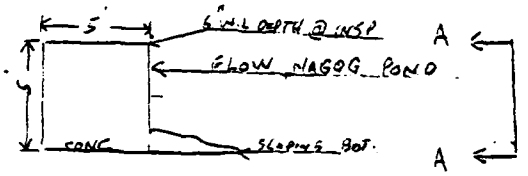


TOP VIEW

SKETCH NOT TO SCALE

3

4-9-2-5

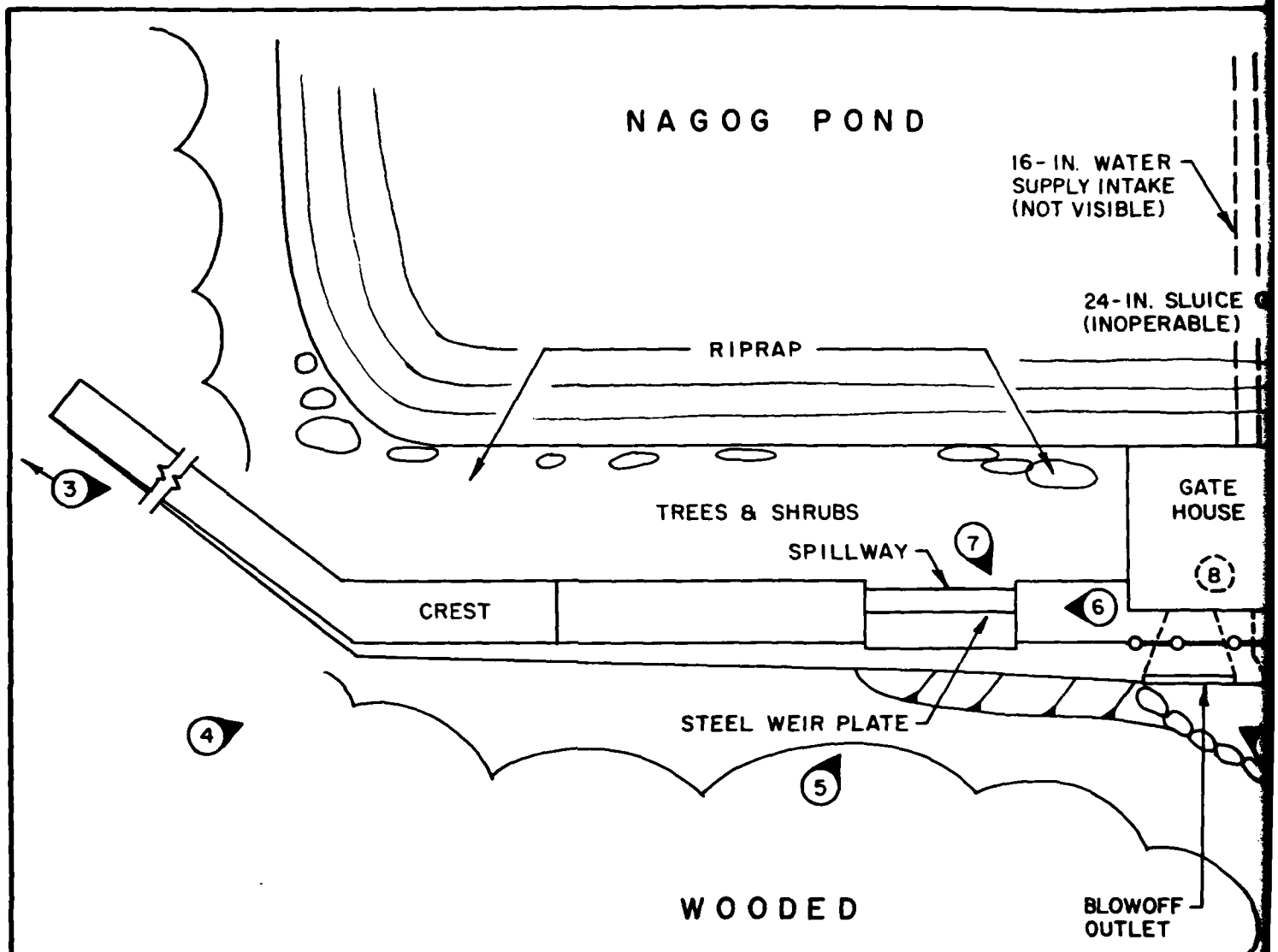


X SECTION AA

SKETCH NOT TO SCALE

APPENDIX C
SELECTED PHOTOGRAPHS OF PROJECT

No.		Roll	Frame	Page No.
1.	Overview of outlet structure and upstream side of dam	20	20A,21A	vii
2.	Crest of dam and left abutment	C19	20	2
3.	Crest of dam and right abutment	C19	24	2
4.	Downstream face of dam	C19	25	3
5.	Spillway with steel weir plate	20	19A	3
6.	Spillway and crest of dam	C19	21	4
7.	Deterioration of surface concrete on upstream face of dam	C19	31	4
8.	Controls inside gate house	C19	33	5
9.	Right wall of discharge channel and blowoff outlet	20	16A	5
10.	Approach channel to reservoir drain	C19	32	6
11.	Left wall at discharge channel and reservoir drain outlet	20	17A	7
12.	Nagog Pond immediately upstream of dam	C19	30	7
13.	Nagog Brook channel downstream of dam	C19	27	7



NOTE:

PLAN DEVELOPED FROM 1909 CONTRACT DRAWING BY METCALF & EDDY, INC. (APPENDIX B) AND VISUAL EXAMINATION ON 3 OCTOBER 1978

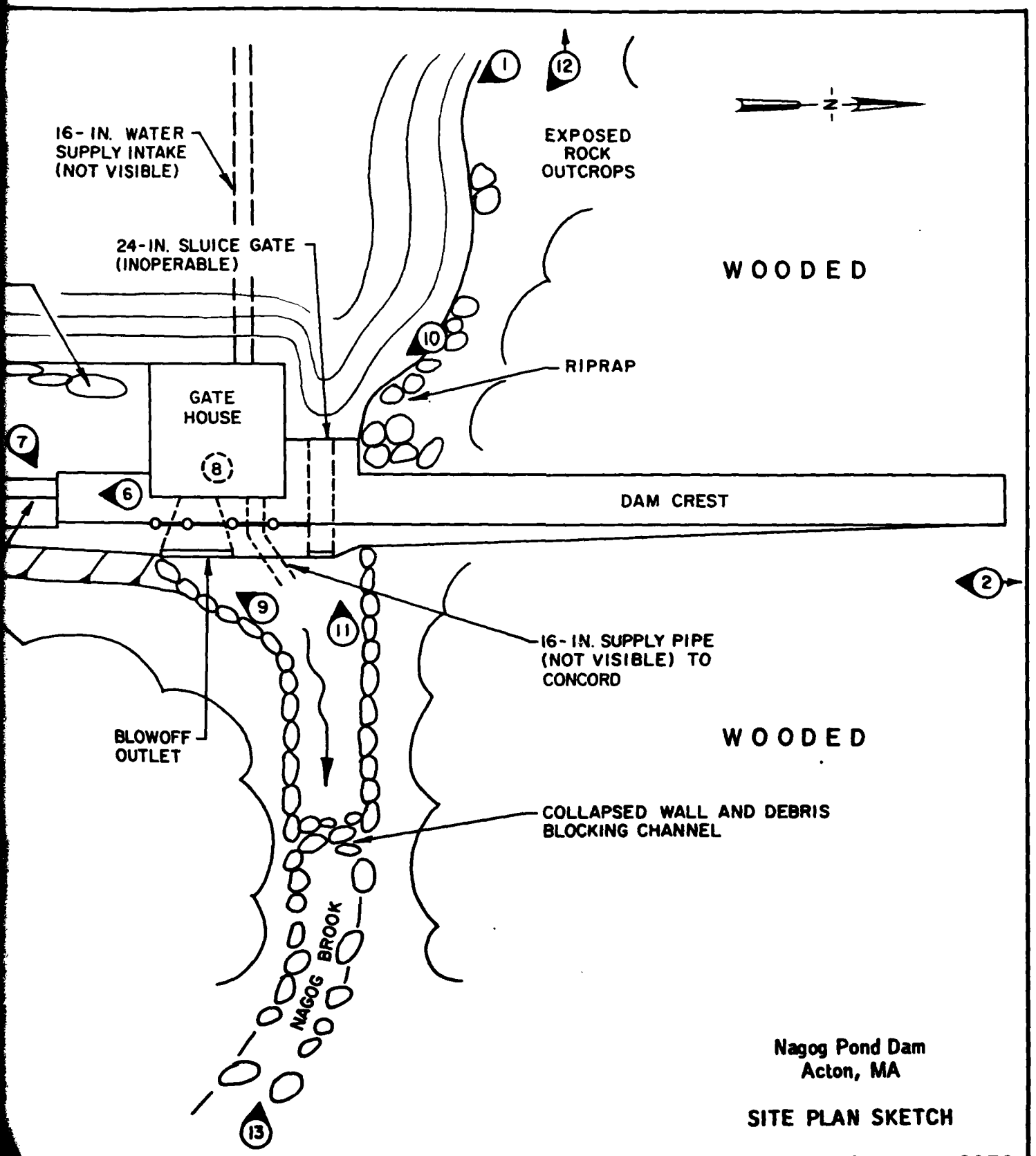
LEGEND:

(5) PHOTO NO. AND DIRECTION OF VIEW

FILE NO. 4160 853

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

(1)

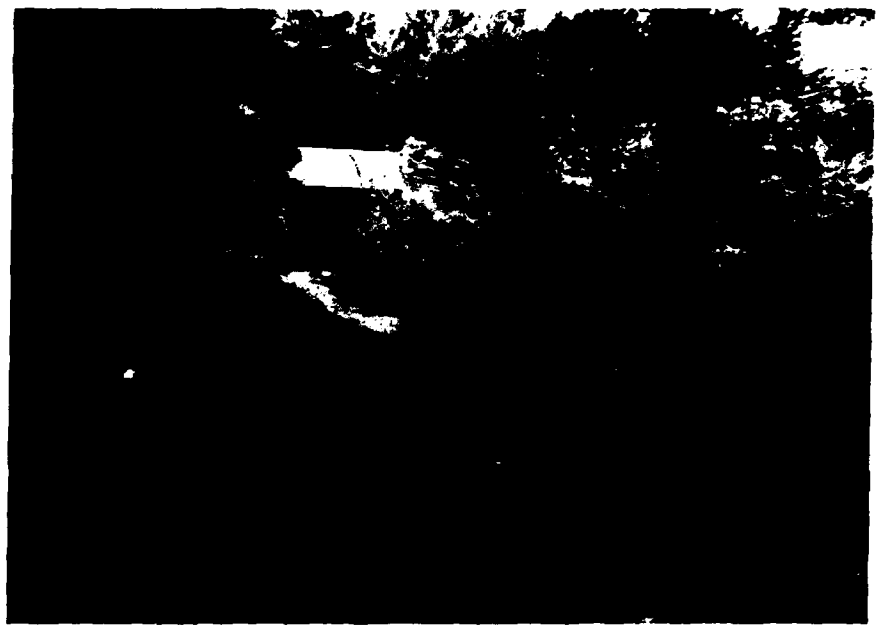


Nagog Pond Dam
Acton, MA

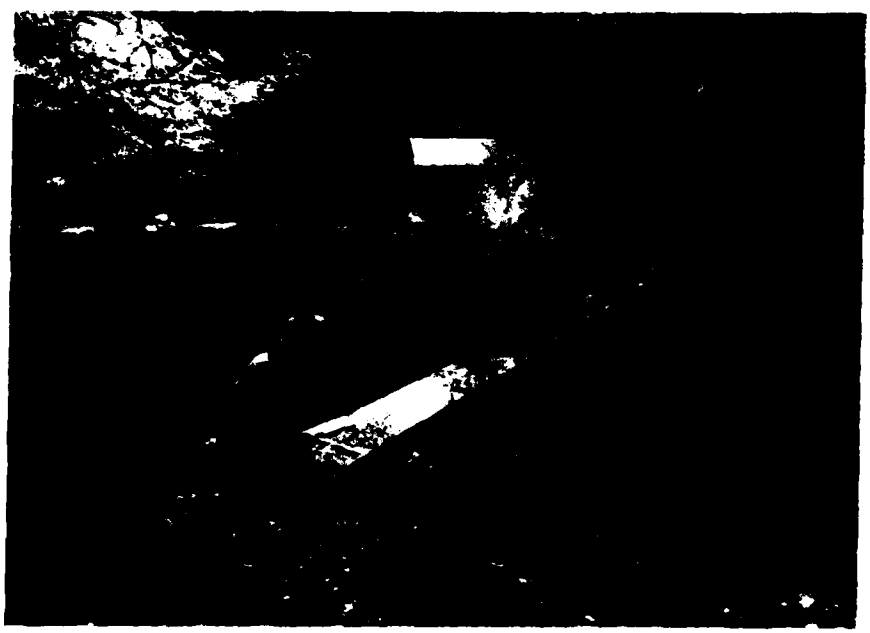
SITE PLAN SKETCH

Scale: 1"=10' Nov. 1978

(2)



2. Crest of dam and left abutment



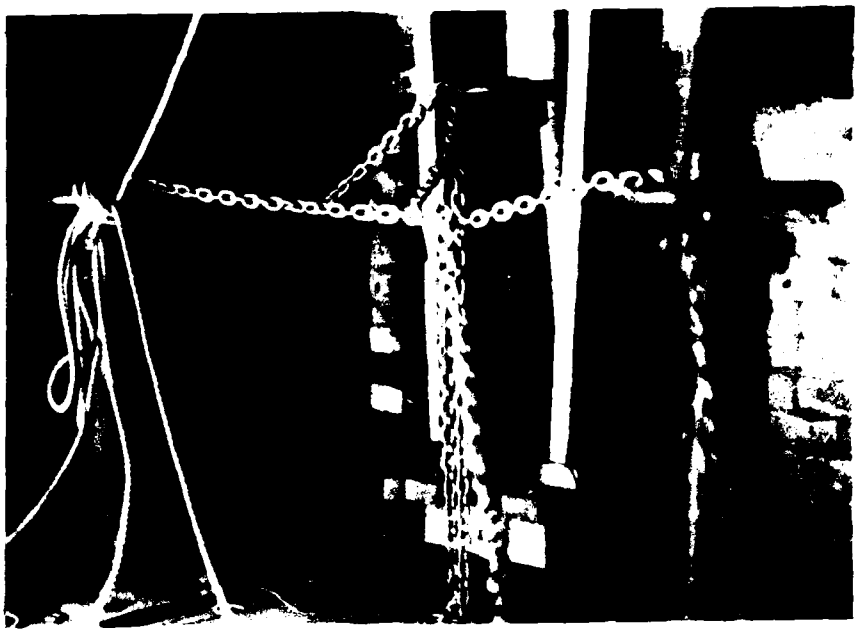
3. Crest of dam and right abutment

4. Downstream face of dam

5. Spillway with steel weir plate

6. Spillway and crest of dam

7. Deterioration of surface concrete on upstream face of dam



8. Controls inside gate house

9. Right wall of discharge channel and blowoff outlet

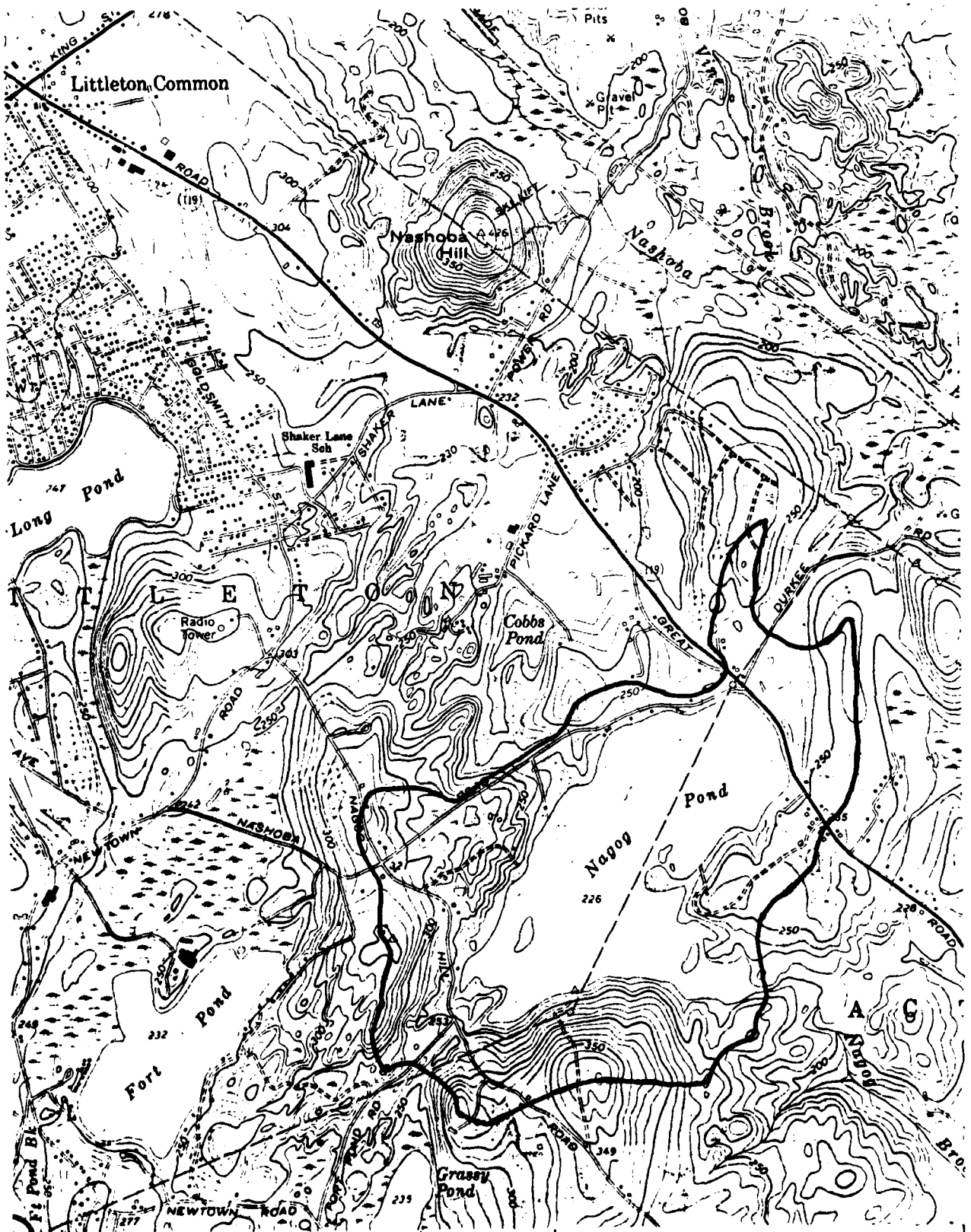
10. Approach channel to reservoir drain

11. Left wall at discharge channel and reservoir drain outlet

12. Nagog Pond immediately upstream of dam

13. Nagog Brook channel downstream of dam

APPENDIX D
OUTLINE OF DRAINAGE AREA AND HYDRAULIC COMPUTATIONS



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Consulting Engineers
Boston, Mass.

N

Nagog Pond Drainage Area
Scale: 1:24,000

CAMP DRESSER & McKEE	CLIENT Haley and Aldrich	JOB NO. [illegible]	PAGE 2 of 22
Environmental Engineers	PROJECT National [illegible]	DATE CHECKED 10-24-78	DATE 10-[illegible]-78
Boston, Mass.	DETAIL [illegible] Dam	CHECKED BY [illegible]	COMPUTED BY [illegible]

Size Classification

Height Dam ≈ 15' 4" (scaled off drawing "Lagog Pond Supply, Construction of Dam at Outlet of Lagog Pond")

Note: height measured at [illegible] (maximum height)

Storage:

Elevations

Top of Dam: 227.66' (msl)

Spillway Crest: 226.16' (msl)

Pond Water Surface Area

Top of Dam: 352 A

Spillway Crest: 231 A

* Assume normal depth = 10' (taken from [illegible] Inspection report dated Aug. 6, 1973)

∴ Storage (at elev. 227.66') = $\frac{879{,}100{,}000 \text{ gal}}{7.48 \times 43560}$ + ([illegible])

≅ 3140 Acre-Ft

Height: 15.33' < 40'

Storage: 3140 Acre-ft > 1000 Acre-ft

So Size Classification = <u>INTERMEDIATE</u>

Hazard Classification

Currently classified as "high" [illegible] by the COE, New England Division.

From field inspection, it leads to an initial assumption of "low" hazard potential.

Test Flood

Size: Intermediate ∴ Test Flood: ½ PMF to 100 yr.

Hazard: Low [illegible]

Drawings - [illegible]

"Lagog Pond Supply, Construction of Dam at Outlet of Lagog Pond", [illegible]

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Environmental Engineers
Boston, Mass.

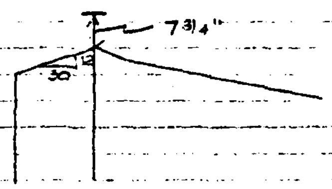
CLIENT [illegible]
PROJECT [illegible]
DETAIL [illegible] Pond

JOB NO. [illegible]
DATE CHECKED [illegible]
CHECKED BY [illegible]

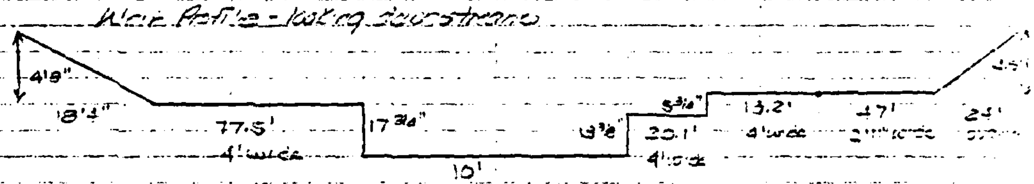
DATE [illegible]
COMPUTED BY [illegible]

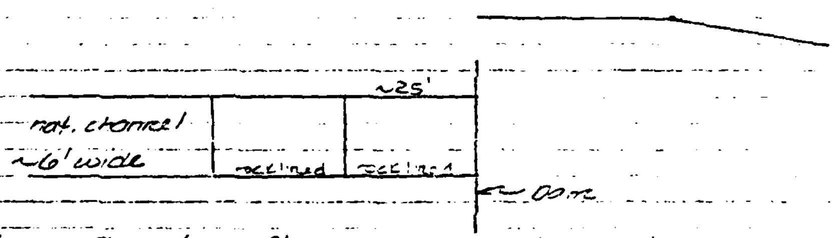
Field Inspection Notes

Weir Cross section



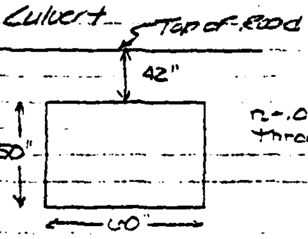
Weir Profile - looking downstream





Downstream Channel - ~3' in width, meandering stream extends from gate house ± 5' in depth, vertical side slopes

Route 27 Culvert



Concrete box culvert

n = .015
through culvert

Length = 40.5'

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DATE
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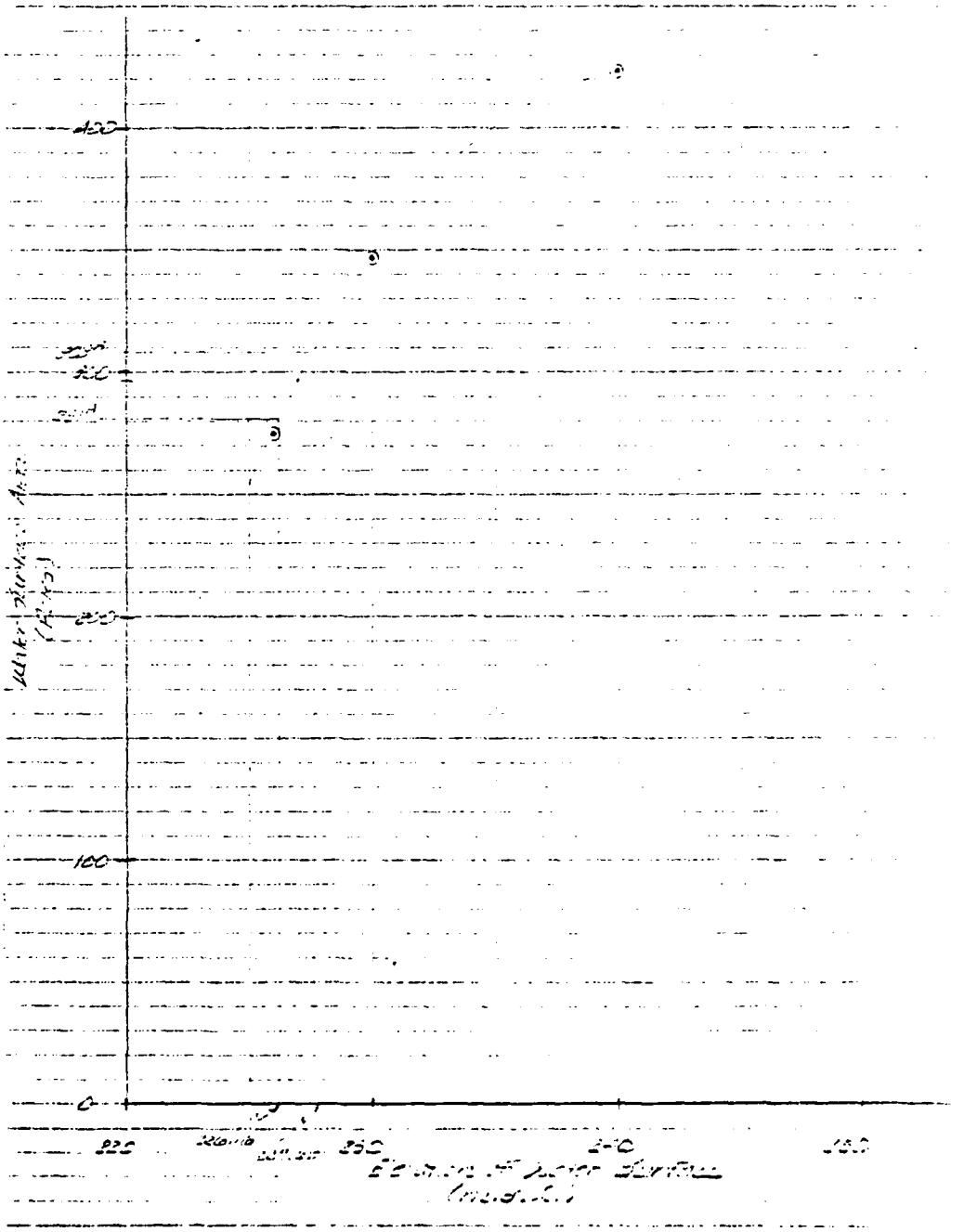

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Environmental Engineers
Boston Mass

CLIENT [illegible] JOB NO [illegible] PAGE 5 of 22
PROJECT [illegible] DATE CHECKED 10-26-78 DATE [illegible]
DETAIL [illegible] CHECKED BY [illegible] COMPUTED BY [illegible]

Computation of Test Flood

Method: SCS – TR 149

A. Drainage Area = [illegible] acres

Hydrologic soil group [illegible]

Land Use	Area	CN	Area x CN
Forest, good cover	491	55	27005
Paved Streets	12	98	1164
Pasture [illegible]	281	100	28100
Residential	12	68	680
	796		Σ [illegible]

Weighted CN = 71.7

say CN = 72

B. Slope – length of watershed = 2030'

15%	435'	265 (m.s.l.)
25%	2465	335 (m.s.l.)

$$Slope = \frac{70}{2030} = .03448 \quad (3.448\,\%)$$

C. $$L = \frac{\ell^{0.8}(S+1)^{0.7}}{1900\,Y^{0.5}}$$

$$S = \frac{1000}{CN} - 10 = \frac{1000}{72} - 10 = 3.888$$

$$L = \frac{2030^{0.8}(3.888+1)^{0.7}}{1900\,(3.448)^{0.5}} = .507 \text{ hrs} \quad \text{say } ½ \text{ hr.}$$

$T_c = L/0.6$ ∴ $T_c = .84$ hours (50 min)

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CLIENT [illegible]
PROJECT [illegible]
DETAIL [illegible]

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DATE CHECKED 10-24-79
CHECKED BY [illegible]

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COMPUTED BY [illegible]

D. Rainfall

50-year 2 hour rainfall [illegible] inches

100-year 2 hour rainfall = 3.4 inches

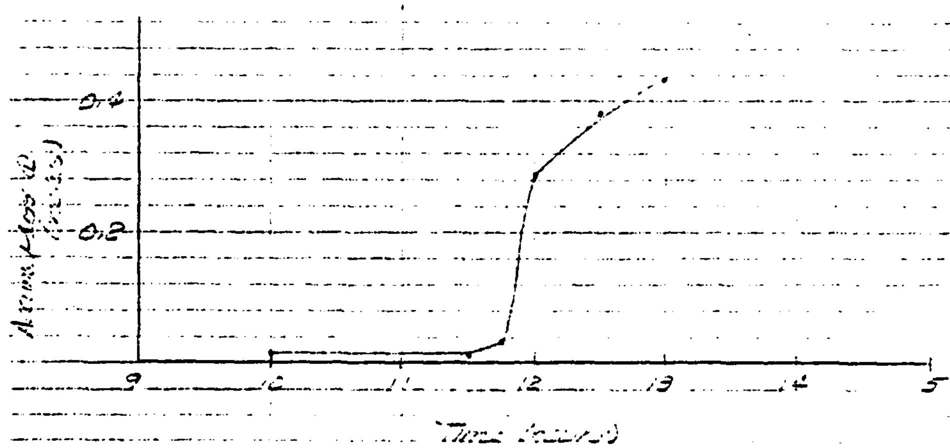
[illegible]

[illegible] = 0.4 x [illegible] = [illegible] hours
[illegible] = 1.4 hours

50-Year Storm

Time (hours)	[illegible]	Mass P (inches)	Mass Q (inches)
10.0	.181	.543	[illegible]
10.5	.204	.612	.002
11.0	.235	.705	.0014
11.5	.283	.849	.0018
11.75	.387	1.161	.032
12.0	[illegible]	1.327	.3[illegible]
12.5	.735	2.205	.323
13.0	.772	2.316	.436

[illegible] = 12.92 hours



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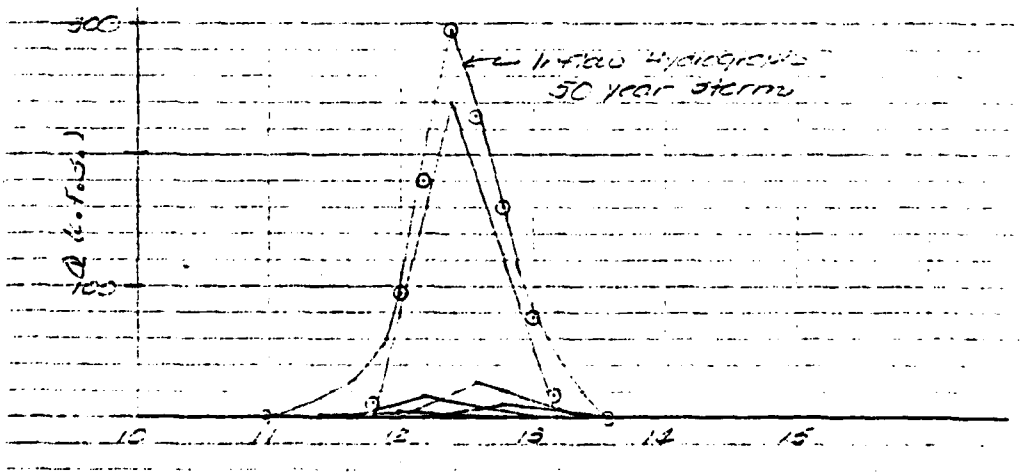
CLIENT _____ JOB NO. _____ PAGE 7 OF 22
PROJECT _____ DATE CHECKED _____ DATE _____
DETAIL _____ CHECKED BY _____ COMPUTED BY _____

Increment	Time (hours)	Flow Rate (cfs)	ΔQ (cfs)	Δq (cfs)	t	$V_{\Delta Q}$ (cf)
	10.98	.015				
ΔQ_1			0	0	0.2	0
ΔQ_2	11.2	.015	0	0	0.2	0
ΔQ_3	11.38	.015	.005	5	0.2	3
ΔQ_4	11.58	.020	.02	20	0.2	12
ΔQ_5	11.78	.035	.12	220	1.0	240
ΔQ_6	12.15	.122	.04	40	0.27	27
ΔQ_7	12.42	.222	.03	30	.333	12
	12.38	.350				Σ 294.15

$\Delta Q_p = \frac{294 \times 1.221}{\frac{0.20}{2} + .50} \Delta Q = 1031 \Delta Q$



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CLIENT [illegible]
PROJECT [illegible]
DETAIL [illegible]

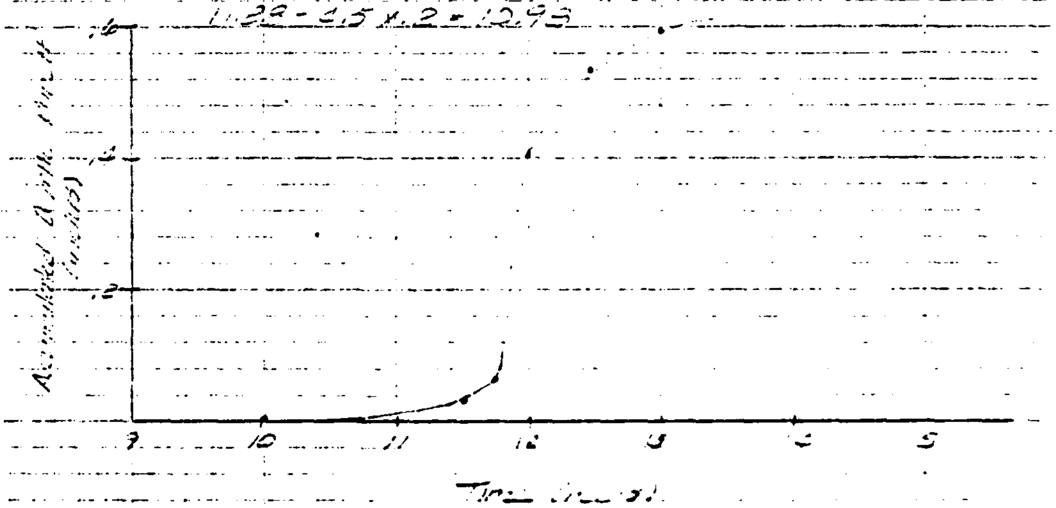
JOB NO. [illegible]
DATE CHECKED [illegible]
CHECKED BY [illegible]

PAGE 2 of 22
DATE [illegible]
COMPUTED BY [illegible]

100 - Year Storm

Time (hours)	Ex/P24	Mass P (inches)	Mass Q (inches)
10.0	.0191	.215	.007
10.5	.208	.271	.012
11.0	.235	.300	.022
11.5	.283	.332	.035
11.75	.327	1.310	.065
12.0	.663	2.254	.206
12.5	.735	3.5	.530
13.0	.772	3.825	.595

1.22 - 4.5 x .2 = 12.93



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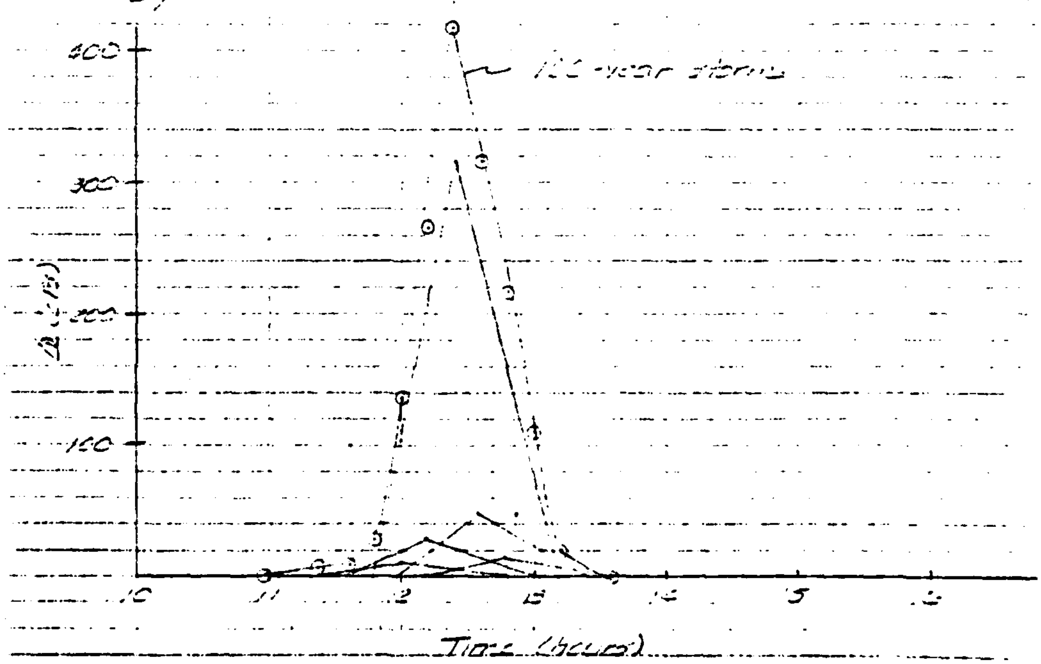
CLIENT [illegible] JOB NO. [illegible] PAGE 9 of 22
PROJECT [illegible] DATE CHECKED 10/28/80 DATE [illegible]
DETAIL [illegible] CHECKED BY [illegible] COMPUTED BY [illegible]

Increment	Time (hrs)	Accum. Runoff (in)	ΔQ (in)	Δq (cfs)	Y	YΔq (cfs)
	10.95	.01				
ΔQ_1			.01	10	0.2	2
	11.3	.02				
ΔQ_2			.005	5	0.4	2
	[illegible]	.025				
ΔQ_3			.015	15	0.6	9
	11.55	.040				
ΔQ_4			.035	35	0.8	28
	11.75	.075				
ΔQ_5			.315	315	1.0	315
	11.95	.390				
ΔQ_6			.030	30	.897	27
	12.15	.420				
ΔQ_7			.045	45	.333	15
	12.35	.465				

Σ 415 cfs.

$\Delta q = 1000\,\Delta Q$



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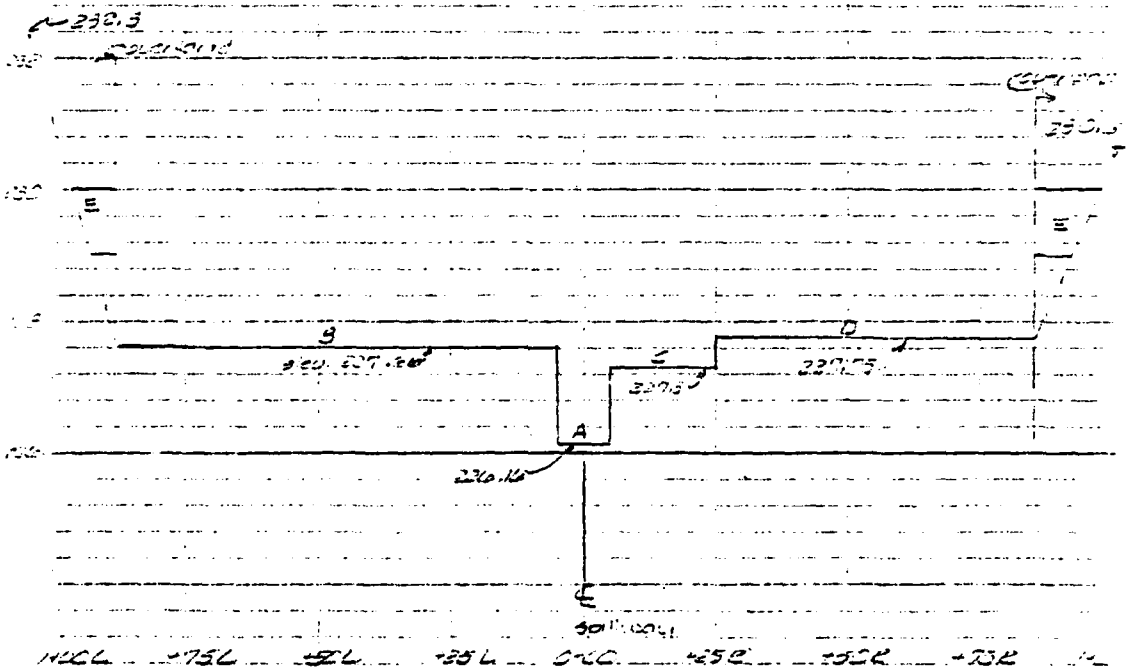
Boston, Mass.

CLIENT _____ JOB NO. _____ PAGE 10 of 22
PROJECT _____ DATE CHECKED _____ DATE _____
DETAIL _____ CHECKED BY _____ COMPUTED BY _____

Outlet Rating Curve

Weir, Dam Profile



Spillway Coefficients

E 1) Overland : 2.5

A 2) Spillway section (sharp-crested weir) : Coeff. taken from Measurement of Peak Discharge at Dams by Indirect Methods", Tw.R.I. of USGS. Page C-0

3) Spillway section (broad-crested weir) : Coeff. taken from King and Brater "Handbook of Hydraulics"

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Environmental Engineers
Boston, Mass.

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PROJECT [illegible]
DETAIL [illegible]

JOB NO. [illegible]
DATE CHECKED 10-25-78
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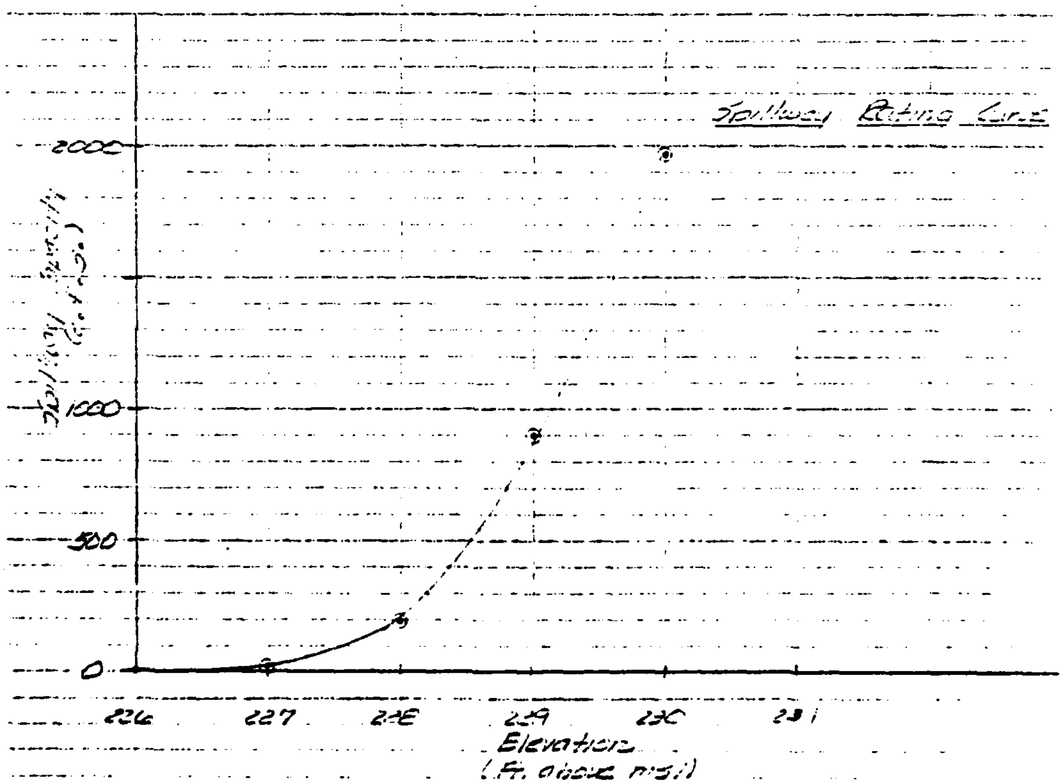
COMPUTED BY [illegible]

Water Surface Elev.	Q_A	Q_B	Q_C	Q_D	Q_E	Q_{Total}
226.16	0 →					0
227	29	0	0	0	0	29
228	120	50	32	15	0	[illegible]
229	204	340	118	223	17	902
230	320	784	243	558	65	1970



CAMP DRESSER & McKEE Environmental Engineers Boston, Mass.	CLIENT: [illegible] Aldrich PROJECT: [illegible] DETAIL: [illegible]	JOB NO. [illegible] DATE CHECKED: 10-25-[illegible] CHECKED BY: [illegible]	PAGE 12 of 22 DATE [illegible] COMPUTED BY [illegible]

Routing - 100 Year Storm [illegible]

Head on Spillway (Ft.)	Elev. W.S. (ft. msl)	Reservoir Area (acres)	Calc. Outflow (c.f.s.)	Storage S (acre-ft)	$\frac{S}{\Delta t}$ cfs	$\frac{S}{\Delta t} - \frac{O}{2}$ cfs	$\frac{S}{\Delta t} + \frac{O}{2}$ cfs
0	226.16	281	0	0	0	0	0
.84	227.0	296	28	242	17570	17556	17584
1.84	228.0	315	197	543	39785	39686	39883
2.84	229.0	332	962	872	63307	[illegible]	[illegible]
3.84	230.0	347	1970	1211	87920	86935	88905

Δt = 10 min = 600 s

Time Number	Obs. Inflow (c.f.s)	Average Inflow (c.f.s)	$\frac{S}{\Delta t} - \frac{O}{2}$	$\frac{S}{\Delta t} + \frac{O}{2}$	Head on Spillway (ft)	Elev. W.S. (ft. msl) (rounded to hundredths)	Outflow O (cfs)
0	0						0
1	5	3					3
2	7	6					6
3	11	9					9
4	18	15			.64	226.80	15
5	48	33	13.376	13.409	.641	226.80	15.5
6	138	93	13.338	13.431	.644	226.80	16.3
7	280	209	13.469	13.678	.653	226.81	19.3
8	400	340	13.656	13.996	.669	226.83	20
9	365	383	13.982	14.365	.686	226.85	20.7
10	285	325	14342	14,667	.701	226.86	21.5
11	200	243	14642	14,857	.711	226.87	21.9
12	110	155	14863	15018	.717	226.88	22.3
13	25	68	14994	15062	.720	226.88	22.4
14	12	19	15038	15057	.719	226.88	22.5
15	2	7	15033	15000	.718	226.88	22.5
16	0	1	15016	15017	.717	226.88	22.3
17	0	0	14993	14.993	.716	226.88	22.2
18	0	0	14969	14969	.715	226.88	22.1
19	0	0	14945	14945	.714	226.87	22.1
20	0	0	14921	14921	.713	226.87	22.0

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CLIENT Valley Gas Pipeline
PROJECT Natural Gas Exp
DETAIL Hagg Pond

JOB NO. 541-9-ET
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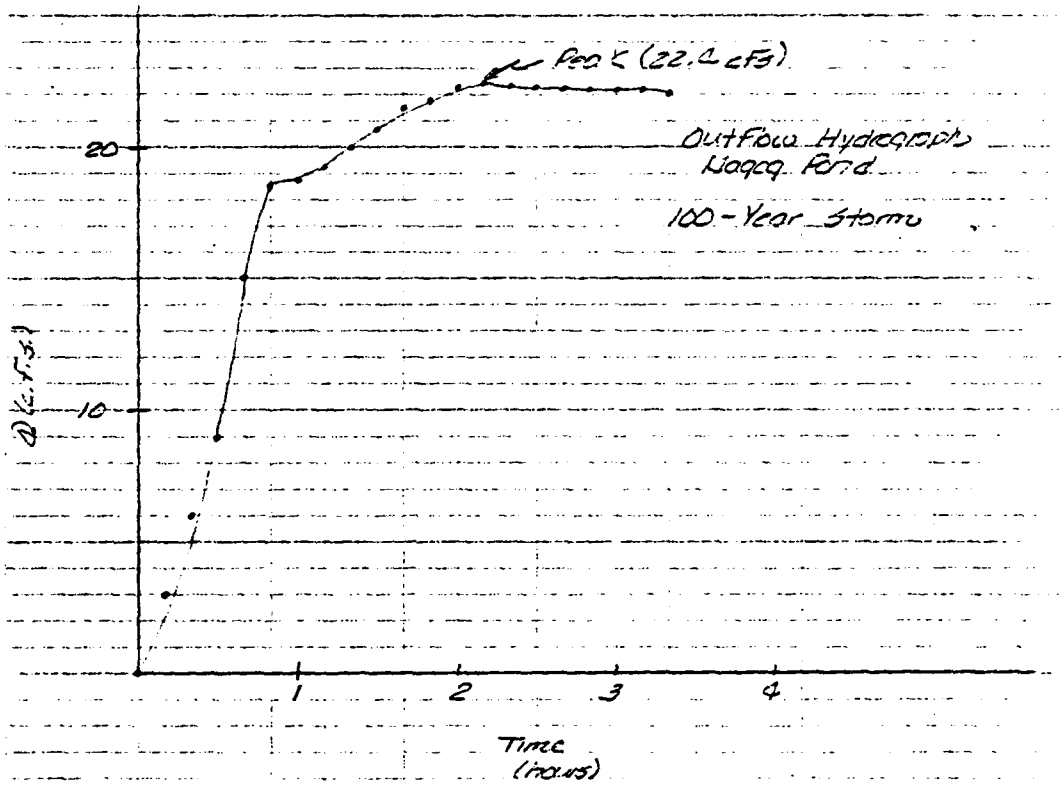

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Dam Failure Analysis

Assume section that will be breached is from the spillway to, but not including, the Gatehouse. (Since the dam is concrete the 40% breach length established by the COE was found to be inappropriate in this case).

Length = 13'
Height ≈ 6' (227'-221')

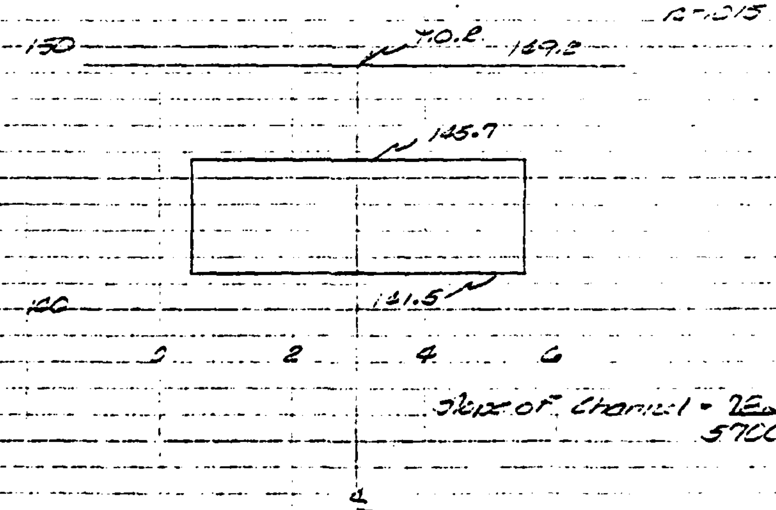
S = 1400 Acre-ft

$Q_{p1} = \frac{8}{27} \times 13' \times \sqrt{32.2} \; g \times (6')^{3/2}$ — average elev. of rock and boulders in pond bottom adjacent to dam

Q_{p1} = 445 cfs.

First Control — Route 27 Culvert : App. invert Elev. 141.5 (msl.)

Concrete Box Culvert



Slope of Channel = $\frac{2.5}{5700}$ = .0134 (?)

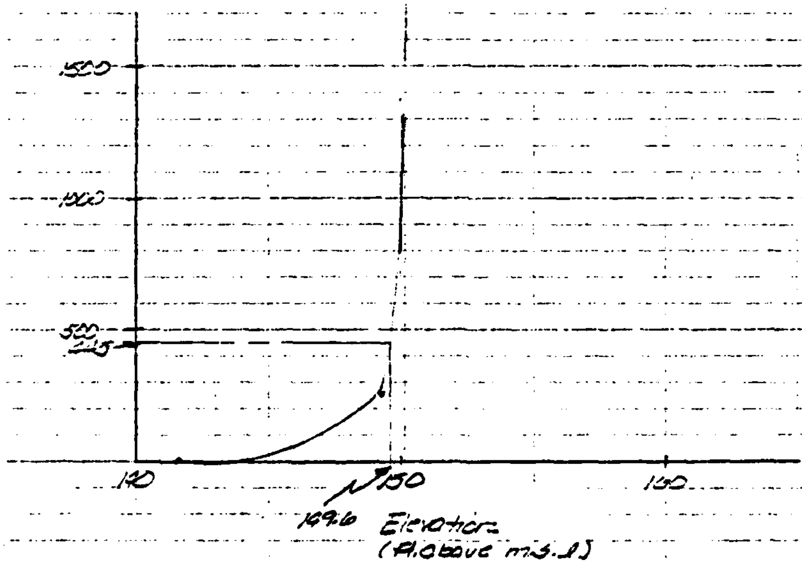
Assume Flow, u.s. water at elev. 149.2
Assume no ponding d.s.

$Q = CA\sqrt{2gh} = 0.86 \times 21 \sqrt{64.4 \times 3.5} = 252$ cfs

Weir Flow over Route 27

At, elev. 150 : L ≈ 480 ft.
say C = 3.3

Q = 252 cfs + 3.3 x 480 ((0.3))$^{3/2}$ ≈ 1385 cfs.



Therefore, say elev. = 149.6

V_1 = [8.1 x 5 + 0.4 x 480] 5700' = 1,325,250 ft^3

V_1 = 30.4 Acre - ft.

$Q_{p2_{TRIAL}}$ = 445 $\left(1 - \frac{30.4}{1420}\right)$ = 435 cfs

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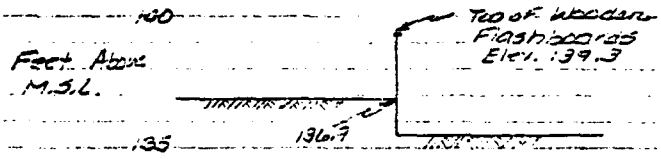
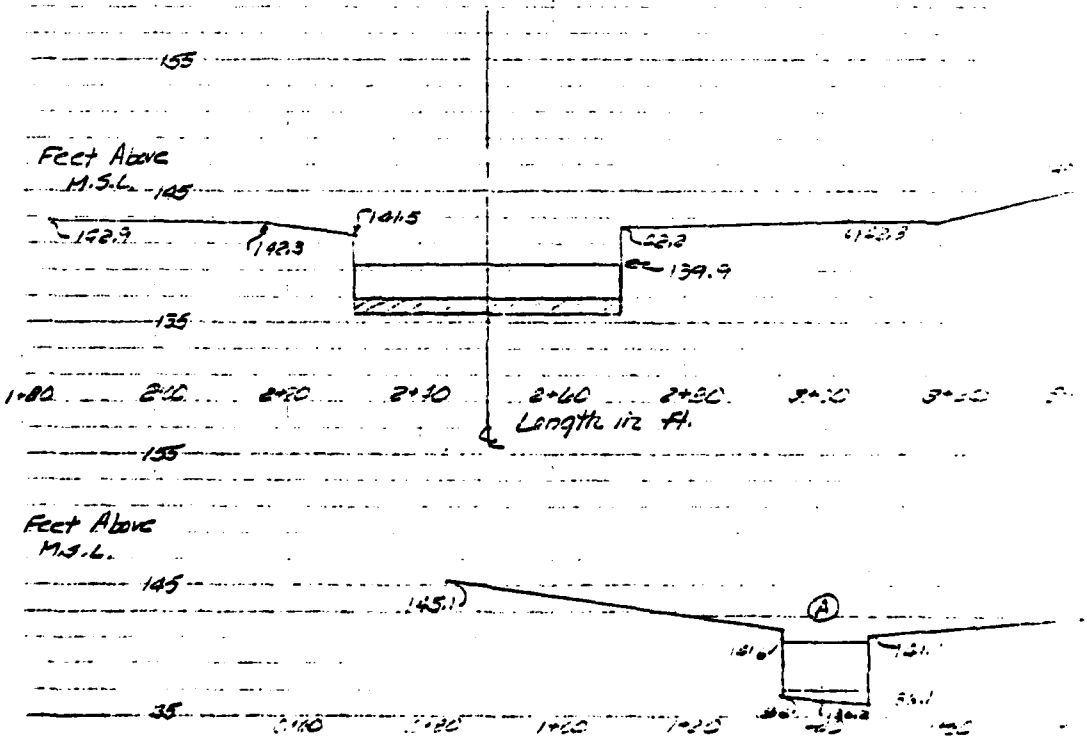
Brook Street Dam

Cross Section of Weir



L.T.S

Profile of Dam
(Looking downstream)



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Spillway Rating Curve for Brook Street Dam

Sharp Crested Weir: L = 40'

Elevation (ft. msl)	Head	"C" Value	Q weir
139.9	0		0
140.0	0.1	3.27	4
141.0	1.1	3.37	154
142.0	2.1	3.46	421
142.2	2.3	3.47	484

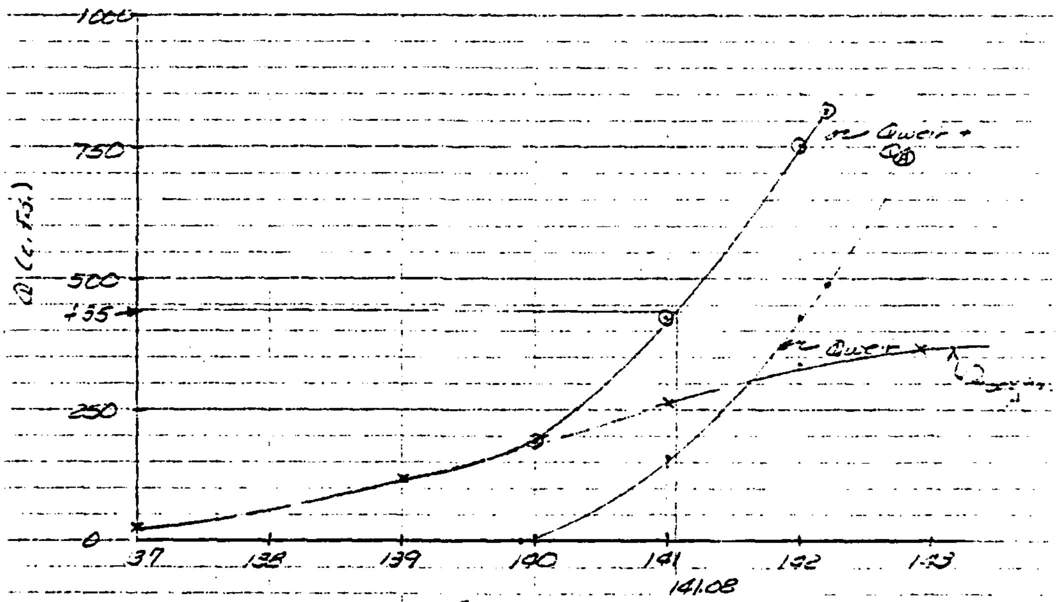
Note: "C" Values Taken from TWRI-USGS: Measurement of Peak Discharge at Dams by Indirect Methods
P = 3.8

Flows for Additional Section (A)

Elev. W.S. (ft. msl)	Head (ft) max.	Area (ft^2)	WP (ft)	R (ft)	S	Q (cfs)
137	0.9	8.45	14.3	.591	.00275	13
139	2.9	34.45	18.3	1.233	↓	117
141	4.9	60.45	22.3	2.711		232
142.9	6.8	99	47	2.106		342

n = .035

Rating Curve for Spillway System



Q_{P1} = 435 cfs

V_1 = Area of Cross Section x Length of Back

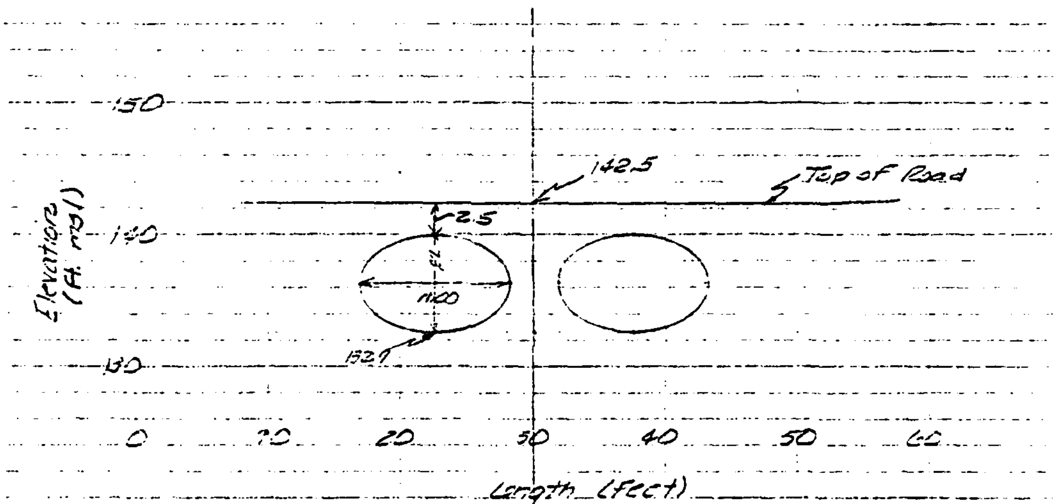
Area = 47.2 ft² + 61.5 ft² = 108.7 ft²
(A_{weir}, $A_{section}$)

$V_1 = \frac{109 \text{ sq.ft} \times 3160 \text{ ft}}{43560 \text{ ft}^2/\text{Acre}} = 7.8$ Acre-ft

$Q_{P2\,TRIAL} = 435 \left(1 - \frac{7.8}{1420}\right) = 433$ cfs

Assume Q_{P2} = 433 cfs (since 435 and 433 are so close)

Brook Street Culvert



Area ellipse = πab

Total Area = $\pi \times 5.5 \times 3.65 = 63$ ft²/each ellipse = 126 ft² total

P = circumference ≅ $2\pi\sqrt{\frac{a^2+b^2}{2}} \approx 2\left(2\pi\sqrt{\frac{[illegible]}{2}}\right) \approx 59'$ for 2 ellipses

Length from Route 27 to Brook St. = 3200 ft.

Slope = $\frac{141.5 - 132.7}{3200} = .00275$

$n = .025$

$Q_{full} = \left(\frac{1.486}{.025}\left(\frac{63}{29.5}\right)^{2/3}(.00275)^{1/2}\,63\right)2 \approx 651$ cfs

$C = 0.74$

At water elev. at 142.5, $Q = 0.74 \times 126\sqrt{64.4 \times 2.5}$

$Q = 1183$ cfs

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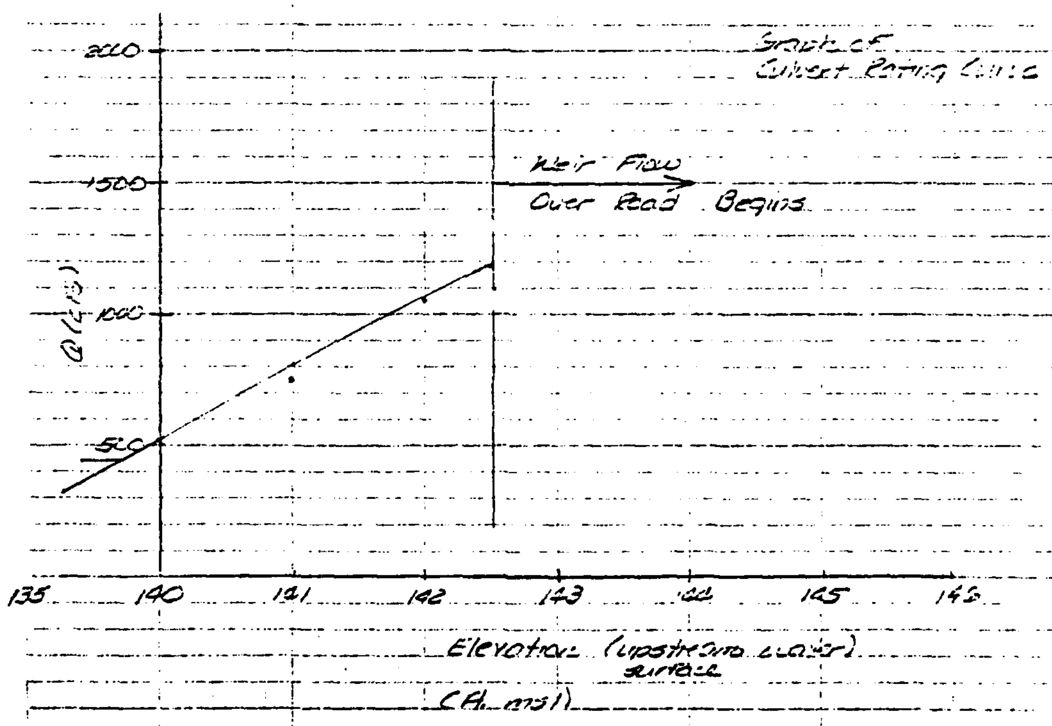
At H = 1, Q = 0.74 x 126 x $\sqrt{64.4}$ = 748 cfs

At H = 2, Q = 0.74 x 126 x $\sqrt{128.8}$ = 1058 cfs

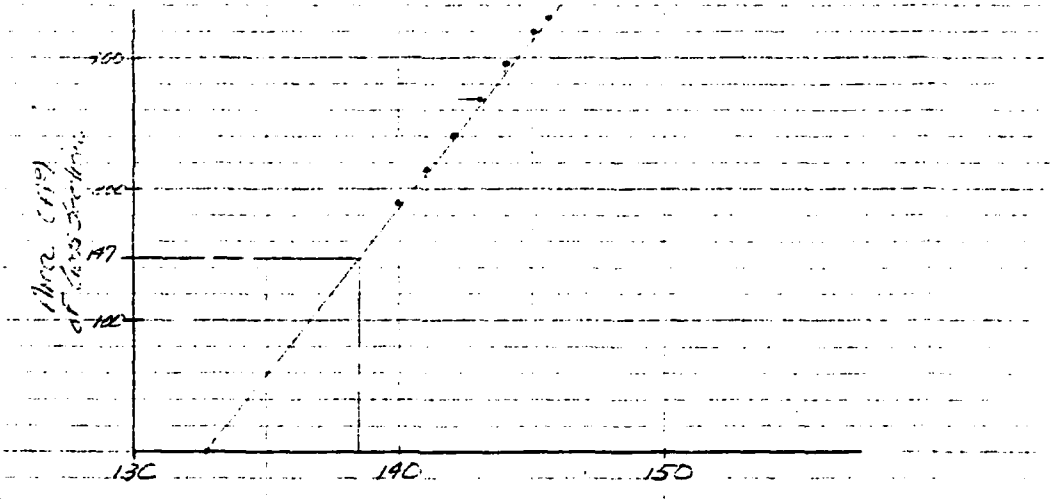
At H = 2.5, Q = 0.74 x 126 x $\sqrt{161}$ = 1183 cfs



At Q = 433 c.f.s., Elev. water surface = 138.5 ft

Area of Cross Section = Located Upstream of Brook Street Culvert

Elevation	Area (ft²)
132.7	0
140.0	190
141.0	210
142.0	242
143.0	263
144.0	294
145.0	320
145.2	330



$Q_{P1} = 432$ cfs

V_1 = Area of Cross Section x Length of Reach

$$V_1 = \frac{147\ ft^2 \times 100\ ft}{93{,}560\ \frac{ft^2}{Acre}} = .30\ Acre\text{-}ft.$$

$$Q_{P2\ TOTAL} = 432\left(1 - \frac{0.30}{1.20}\right) = 432\ cfs$$

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At Q = 432 cfs, water surface Elevation = 133.5 ft.

From the USGS Maynard Quadrangle, it appears that the flow will be contained within the confines of the flood plain that exists downstream of Brook St across the N.Y. N.H. & H. Railroad Tracks.

APPENDIX E
INFORMATION AS CONTAINED IN THE NATIONAL INVENTORY OF DAMS

INVENTORY OF DAMS IN THE UNITED STATES

(1) STATE	(2) IDENTITY NUMBER	(3) DIVISION	(4) STATE	(5) COUNTY	(6) CONGR DIST.	(8) NAME	(10) LATITUDE (NORTH)	(11) LONGITUDE (WEST)	(13) REPORT DATE DAY | MO | YR
MA	12[illegible]	NEW [illegible]				NAGOG POND DAM	4230.6	7126.0	15NOV78

(12) POPULAR NAME	(14) NAME OF IMPOUNDMENT
	NAGOG POND

(15) RIVER OR STREAM	(16) NEAREST DOWNSTREAM CITY–TOWN–VILLAGE	(18) DIST FROM DAM (MI.)	(19) POPULATION
NAGOG BROOK	CONCORD	4	17270

(20) TYPE OF DAM	(21) YEAR COMPLETED	(22) PURPOSES	(23) STRUCTURAL HEIGHT (FT.)	(24) HYDRAULIC HEIGHT (FT.)	(25) IMPOUNDING CAPACITIES MAXIMUM (ACRE-FT.)	(27) IMPOUNDING CAPACITIES NORMAL (ACRE-FT.)
[illegible]	1[illegible]9	S	17	15	3140	2498

DIST	OWN	FED R	PRV/FED	SCS A	VER/DATE
NED	N	N	N	N	13DEC78

(28) REMARKS

(29) SPILLWAY [illegible]	(30) MAXIMUM DISCHARGE (FT.)	(31) VOLUME OF DAM (CY)	(32) POWER CAPACITY INSTALLED (MW)	(33) POWER CAPACITY PROPOSED (MW)	(34) NAVIGATION LOCKS NO	(35) LENGTH (FT.)	(36) WIDTH (FT.)	(37) LENGTH (FT.)	(38) WIDTH (FT.)	(39) LENGTH (FT.)	(40) WIDTH (FT.)	(41) LENGTH (FT.)	(42) WIDTH (FT.)
[illegible]	60	310											

(41) OWNER	(43) ENGINEERING BY	(44) CONSTRUCTION BY
TOWN OF CONCORD	METCALF + EDDY, INC.	HENRY SPINACH CO.

(45) REGULATORY AGENCY [illegible]	CONSTRUCTION	OPERATION	MAINTENANCE
[illegible]	NONE	NONE	MA DPW

(47) INSPECTION BY	(48) INSPECTION DATE DAY | MO | YR	(49) AUTHORITY FOR INSPECTION
[illegible] + ALDRICH, INC.	030CT78	PUBLIC LAW 92-367

(50) REMARKS


DATE
ILME