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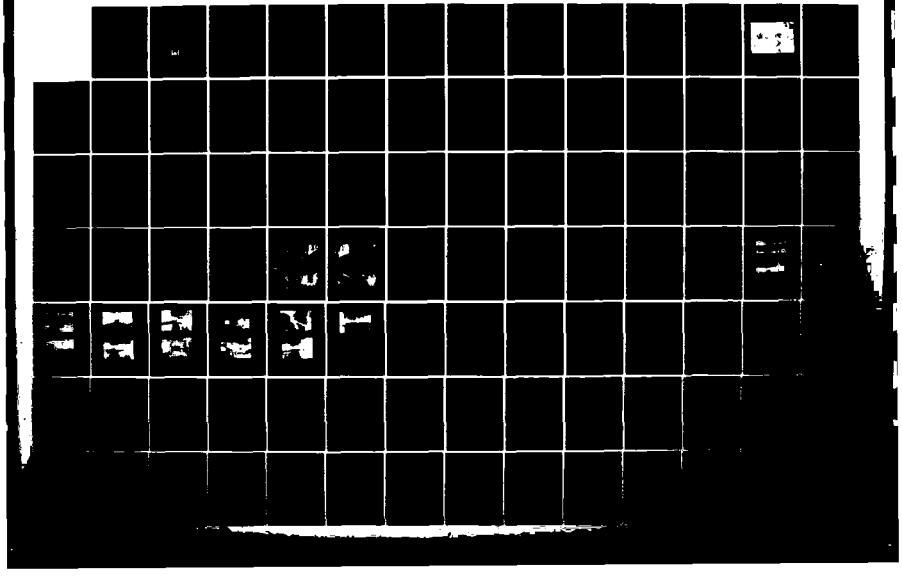

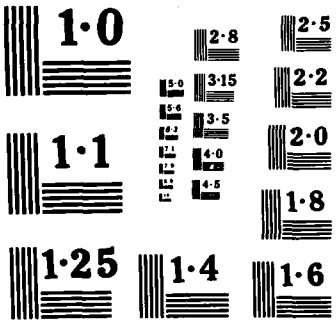

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AD-A156 405

MERRIMACK RIVER BASIN

NASHUA, NEW HAMPSHIRE

BOWERS DAM

NH 00330

NHWRB NO. 165.04

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

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

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Nashua, New Hampshire
Pennichuck River

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

THe dam is an earthen embankment about 420 ft. long with a maximum height of about 25 ft. The dam impounds water from the Brook and the spillway discharges to Harris Pond immediately below the dam. The dam is considered to be in fair condition. It is intermediate in size with a significant hazard potential.

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BOWERS DAM
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MERRIMACK RIVER BASIN
NASHUA, NEW HAMPSHIRE

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

NATIONAL DAM INSPECTION PROGRAM
PHASE I - INSPECTION REPORT
BRIEF ASSESSMENT

Identification No: NH 00330

Name of Dam: Bowers Dam

Town: Nashua

County and State: Hillsborough, New Hampshire

Stream: Pennichuck Brook

Date of Inspection: March 25, 1980

Bowers Dam is an earthen embankment dam about 420 feet long with a maximum height of approximately 25 feet. Located near the right abutment is the principal spillway which consists of a 56 feet long wood spillway structure approximately 25 feet high from the bottom of the downstream channel to the top of the stoplog bays and constructed between mortared cut stone training walls. Located about 80 feet to the left of the spillway structure is a 5.0 feet diameter riveted steel plate penstock which extends about 58 feet through the left embankment and discharges at the downstream toe.

The dam impounds water from Pennichuck Brook and the spillway discharges to Harris Pond immediately below the dam. The purpose of the dam is to create Bowers Pond as a water supply for the Pennichuck Water Works and to regulate the level of Harris Pond immediately downstream. The pond is about 1.67 miles in length with a surface area of about 87.3 acres. The maximum storage capacity is about 1,120 acre feet.

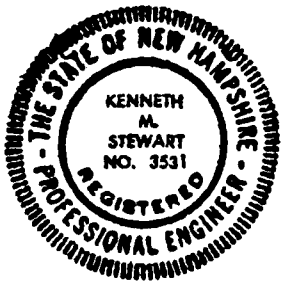
As a result of the visual inspection and the review of available data regarding this facility, the dam is considered to be in FAIR condition. Major concerns are: lack of erosion protection on the crest and slopes of the embankment; damage to the penstock gate stems; lack of a low level regulating outlet that would allow drawdown of the pond below elevation 169.30 in an emergency; and the inadequacy of the spillway to pass the test flood.

This dam is classified as INTERMEDIATE in size and a SIGNIFICANT hazard structure in accordance with the recommended guidelines established by the Corps of Engineers. The test flood for this dam, therefore, ranges from one-half the Probable Maximum Flood (1/2 PMF) to the Probable Maximum Flood (PMF). Since the dam falls on the lower end of the intermediate size range, the 1/2 PMF was utilized for this hydrologic analysis. The test flood inflow was estimated to be 11,500 cfs and resulted in a routed test flood outflow equal to 10,200 cfs which would overtop the dam crest by about 5.0 feet. The spillway capacity (with the "typical" arrangement of stoplogs in place) with the water level at the dam crest

was esimated to be 950 cfs which is only about 9 per cent of the routed test flood outflow. An assumed breach with the reservoir surface at the dam crest would overtop Manchester Street by more than 3 feet and the Harris Pond Dam crest by nearly 1 foot. This could compromise the integrity of Harris Pond Dam and would result in the loss of a significant portion of the water supply for the city of Nashua. The Supply Pond Dam, which is located downstream of Harris Pond Dam, would also probably be overtopped. Beyond Supply Pond Dam the failure discharge would pass beneath New Hampshire Route 3 before entering the Merrimack River. The Route 3 culvert appears to have more than adequate capacity to handle the failure discharge. Consequently, this roadway, as well as any other structures below Supply Pond Dam, would not be damaged.

It is recommended that the owner engage a qualified registered professional engineer to design or specify erosion protection for the crest and slopes of the embankment, to perform a detailed hydrologic-hydraulic investigation to assess further the potential of overtopping the dam and the need for and means to increase project discharge capacity, and to assess the need for and means to provide a low level regulating outlet that would allow drawdown of the pond below elevation 169.30 in an emergency. It is also recommended that the owner make repairs to the penstock gate stems and maintain the gate in an operable condition.

The recommendations and remedial measures are described in Section 7 and should be adressed by the owner within one year after receipt of this Phase I Inspection Report.



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S E A Consultants Inc.
Rochester, New Hampshire

PREFACE

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

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

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

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established guidelines, the Spillway Test flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. Because of the magnitude and

rarity of such a storm event, 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 trespassing 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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OVERVIEW PHOTO - BOWERS DAM

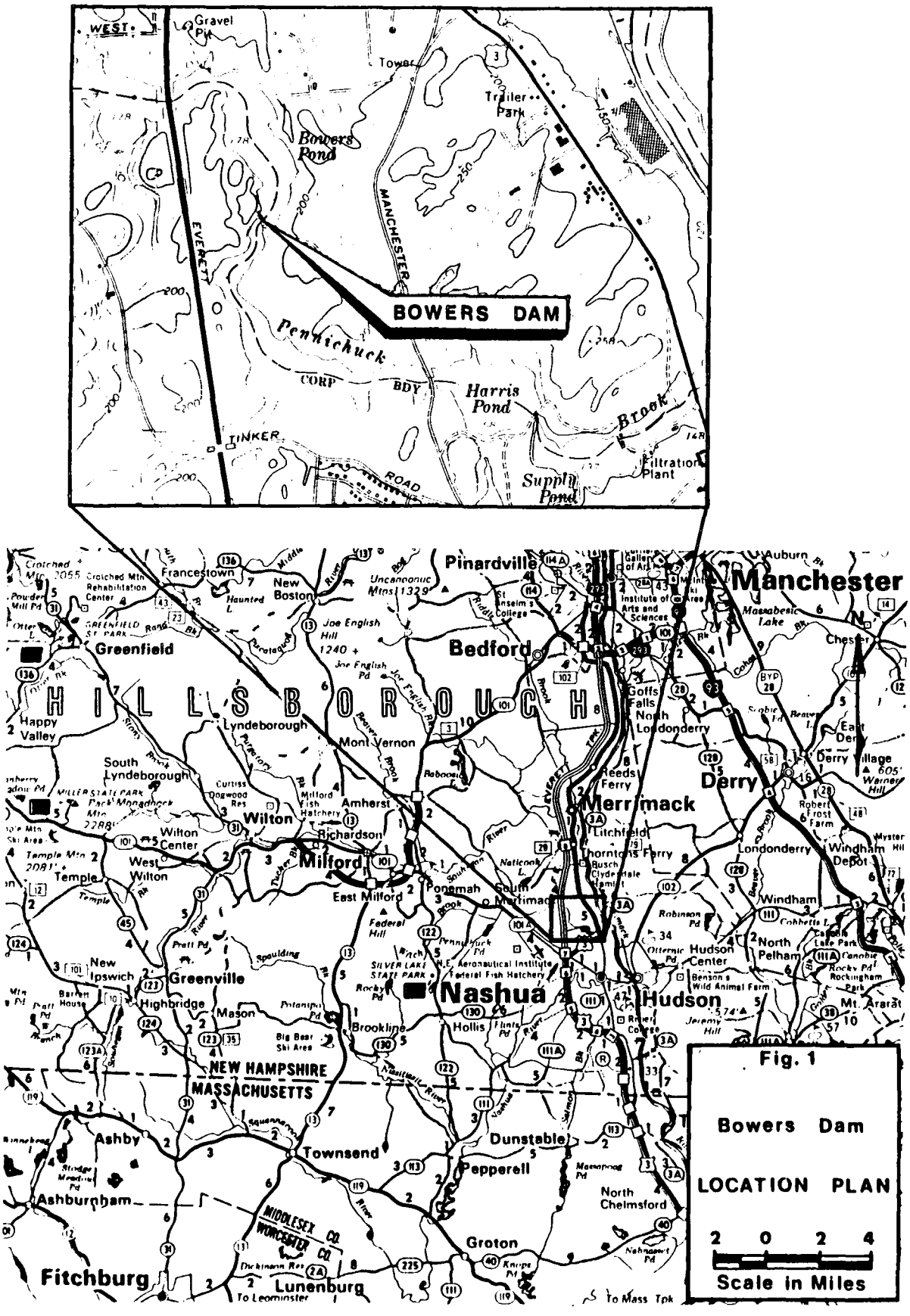


Fig. 1

Bowers Dam

LOCATION PLAN

2 0 2 4

Scale in Miles

NATIONAL DAM INSPECTION
PHASE I INSPECTION REPORT
BOWERS 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. S E A Consultants Inc. has been retained by the New England Division to inspect and report on selected dams in the State of New Hampshire. Authorization and notice to proceed were issued to S E A Consultants Inc. under a letter of November 5, 1979 from William Hodgson, Jr., Colonel, Corps of Engineers. Contract No. DACW33-80-C-0008 has been assigned by the Corps of Engineers for this work.

b. Purpose

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

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

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

1.2 Description of Project

a. Location. Bowers Dam is located on the corporate boundary line between Nashua and Merrimack, New Hampshire, on the south end of Bowers Pond. The dam impounds water from Bowers Pond and the spillway discharges to Harris Pond immediately below the dam. Bowers Pond and Harris Pond are two of a series of four water supply ponds located on the Pennichuck Brook and operated by the Pennichuck Water Works. The dam is shown on U.S.G.S. Quadrangle, Nashua North, New Hampshire, with coordinates approximately at N42°48'00", W71°29'39", Hillsborough County, New Hampshire.

b. Description of Dam and Appurtenances. Bowers Dam is an earthen embankment dam about 420 feet long with a maximum height of approximately 25 feet. The dam is constructed of sand and gravel with an upstream slope of approximately 1 foot vertical to 1.8 feet horizontal (1:1.8) from crest of dam to pond elevation. The downstream slope is also approximately 1 foot vertical to 1.8 feet horizontal (1:1.8) from crest of dam to tailwater elevation. The crest width is about 26 feet at the narrowest point.

Located near the right abutment is the principal spillway which consists of a 56 feet long wood spillway structure approximately 25 feet high from the bottom of the downstream channel to the top of the stoplog bays and constructed between mortared cut stone training walls. Ten (10) stoplog bays and a 4 feet diameter riveted steel tube gate are incorporated into this structure. The stoplog bays have a total weir length of 42.6 feet

Located about 80 feet to the left of the spillway structure is a 5.0 feet diameter riveted steel plate penstock which extends about 58 feet through the left embankment and discharges at the downstream toe. Penstock discharge is controlled by a gate on the upstream end of the penstock.

c. Size Classification. Intermediate (Height - 25 feet; total storage -1120 acre-feet) based on storage (greater than or equal to 1000 acre-feet and less than 50,000 acre-feet) as given in the Recommended Guidelines for Safety Inspection of Dams.

d. Hazard Classification. Significant Hazard. An assumed breach with the reservoir surface at the dam crest would overtop Manchester Street by more than 3 feet and the Harris Pond Dam crest by nearly 1 foot. This could compromise the integrity of Harris Pond Dam and would result in the loss of a significant portion of the water supply for the city of Nashua. Supply Pond Dam, which is located downstream from Harris Pond Dam, would also probably be overtopped. However, no structures below Supply Pond Dam would be impacted.

e. Ownership. The dam was constructed in 1884 and has been continually owned by the Pennichuck Water Works, 11 High Street, Nashua, New Hampshire 03060. Telephone No. (603) 882-5191.

f. Operator. The dam is maintained and operated by Augustus Grakas, Chief Engineer, Pennichuck Water Works, 11 High Street, Nashua, New Hampshire 03060. Telephone No. (603) 882-5191.

g. Purpose of Dam. The dam was constructed to create Bowers Pond as a water supply for Pennichuck Water Works and to regulate the level of Harris Pond immediately downstream.

h. Design and Construction History. The early structures of the dam are believed to have been constructed in 1884. An early sketch of the dam (date unknown) on file at the Pennichuck Water Works indicates the spillway structure is made of wood and built on an earth foundation. In 1976, the upstream and downstream face of the spillway structure was dewatered and repairs made by Pennichuck Water Works personnel. No in-depth design calculations or as-built drawings were disclosed for this dam.

i. Normal Operating Procedure. The Bowers Dam is used primarily for the retention of Bowers Pond as a water supply and to regulate the level of Harris Pond immediately downstream. The normal operating procedure for this dam is to monitor the water level of Bowers Pond at least once a day and remove and replace stoplogs as required to maintain the desired water level of Harris Pond. More frequent monitoring of water levels are performed during heavy rains.

1.3 Pertinent Data.

a. Drainage Area. The drainage area above the Bowers Dam covers nearly 23 square miles (approximately 14,720 acres), consisting of moderately sloping terrain surrounding a broad swampy area located upstream from Bowers Pond. The topography in the drainage basin ranges from 821 feet (NGVD) on top of Birch Hill to approximately 156 feet (NGVD) at the base of the dam. The majority of the basin is wooded and numerous houses are located along the roadways which transect the drainage area.

b. Discharge at Damsite. Discharge at the dam site occurs through the ten (10) stoplog bays which are constructed across the 56 feet long spillway. The stoplog bay openings provide a total weir length of 42.6 feet. The crest elevation of the stop logs varies from bay to bay. Stoplogs are removed and replaced as required to maintain the desired water level in Bowers Pond, which normally corresponds to an elevation of about 177.8 feet. The permanent weir crest in each stoplog bay is set at an elevation of 172.32 feet. Located between the spillway training walls is a 4.0 feet diameter steel tube gate. This tube gate originally provided an overflow capabilty and a low level outlet which would discharge through the bottom of the spillway structure, but the outlet was sealed with a 1/4-inch steel plate when repairs were made to the dam in March of 1976 and, consequently, the gate can no longer be used to withdraw water from the pond. A 5.0 feet diameter penstock is located approximately 80 feet to the left of the spillway structure. The inlet invert of the penstock gate is at elevation 169.3 feet.

(1) The capacity of the penstock was estimated to be 725 cfs with the water surface at the crest of the dam (elevation 180.9 feet) and 930 cfs with the water surface at the test flood elevation (elevation 185.9 feet).

(2) Maximum known flood at damsite - unknown.

(3) The ungated spillway capacity with the water surface elevation at the top of the dam (elevation 180.9 feet) was estimated to be 950 cfs with the "typical" arrangement of stop logs in place and 3,500 cfs with all stoplogs removed.

(4) The ungated spillway capacity with the water surface elevation at the test flood elevation (elevation 185.9 feet) was estimated to be 2,660 cfs with the "typical" arrangement of stoplogs in place and 6,000 cfs with all stoplogs removed.

(5) Gated spillway capacity at normal pool elevation - N/A

(6) Gated spillway capacity at test flood elevation - N/A

(7) The total capacity of the spillway ("typical" arrangement of stoplogs in place) at the test flood elevation (elevation 185.9 feet) was estimated to be 2,660 cfs.

(8) The total project discharge at the top of the dam (elevation 180.9 feet) was estimated to be 950 cfs with the "typical" arrangement of stoplogs and 3,500 cfs with all stoplogs removed. (Penstock gate closed)

(9) The total project discharge at the test flood elevation (elevation 185.9 feet) was estimated to be 10,200. (Penstock gate closed)

c. Elevation (feet, NGVD) based on datum obtained from Pennichuck Water Works.

(1) Streambed at toe of dam - 156.5

(2) Bottom of cutoff - unknown

(3) Normal tailwater - 168.3

(4) Normal pool - 177.8

(5) Full flood control pool - N/A

(6) Spillway crest - 181.84 (all stoplogs in place)
- 177.2 (average elevation of "typical" stoplog arrangement)
- 172.32 (permanent weir crest)

(7) Design surcharge (Original Design) - unknown

(8) Top of dam - 180.9

(9) Test flood surcharge - 185.9

d. Reservoir (Length in feet)

(1) Normal pool - 8,800

(2) Flood control pool - N/A

(3) Spillway crest pool - 8,700 (permanent crest)

(4) Top of dam - 8,800

(5) Test flood pool - 8,800

e. Storage (acre-feet)

(1) Normal pool - 761

(2) Flood control pool - N/A

(3) Spillway crest pool - 377 (permanent crest)

(4) Top of dam - 1,120

(5) Test flood pool - 2,090

f. Reservoir Surface (acres)

(1) Normal pool - 87.3

(2) Flood control pool - N/A

(3) Spillway crest - 51.8 (permanent crest)

(4) Test flood pool - 242

(5) Top of dam - 147

g. Dam

(1) Type - earthen embankment

(2) Length - 420 feet overall

(3) Height - 25 feet maximum (at spillway structure)

(4) Top Width - 26 feet minimum (at earthen embankment)

(5) Side Slopes - Upstream and downstream 1V to 1.8H

(6) Zoning - unknown

(7) Impervious Core - unknown

(8) Cutoff - unknown

(9) Grout Curtain - none

(10) Other - none

h. Diversion and Regulating Tunnel

Not applicable (See Section j)

i. Spillway

(1) Type - wooden "buttress" structure between mortared stone block training walls

(2) Length of weir - 10 stoplog bays with an equivalent length of 42.6 feet

(3) Crest elevation - 181.84 (with all stoplogs in place)
- 177.2 (average elevation of "typical" stoplog arrangement)
- 172.32 (permanent weir crest)

(4) Gates - 4.0 feet diameter vertical steel tube gate originally outletting through the bottom of the spillway; the outlet has been sealed with a 1/4-inch thick steel plate, so the gate can no longer be used to withdraw water from the pond.

(5) U/S Channel - The banks of the approach channel are tree lined. Some small trees are located along the water's edge just upstream from the right training wall of the spillway and overhang the channel. For the most part, the banks of the pond appear to be stable, although some trees adjacent to the edge of the pond have died and have fallen into the pond.

(6) D/S Channel - The spillway discharges into Harris Pond which forms the downstream channel. The main channel immediately downstream of the spillway is generally wide and unobstructed. Some trees overhang the right side of this channel. Located downstream of the spillway is a sand and gravel dike which was about 2 feet higher than the tailwater elevation at the time of the inspection and which extends from the left bank of the channel about 300 feet toward the right bank of the channel. The width of the constricted channel between the end of the dike and the right bank is about 20 feet. This dike is the remnant of a cofferdam that was constructed for the purpose of dewatering the downstream side of the spillway when it was reconstructed in 1976.

j. Regulating Outlets

(1) Invert - Penstock - 169.30

(2) Size - Penstock - 5.0 feet diameter

(3) Description - Penstock - 58 feet long riveted steel plate tube extending through the earth embankment to the left of the spillway

(4) Control Mechanism - Penstock - discharge through the penstock is controlled by a gate on the upstream end; the gate is normally operated by a manual crank type operator; however, the gate stems are currently damaged and a backhoe must be used to open the gate.

(5) Other - None

SECTION 2
ENGINEERING DATA

2.1 Design

No design data were disclosed for Bowers Dam.

2.2 Construction

Records from the State of New Hampshire Water Resources Board indicate the dam was built in 1884. Records from Pennichuck Water Works indicate major repairs were made to the dam in 1976. A sketch from the Pennichuck Water Works (date unknown) shows detail of the spillway structure and indicates it is built on an earth foundation.

2.3 Operational

No engineering operational data were found.

2.4 Evaluation

a. Availability. No engineering data were available for Bower Dam, other than a sketch of the spillway structure (date unknown).

b. Adequacy. The final assessments and recommendations of this investigation are based on the visual inspection and the hydrologic and hydraulic calculations.

c. Validity. The field investigation indicated that the external features of Bowers Dam substantially agree with those shown on the sketch on file at the Pennichuck Water Works.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. General. Bowers Dam impounds a pond area of moderate size. The drainage area above the dam consists of moderately sloping terrain surrounding a broad swampy area located upstream from Bowers Pond. The majority of the basin is wooded and numerous houses are located along the roadways which transect the drainage area.

The field inspection of Bowers Dam was made on March 25, 1980. The inspection team consisted of personnel from S E A Consultants Inc. and Geotechnical Engineers, Inc. Inspection checklists completed during the visual inspection are included in Appendix A. At the time of inspection, water was passing approximately 21 inches deep over the lowest of the ten stoplog bays provided. The pool elevation was at approximately 178.1 NGVD. The upstream face of the dam could only be inspected above this water level. Inspection of the downstream face of the spillway structure was not possible due to the discharge of water.

b. Dam. Bowers Dam is an earthen embankment dam about 420 feet long with a maximum height of approximately 25 feet. The crest width is about 26 feet at the narrowest point. There is practically no vegetation on the dam, except for several large pine trees growing on the upstream and downstream slopes of the embankment section between the left abutment and the spillway. There are also a few stumps on the upstream and downstream slopes of the embankment section between the left abutment and the spillway. Some small trees are growing on the right abutment at and below the elevation of the crest of the dam. The soil exposed on the crest and slopes of the embankment sections of the dam is primarily clean sand and gravel.

The upstream slope of the embankment is inclined at about 1 foot vertical to 1.8 feet horizontal (1:1.8). Some erosion is taking place at the waterline. It appears that some sand and gravel have been dumped on the upstream side of the dam, particularly near the left abutment. There is no erosion protection on the upstream slope.

The downstream slope of the embankment is also inclined at about 1 foot vertical to 1.8 feet horizontal (1:1.8). There is evidence of trespassing on the downstream slope at several locations, and some erosion has occurred where the trespassing has taken place, particularly near the right end of the spillway and near the right side of the penstock outlet.

At the downstream toe of the embankment between the spillway and the right abutment, some erosion has occurred, apparently the result of eddying tailwater

between the spillway and the right bank of the discharge channel. According to a representative of the Pennichuck Water Works who was present during a portion of the inspection, this condition has existed and has not changed significantly during the past several years. Both abutments of the dam appear to consist of soil.

No evidence of seepage on the downstream slope or at the downstream toe of the dam was observed.

c. Appurtenant Structures. The principal spillway is located near the right abutment and consists of a wooden buttress structure approximately 56 feet wide between mortared cut stone training walls. The buttress structure consists of wood beams and braces with 2-inch thick wood planking across the upstream face and acts as the permanent crest. Ten stoplog bays with an average width of 4.3 feet are provided on top of the permanent crest which can accommodate removable stoplogs to raise the ponding elevation approximately 9.5 feet. The total height of the spillway structure is approximately 25 feet from the bottom of the downstream channel to the top of the stoplog bays. At the left end of the spillway is a gate house which contains the lifting mechanism for a 4 feet diameter riveted steel plate tube gate. The original purpose of this tube gate was to provide an overflow capability through the top of the tube which would discharge through the bottom of the spillway structure. A low level outlet was provided by raising the tube and allowing discharge directly through the bottom of the spillway structure. According to a representative of the Pennichuck Water Works, the tube gate has been made inoperable by sealing the opening through the bottom of the spillway with a 1/4-inch thick steel plate when repairs were made to the dam in March of 1976. The entire spillway structure appears to be in very good condition.

Located about 80 feet to the left of the spillway structure is 5.0 feet diameter riveted steel plate penstock. The original purpose of the penstock was to provide power to a small saw mill. The saw mill at the penstock outlet was dismantled in the early 1970's. The penstock has a concrete intake structure with a manual crank operated gate lifting mechanism. According to a representative of the Pennichuck Water Works, the gate and lifting mechanism are still in working order although the gate stems were severely damaged when the penstock was used to dewater Bowers Pond for repairs to the spillway structure in 1976. Due to the damaged gate stems, it is necessary to use a backhoe to open the penstock gate. At the time of the inspection, there was minor seepage through the gate. A narrow discharge channel, about 5 feet wide, is provided downstream of the penstock outlet between the left bank of the main downstream channel and the higher ground at the left abutment.

d. Reservoir Area. The slopes of the pond appear to be stable. No evidence of significant sedimentation was observed. Some trees are growing on the right side of the pond close to the dam, but the approach channel is wide and unobstructed.

e. Downstream Channel. The main channel immediately downstream of the spillway is generally wide and unobstructed. Some trees overhang the right side of this channel. Located downstream of the spillway is a sand and gravel dike which was about 2 feet higher than the tailwater elevation at the time of the

inspection and which extends from the left bank of the channel about 300 feet toward the right bank of the channel. The width of the constricted channel between the end of the dike and the right bank is about 20 feet. This dike is the remnant of a cofferdam that was constructed for the purpose of dewatering the downstream side of the spillway when it was reconstructed in 1976.

3.2 Evaluation

On the basis of the results of the visual inspection, Bowers Dam is considered to be in fair condition.

Trespassing and erosion of the embankment, if not controlled, could lead to breaching of the dam.

The lack of erosion protection on the embankment makes it susceptible to erosion by rainfall or, if the dam should be overtopped, by overflowing water.

Trees growing on the embankment could lead to seepage or erosion problems if a tree blows over and pulls out its roots, or if a tree dies and its roots rot. Rotting of roots connected to the stumps on the embankment could also lead to seepage or erosion problems.

The severe damage to the penstock gate stems could cause the gate to become inoperable when an attempt is made to open the penstock. The minor visible seepage through the gate could be a further indication of a problem with the gate mechanism; in other words, gate not properly seated.

SECTION 4
OPERATIONAL AND MAINTENANCE PROCEDURES

4.1 Operational Procedures

a. General. Bowers Dam is used primarily for the retention of Bowers Pond as a water supply and to regulate the level of Harris Pond immediately downstream. The normal operating procedure for this dam is to monitor the water level of Bowers Pond at least once a day and remove and replace stoplogs as required to maintain the desired water level of Harris Pond. The stoplogs are removed with two long lifting hooks. The procedure can be accomplished by a single individual, although the lifting hooks become a bit awkward to handle and it is easier to use two people to complete the task. Also, it appears that the stoplogs would be difficult to pull out during high discharge conditions over the spillway.

No written instructions on opening the penstock gate or for removal of flashboards during a flood exist, although more frequent monitoring of pond water levels are performed during heavy rains.

b. Description of Any Warning System in Effect. No written warning system exists for the dam.

4.2 Maintenance Procedures

a. General. The owner, Pennichuck Water Works, is responsible for the maintenance of the dam. The maintenance procedure for this dam is to make a brief visual inspection whenever the Bowers Pond water level is monitored.

b. Operating Facilities. No formal plan for maintenance of operating facilities was disclosed.

4.3 Evaluation

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

SECTION 5
EVALUATION OF HYDROLOGIC/HYDRAULIC FEATURES

5.1 General. Bowers Dam is an earthen embankment dam approximately 420 feet long. Located near the right abutment is a 56 feet long spillway structure which is approximately 25 feet high from the top of the dam to the channel bottom. Flow discharges through 10 stoplog bays located between the spillway training walls. The bays have a total weir length of 42.6 feet. Also located between the spillway training walls is a 4.0 feet diameter steel tube gate. The outlet of the gate was sealed when repairs were made to the dam in 1976. Consequently, the gate can no longer withdraw water from the pond. A 5.0 feet diameter penstock is located approximately 80 feet to the left of the spillway structure.

The drainage area above the dam consists of moderately sloping terrain surrounding a broad swampy area located upstream from Bowers Pond. Runoff from much of the drainage basin must pass through this swampy area before reaching Bowers Pond Dam. The dam is classified as intermediate in size, having a maximum storage of approximately 1,120 acre-feet.

5.2 Design Data. No hydrological or hydraulic design data were disclosed.

5.3 Experience Data. No experience data were disclosed. Maximum flood flows or elevations are unknown.

5.4 Test Flood Analysis. Due to the absence of detailed design and operational information, the hydrologic evalution was performed utilizing data gathered during field inspection, watershed size and an estimated test flood determined from the Corps of Engineers guide curves. For this dam (intermediate size and significant hazard) the test flood ranges from one-half the Probable Maximum Flood (1/2 PMF) to the full Probable Maximum Flood (PMF). Since the dam falls on the low end of the intermediate size range, the 1/2 PMF was selected for this hydrologic analysis. Since the drainage area consists of a combination of moderately sloped and flat terrain and since there is a considerable amount of storage available in the swampy area upstream from Bowers Pond, a point mid-way between the "rolling" curve and "flat" curve, from the Corps of Engineers set of guide curves, was used to estimate the maximum probable flood peak flow rate. It was assumed that the 5.0 feet diameter penstock remained closed for this analysis, since it is very difficult to open. Also, it was assumed that the "typical" stoplog arrangement remained in place during the test flood routing, since it appears that it would be difficult to remove the stoplogs quickly under high spillway discharge conditions. However, discussion concerning an alternative stoplog arrangement is included in this section.

Based on an estimated maximum probable flood peak flow rate of 1,000 cfs per square mile and a drainage area of 23 square miles, the test flood inflow was estimated to be 11,500 cfs. The test flood was routed through the reservoir in accordance with the Corps of Engineers procedure for Estimating Effect of

Surcharge Storage on Maximum Probable Discharge. The reservoir water surface was assumed to be at elevation 177.2 prior to the flood routing. The routed test flood outflow was estimated to be 10,200 cfs. This analysis indicated that the dam crest would be overtopped by 5.0 feet. The maximum spillway capacity (with the "typical" arrangement of stoplogs in place) with the water level at the dam crest was estimated to be 950 cfs, which is only about 9 percent of the routed test flood outflow.

Since the discharge through the spillway would increase significantly if all the stoplogs were removed, a test flood routing with all stoplogs removed and an initial water surface elevation at the permanent spillway crest (Elevation 172.32 feet) was examined. This analysis indicated that the routed test flood outflow would be virtually the same as that for the previous analysis, 10,300 cfs, and would overtop the dam by 4.5 feet instead of 5.0 feet. However, under these conditions, the spillway capacity would be about 34 percent of the routed test flood outflow.

5.5 Dam Failure Analysis. The impact of dam failure with the reservoir surface at the dam crest was assessed utilizing the "Rule of Thumb" Guidance for Estimating Dowstream Dam Failure Hydrographs published by the Corps of Engineers. The analysis covered a reach extending approximately 1.2 miles downstream to Harris Pond Dam. Based on this analysis, Bowers Dam has been classified as a significant hazard.

An assumed breach in Bowers Pond Dam would increase the stage in the portion of Harris Pond between Bowers Dam and Manchester Street by between 7 and 8 feet. This discharge would overtop Manchester Street by more than 3 feet. In the portion of Harris Pond between Manchester Street and Harris Pond Dam the stage would increase approximately 6 feet, overtopping Harris Pond Dam by nearly 1 foot. The discharge over the dam crest could compromise the integrity of this dam. Failure of Bowers Pond Dam would result in the loss of a significant portion of the water supply for the city of Nashua. The Supply Pond Dam, which is located downstream of Harris Pond Dam, would also probably be overtopped. Beyond Supply Pond Dam, the failure discharge would pass beneath New Hampshire Route 3 before entering the Merrimack River. The Route 3 culvert appears to have more than adequate capacity to handle the failure discharge. Consequently, this roadway, as well as any other structures below Supply Pond Dam, would not be damaged.

SECTION 6
EVALUATION OF STRUCTURAL STABILITY

6.1 Visual Observations. The visual examination indicates the following potential structural problems:

a. Lack of vegetation or other erosion protection on the crest and slopes of the embankment makes those areas susceptible to erosion by rainfall or, in case of overtopping, by overflowing water.

b. Erosion of both the upstream and downstream slopes of the embankment, if not controlled, could lead to breaching of the dam.

c. Trees growing on the upstream and downstream slope of the embankment could lead to seepage or erosion problems if a tree blows over and pulls out its roots, or if a tree dies and its roots rot.

d. Damage to the penstock gate stems which could cause the gate to become inoperable when an attempt is made to open the penstock, and the visible seepage through the gate.

6.2 Design and Construction Data

No information regarding the original design or construction of the dam was found, although it is believed the early structures of the dam were built in 1884. An early sketch of the dam (date unknown) on file at the Pennichuck Water Works shows detail of the spillway structure and indicates it is built on an earth foundation.

6.3 Post-Construction Changes

In 1976, the upstream and downstream face of the spillway structure was dewatered and repairs made by Pennichuck Water Works personnel. These repairs consisted of applying two layers of 1-1/2 inch thick treated wood planking and felt paper to the upstream surfaces of the spillway. Aluminum flashing was applied at and above pond level on the upstream face. The 4.0 feet diameter tube gate outlet through the bottom of the spillway structure was sealed with a 1/4-inch steel plate.

6.4 Seismic Stability. This dam is located in Seismic Zone 2, and, in accordance with the Phase I guidelines, does not warrant seismic analysis.

SECTION 7
ASSESSMENT, RECOMMENDATIONS, AND REMEDIAL MEASURES

7.1 Dam Assessment

a. Condition. The visual examination indicates that Bowers Dam is in fair condition. The major concerns with respect to the integrity of the dam are:

(1) Trespassing and erosion on the embankment

(2) Lack of erosion protection on the embankment

(3) Trees growing on the embankment

(4) Damage to the penstock gate stems and seepage through the gate

(5) Lack of a low level regulating outlet that would allow drawdown of the pond below elevation 169.30 in an emergency

b. Adequacy of Information. The information available from the visual inspection and hydraulic computations is adequate to identify the problems mentioned in 7.2. These problems will require the attention of a registered professional engineer qualified in the design and construction of dams, who will have to make additional engineering studies to design or specify remedial measures. No additional information is needed for the purposes of this Phase I investigation.

c. Urgency. The owner should implement the recommendations in 7.2 and 7.3 within one year after receipt of this Phase I report.

7.2 Recommendations

The owner should retain a registered professional engineer qualified in the design and construction of dams to:

(1) Design and specify repairs for the erosion that has occurred on the embankment section of the dam

(2) Design and specify erosion protection for the embankment

(3) Specify procedures for removal of trees and their root systems from the embankment and right abutment

(4) Investigate the seepage through the penstock gate

(5) Inspect the downstream face of the spillway under no flow conditions.

(6) Assess the need for and means to provide a low level regulating outlet that would allow drawdown of the pond below elevation 169.30 in an emergency

(7) Perform a detailed hydrologic-hydraulic investigation to assess further the potential for overtopping the dam and the need for and means to increase project discharge capacity

The owner should implement the recommendations made by the engineer.

7.3 Remedial Measures

a. Operating and Maintenance Procedures. The owner should:

(1) Control trespassing on the embankment

(2) Make repairs to the penstock gate stems and maintain the gate in an operable condition

(3) Prepare spalled concrete on penstock headwalls

(4) Establish written maintenance and operating procedures, especially for removal of flashboards and opening of penstock gate during flood periods

(5) Engage a registered professional engineer qualified in the design and construction of dams to make a comprehensive technical inspection of the dam once every year

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

7.4 Alternatives

There are no practical alternatives to the recommendations of 7.2 and 7.3.

APPENDIX A
INSPECTION CHECKLIST

INSPECTION CHECK LIST
PARTY ORGANIZATION

PROJECT: Bowers Dam, NH

DATE: March 25, 1980

TIME: 8:30 a.m.

WEATHER: Overcast, cold

W.S. ELEV. 178.1 U.S. 168.3 DN.S.
(NGVD)

PARTY:

1. Kenneth Stewart, S E A
2. Robert Durfee, S E A
3. Bruce Pierstorff, S E A
4. Philip Ricardi, S E A
5. Ronald Hirschfeld, GEI
6. Kenneth Stern, NHWRB
7.
8.
9.
10.

	PROJECT FEATURE	INSPECTED BY	REMARKS
1.	Structural Stability	K. Stewart/R. Durfee	
2.	Hydrology/Hydraulics	B. Pierstorff/P. Ricardi	
3.	Soils and Geology	R. Hirschfeld	
4.			
5.			
6.			
7.			
8.			
9.			
10.			

INSPECTION CHECK LIST

PROJECT: Bowers Dam, NH DATE: March 25, 1980

PROJECT FEATURE: Dam Embankment NAME:

DISCIPLINE: NAME:

AREA EVALUATED	CONDITIONS
DAM EMBANKMENT	
Crest Elevation	180.9
Current Pool Elevation	178.1
Maximum Impoundment to Date	Unknown
Surface Cracks	None observed
Pavement Condition	Not paved
Movement or Settlement of Crest	None observed
Lateral Movement	None observed
Vertical Alignment	Somewhat irregular, but apears to be due to irregular dumping of fill on crest
Horizontal Alignment	Good
Condition At Abutment and at Concrete Structures	Good
Indications of Movement of Structural Items on Slopes	None observed
Trespassing on Slopes	Evidence of trespassing on downstream slope
Vegetation on Slopes	Trees growing on upstream and downstream slopes of both left and right embankments
Sloughing or Erosion of Slopes or Abutments	Erosion on upstream and downstream slopes of both left and right embankments
Rock Slope Protection - Riprap Failures	No riprap
Unusual Movement or Cracking at or near Toes	None observed
Unusual Embankment or Downstream Seepage	None observed
Piping or Boils	None observed
Foundation Drainage Features	None observed
Toe Drains	None observed
Instrumentation System	None observed

INSPECTION CHECK LIST

PROJECT: Bowers Dam, NH DATE: March 25, 1980

PROJECT FEATURE: Dike Embankment NAME: _____

DISCIPLINE: _____ NAME: _____

AREA EVALUATED	CONDITIONS
DIKE EMBANKMENT	No dike
Crest Elevation	
Current Pool Elevation	
Maximum Impoundment to Date	
Surface Cracks	
Pavement Condition	
Movement or Settlement of Crest	
Lateral Movement	
Vertical Alignment	
Horizontal Alignment	
Condition at Abutment and at Concrete Structures	
Indications of Movement of Structural Items on Slopes	
Trespassing on Slopes	
Vegetation on Slopes	
Sloughing or Erosion of Slopes or Abutments	
Rock Slope Protection - Riprap Failures	
Unusual Movement or Cracking at or near Toes	
Unusual Embankment or Downstream Seepage	
Piping or Boils	
Foundation Drainage Features	
Toe Drains	
Instrumentation System	

INSPECTION CHECK LIST

PROJECT: Bowers Dam, NH DATE: March 25, 1980

PROJECT FEATURE: Intake Channel NAME: _____

DISCIPLINE: _____ NAME: _____

AREA EVALUATED	CONDITIONS	
	Tube Gate	Penstock
OUTLET WORKS - INTAKE CHANNEL AND INTAKE STRUCTURE	4.0 foot diameter vertical tube gate closed and sealed	5.0 foot diameter penstock, gate closed
a. Approach Channel		
Slope Conditions	Good	Good
Bottom Conditions	Not visible, beneath pond surface	Not visible, beneath pond surface
Rock Slides or Falls	None	None
Log Boom	None	None
Debris	None observed	None observed
Condition of Concrete Lining	Not applicable	Not visible, beneath pond surface
Drains or Weep Holes	None	None
b. Intake Structure		
Condition of Concrete	Not applicable	Some spalling above water surface elevation
Stop Logs and Slots	None	None

INSPECTION CHECK LIST

PROJECT: Bowers Dam, NH DATE: March 25, 1980

PROJECT FEATURE: Control Tower NAME:

DISCIPLINE: NAME:

AREA EVALUATED	CONDITIONS Tube Gate	Penstock
OUTLET WORKS - CONTROL TOWER	Control works located inside gate house	Control works located on top of penstock intake structure
a. Concrete and Structural		
General Condition	Tube gate closed and sealed	
Condition of Joints	None	Concrete spalling at joints
Spalling	Not applicable	Some spalling at joints
Visible Reinforcing	Not applicable	None
Rusting or Staining of Concrete	Not applicable	None
Any Seepage or Efflorescence	Not applicable	None
Joint Alignnment	Not applicable	Good
Unusual Seepage or Leaks in Gate Chamber	Gate not visible beneath pond surface	Slight leak through penstock gate
Cracks	Not applicable	Minor
Rusting or corrosion of Steel	Lifting mechanism in good shape	Lifting mechanism gears in operable condition
b. Mechanical and Electrical		
Air Vents	None	None
Float Wells	Inoperable	None
Crane Hoist	None	None
Elevator	None	None
Hydraulic System	None	None
Service Gates	Closed and sealed	Gate closed. Gate stems severely damaged above lifting mechanism gears
Emergency Gates	See service gates	See service gates
Lightning Protection System	None	None
Emergency Power System	None	None
Wiring and Lighting System	None	None

INSPECTION CHECK LIST

PROJECT: Bowers Dam, NH

DATE: March 25, 1980

PROJECT FEATURE: Transition and Conduit

NAME:

DISCIPLINE:

NAME:

AREA EVALUATED	CONDITIONS	
	Tube Gate	Penstock
OUTLET WORKS - TRANSITION AND CONDUIT	No transition and conduit	5.0 foot diameter riveted steel plate penstock conduit
General Condition of Concrete		Not applicable
Rust or Staining on Concrete		None
Spalling		Not applicable
Erosion or Cavitation		None
Cracking		Not applicable
Alignment of Monoliths		Penstock below ground, not visible
Alignment of Joints		Penstock below ground, not visible
Numbering of Monoliths		Not applicable

INSPECTION CHECK LIST

PROJECT: Bowers Dam, NH DATE: March 25, 1980

PROJECT FEATURE: Outlet Structure NAME:

DISCIPLINE: NAME:

AREA EVALUATED	CONDITIONS	
	Tube Gate	Penstock
OUTLET WORKS - OUTLET STRUCTURE AND OUTLET CHANNEL	Original outlet through bottom of wood spillway structure. Outlet currently sealed.	Original outlet into power wheel. Wheel removed, penstock outlets into foundation of old saw mill.
General Condition of Concrete	Not applicable	No outlet structure
Rust or Staining	Not applicable	No outlet structure
Spalling	Not applicable	No outlet structure
Erosion or Cavitation	Not applicable	No outlet structure
Visible Reinforcing	Not applicable	No outlet structure
Any Seepage or Efflorescence	Not applicable	No outlet structure
Condition at Joints	Not applicable	No outlet structure
Drain holes	Not applicable	No outlet structure
Channel	Not applicable	No outlet structure
Loose Rock or Trees Overhanging Channel	Several large trees overhanging channel	One large tree overhanging channel
Condition of Discharge Channel	Fair	Fair

INSPECTION CHECK LIST

PROJECT: Bowers Dam, NH DATE: March 25, 1980

PROJECT FEATURE: Spillway Weir NAME: _____

DISCIPLINE: _____ NAME: _____

AREA EVALUATED	CONDITIONS
OUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS	
a. Approach Channel	
General Condition	Good
Loose Rock Overhanging Channel	None
Trees Overhanging Channel	A few trees overhang channel
Floor of Approach Channel	Not visible beneath reservoir surface
b. Weir and Training Walls	
General Condition of Concrete	Mortared cut stone training walls, some stones settled out of place
Rust or Staining	Not applicable
Spalling	Not applicable
Any Visible Reinforcing	Not applicable
Any Seepage or Efflorescence	None
Drain Holes	None
c. Discharge Channel	
General Condition	Good
Loose Rock Overhanging Channel	None
Trees Overhanging Channel	Trees overhang channel
Floor of Channel	Not visible beneath tailwater
Other Obstructions	Sand and gravel dike has been built out from left bank of channel about 7/8 of distance across channel.

INSPECTION CHECK LIST

PROJECT: Bowers Dam, NH DATE: March 25, 1980

PROJECT FEATURE: Service Bridge NAME:

DISCIPLINE: NAME:

AREA EVALUATED	CONDITIONS
OUTLET WORKS - SERVICE BRIDGE	Service bridge (wood planked vehicle crossing) located over wood spillway structure
a. Super Structure	
Bearings	Longitudinal members supported over spillway structure
Anchor Bolts	No anchor bolts
Bridge Seat	See bearing
Longitudinal Members	Six treated wood beams 6" wide x 12" deep
Under Side of Deck	Not visible
Secondary Bracing	None
Deck	7" wide x 2" deep treated wood planking
Drainage System	None
Railings	None
Expansion Joints	None
Paint	No paint - all wood is treated
b. Abutment & Piers	
General Condition of Concrete	Cut stone block masonry, settlement of a few stones
Alignment of Abutment	Good
Approach to Bridge	Good
Condition of Seat & Backwall	Not visible

APPENDIX B

ENGINEERING DATA

AVAILABLE ENGINEERING DATA

No engineering data other than reports and sketches from the Pennichuck Water Works and the State of New Hampshire Water Resources Board were available. It should be noted that at the time of the writing of this report, the file on Bowers Pond Dam at the State of New Hampshire Water Resources Board was missing.

PAST INSPECTION REPORTS

NEW HAMPSHIRE WATER CONTROL COMMISSION
DATA ON DAMS IN NEW HAMPSHIRE

LOCATION STATE NO. 135.04

Town Nashua : County Hillsboro

Stream Pennichuck [illegible]

Basin-Primary [illegible] : Secondary Pennichuck Br.

Local Name Barrett's Dam

Coordinates—Lat. 42°50' - 1.4200 : Long. 71°30' - 1.200

GENERAL DATA

Drainage area: Controlled Sq. Mi.: Uncontrolled Sq. Mi.: Total 22.22 Sq. Mi.

Overall length of dam 350 ft.: Date of Construction 2216, 1884

Height: Stream bed to highest elev. 25 ft.: Max. Structure 15'3" ft.

Cost—Dam : Reservoir

DESCRIPTION "A" frame Earth and timber

Waste Gates Foundation earth

Type

Number : Size ft. high x ft. wide

Elevation Invert : Total Area sq. ft.

Hoist

Waste Gates Conduit PENSTOCK - METAL OVERFLOW

Number : Materials

Size 1 ft.: Length ft.: Area sq. ft.

Embankment

Type

Height—Max. ft.: Min. ft.

Top—Width : Elev. ft.

Slopes—Upstream on : Downstream on

Length—Right of Spillway : Left of Spillway

Spillway

Materials of Construction 1-4'10" pipe vertical overflow

Length—Total ft.: Net used as a gate ft.

Height of permanent section—Max. ft.: Min. ft.

Flashboards—Type Removable stop planks 8'10" Height 5.5 ft.

Elevation—Permanent Crest : Top of Flashboard

Flood Capacity 2200 cfs.: cfs/sq. mi.

Abutments

Materials:

Freeboard: Max. 9'2" ft.: Min. ft.

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

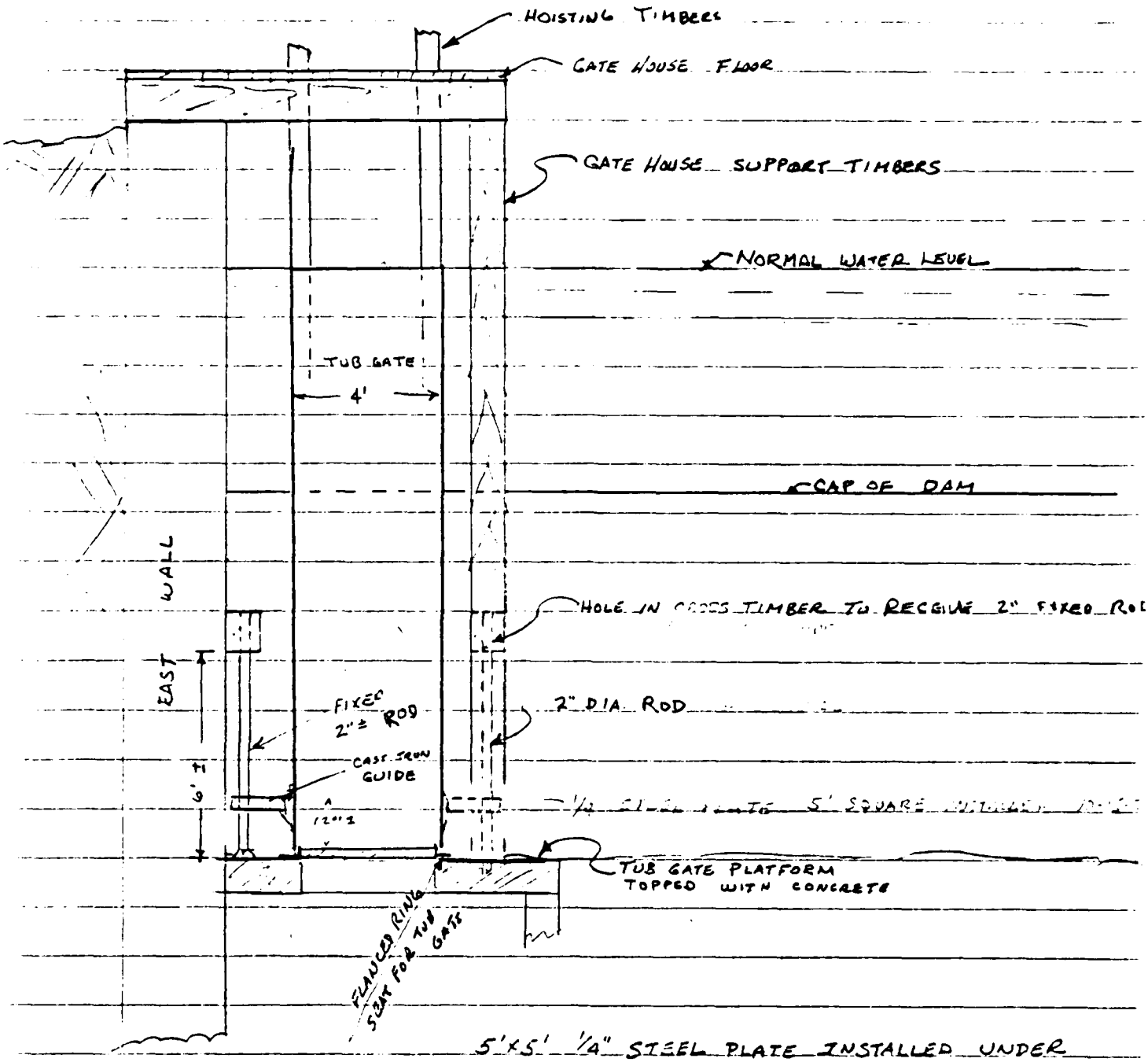
OWNER Pennichuck Water Works

REMARKS Condition good. Subject to inspection.
Storage Cap. — 225 M.G.

INFORMATION FROM
PENNICHUCK WATER WORKS

DRAWING OF TUB GATE AT BOWERS DAM - DEWATERED 3-12-76
PLANKING REPLACED

NO SCALE



5'x5' 1/4" STEEL PLATE INSTALLED UNDER TUB GATE TO CLOSE OPENING. TUB GATE IS BADLY RUSTED WITH HOLES IN IT RANGING FROM PIN SIZE TO 3" IN DIAMETER

Downstream face of dam at right training wall.

Upstream face of dam at left training wall.

Upstream face of dam at right training wall.

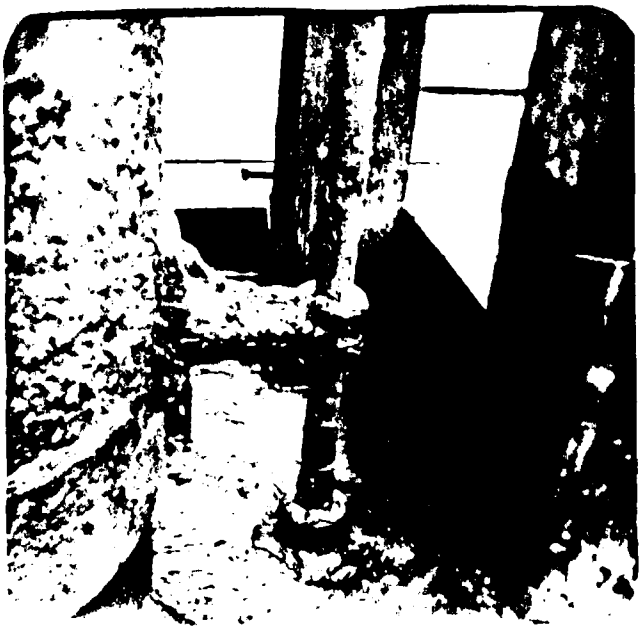
Four foot diameter tube gate at left training wall.

Repairs to Bowers Dam
March 13, 1976

Four foot diameter tube gate at left training wall.

Metal tube gate and flanged ring seat.

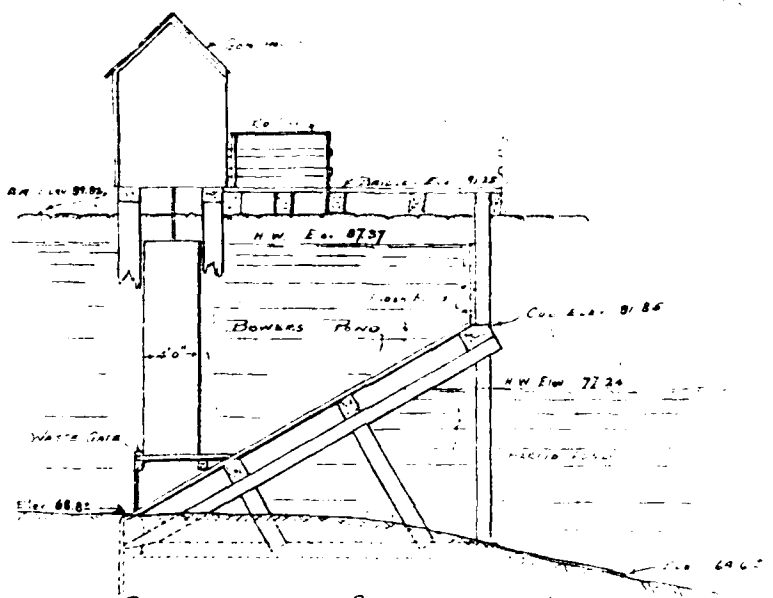
Cast iron guide of tube gate around two inch diameter rod.



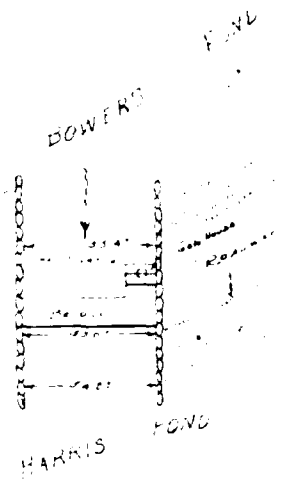
Two inch diameter guide rod.

Repairs to Bowers Dam
March 13, 1976

Discharge opening for tube gate.



SECTION THROUGH SPILLWAY
SCALE = 1/8" TO 1'



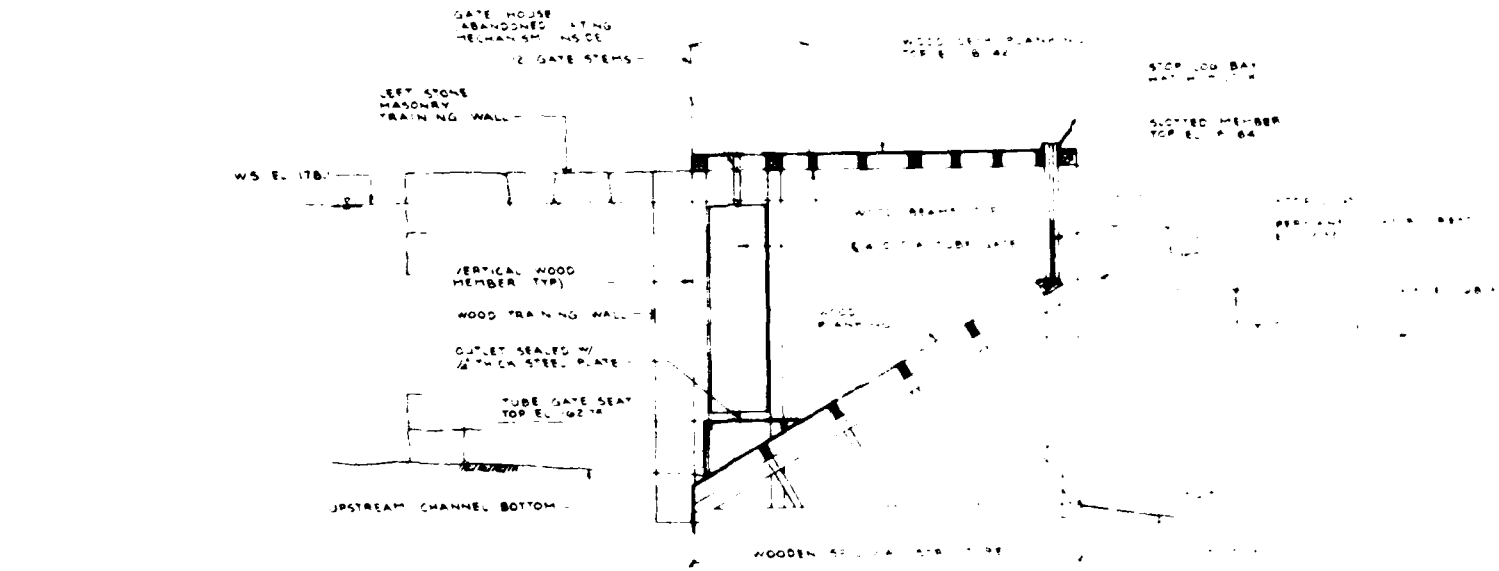
PENNICHUCK WATER WORKS
NASHUA, N.H.

BOWERS DAM

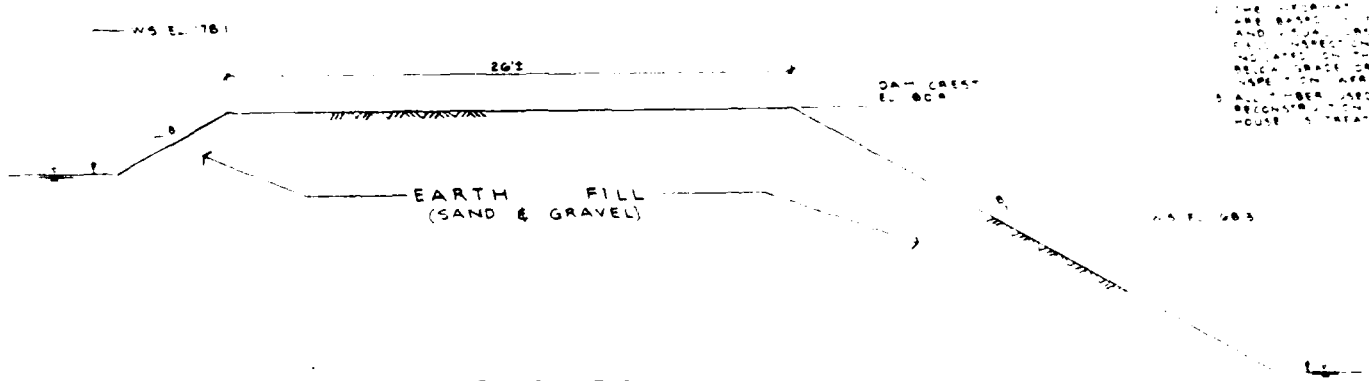
NOTE: – PORTIONS OF DAM BELOW ELEV 77 ARE NOT ACCESSIBLE, AND DRAWINGS OF THOSE [illegible] ARE BASED [illegible]

REPRODUCED AT GOVERNMENT EXPENSE

PLANS AND DETAILS



SECTION Y-Y



SECTION Z-Z

SCALE 3/16"=1'

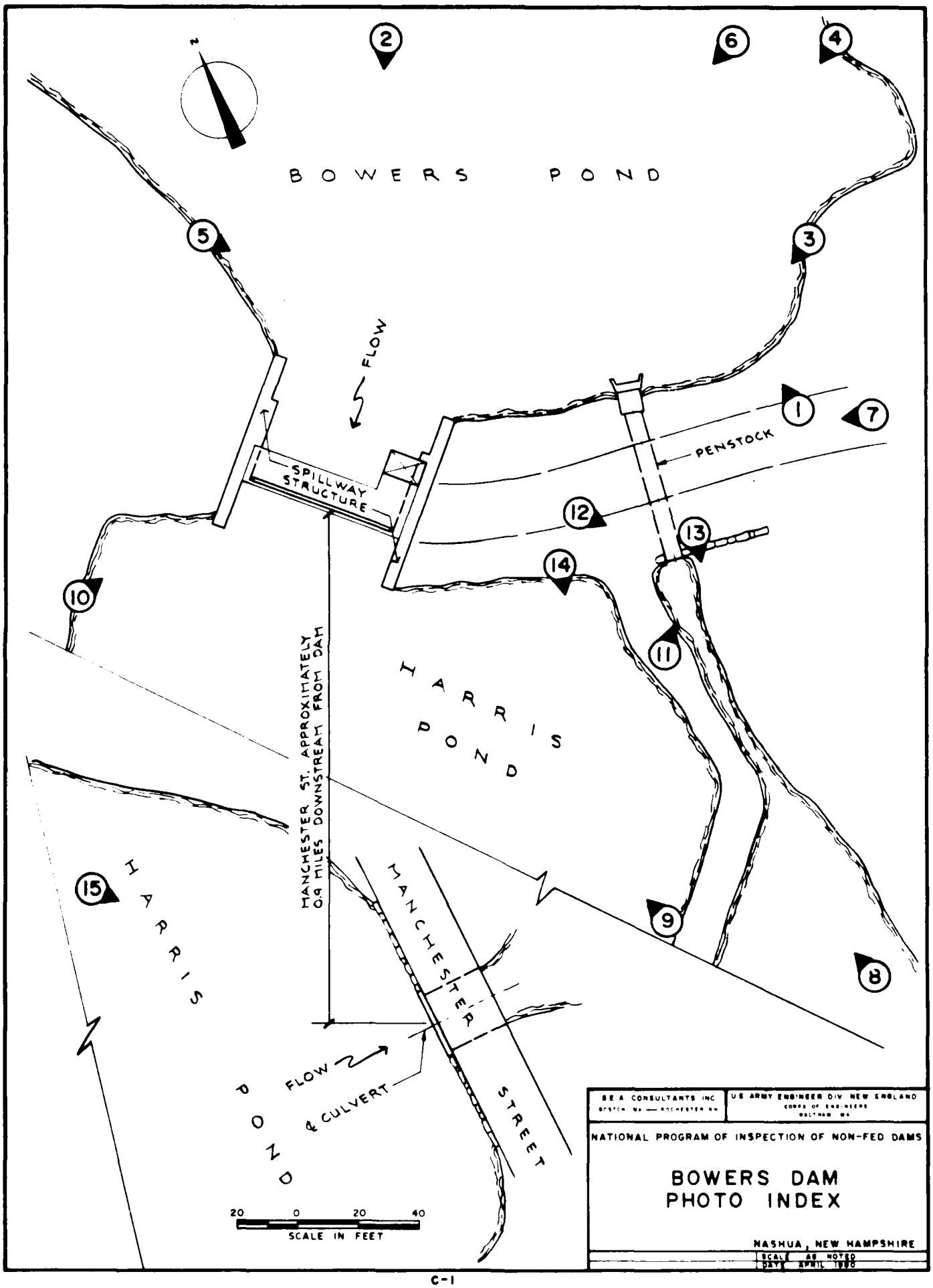
NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

BOWERS DAM

NASHUA, NEW HAMPSHIRE

APPENDIX C

SELECTED PHOTOGRAPHS


BOWERS POND
FLOW
SPILLWAY STRUCTURE
PENSTOCK
HARRIS POND
HARRIS POND
MANCHESTER ST. APPROXIMATELY 0.9 MILES DOWNSTREAM FROM DAM
MANCHESTER STREET
FLOW
℄ CULVERT
20 0 20 40
SCALE IN FEET
1
2
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BEA CONSULTANTS INC
BOSTON MA — ROCHESTER NH
U.S. ARMY ENGINEER DIV. NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM MA
NATIONAL PROGRAM OF INSPECTION OF NON-FED DAMS
BOWERS DAM
PHOTO INDEX
NASHUA, NEW HAMPSHIRE
SCALE AS NOTED
DATE APRIL 1980

Photo No. 1 - General view of pond from dam.

Photo No. 2 - General view of dam from pond.

REPRODUCED AT GOVERNMENT EXPENSE

Photo No. 3 - View of upstream face of left side of dam from left shoreline.

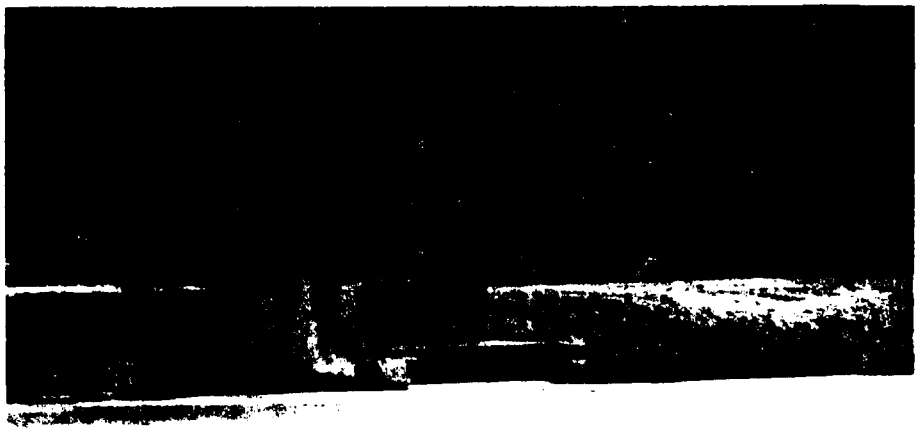


Photo No. 4 - View of upstream face of penstock intake structure.

REPRODUCED AT GOVERNMENT EXPENSE

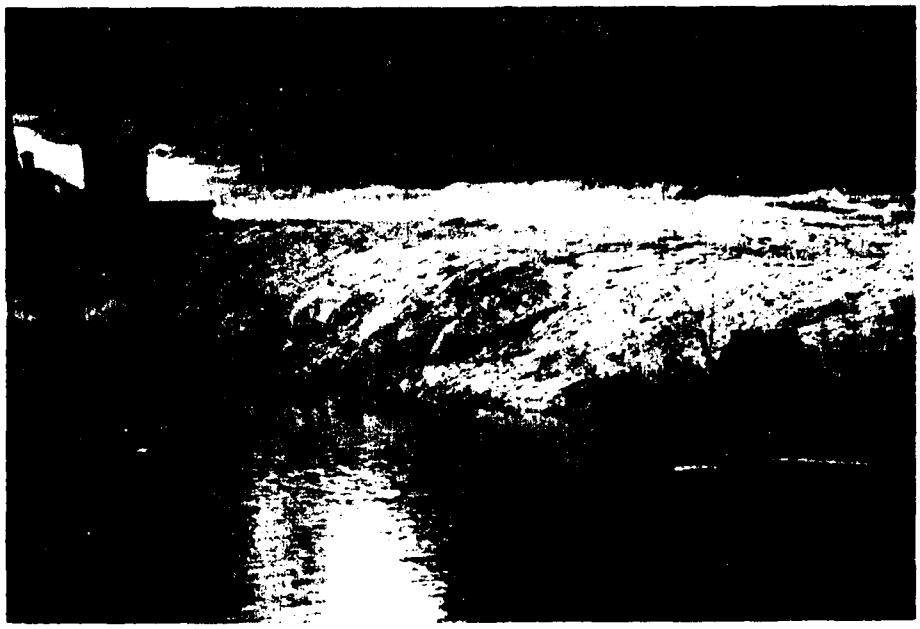


Photo No. 5 - View of upstream face of dam between penstock intake structure and spillway structure.

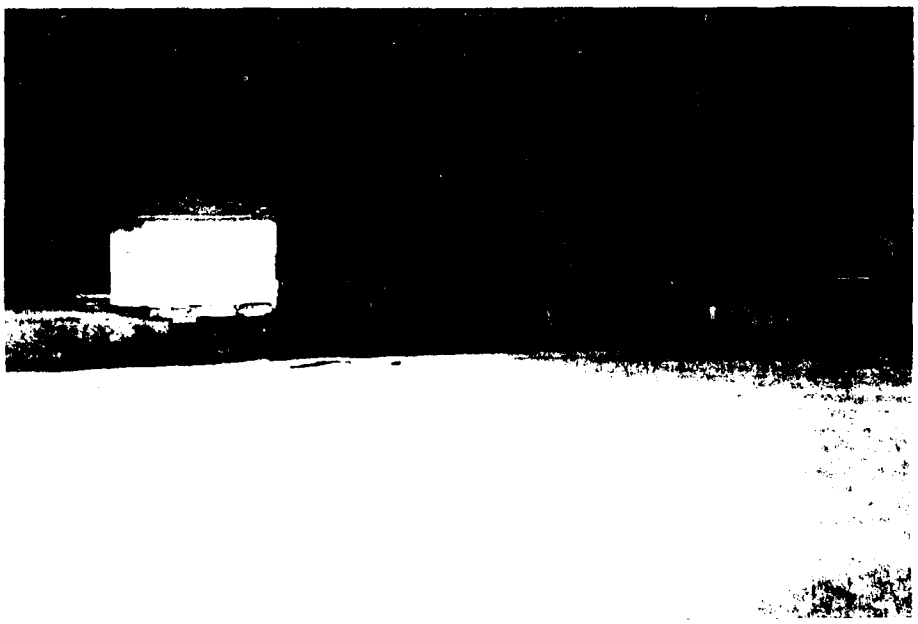


Photo No. 6 - View of upstream face of spillway structure.

REPRODUCED AT GOVERNMENT EXPENSE

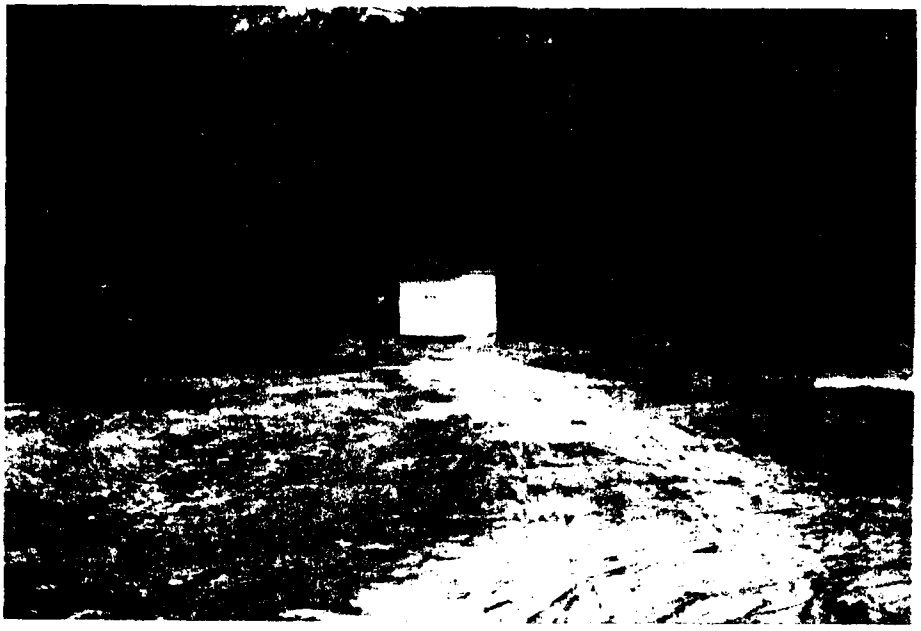


Photo No. 7 - View of crest of dam from left abutment.

Photo No. 8 - View of downstream face of dam.

REPRODUCED AT GOVERNMENT EXPENSE

Photo No. 9 - View of downstream face of spillway structure.

Photo No. 10 - Closeup view of downstream face of dam at right training wall of spillway structure.

REPRODUCED AT GOVERNMENT EXPENSE

Photo No. 11 - View of downstream face of penstock outlet.

Photo No. 12 - Closeup view of downstream face of dam at penstock outlet.

REPRODUCED AT GOVERNMENT EXPENSE

Photo No. 13 - Downstream view of penstock outlet channel.

Photo No. 14 - View of downstream pond from dam.

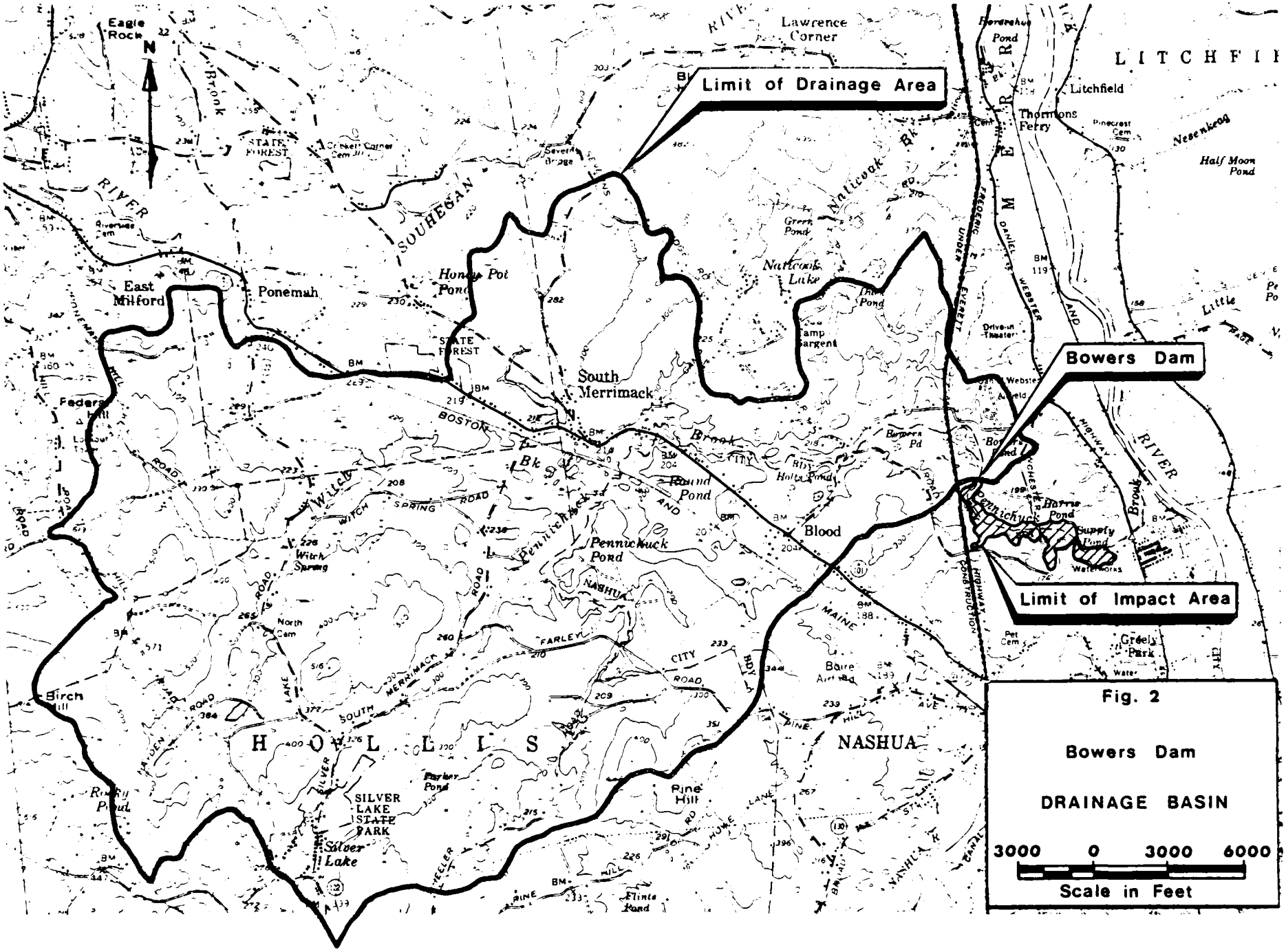
REPRODUCED AT GOVERNMENT EXPENSE

Photo No. 15 - View of downstream pond and roadway culvert.

REPRODUCED AT GOVERNMENT EXPENSE

APPENDIX D

HYDROLOGIC AND HYDRAULIC COMPUTATIONS


Limit of Drainage Area
Bowers Dam
Limit of Impact Area
Eagle Rock
N
Lawrence Corner
Horseshoe Pond
LITCHFIELD
Litchfield
Thornions Ferry
Half Moon Pond
Nesenkeag
Little
East Milford
Ponemah
Honey Pot Pond
Natticook Lake
Green Pond
Camp Sargent
South Merrimack
Round Pond
Pennichuck Pond
Blood
Pennichuck
Barrett Pond
Supply Pond
Waterworks
Greely Park
Witch Spring
North Cem
Birch Hill
HOLLIS
NASHUA
Pine Hill
SILVER LAKE STATE PARK
Silver Lake
Parker Pond
Flints Pond
Baire Airfield
Drive-in Theater
Fig. 2
Bowers Dam
DRAINAGE BASIN
3000 0 3000 6000
Scale in Feet

I. Basic Data

A. Drainage Area

1. 22.99 square miles - based on information on file with Pennichuck Water Works

2. drainage area would classify as rolling for estimating MPF Peak Flow Rates

B. Dam and Storage Information

1. Size Classification: INTERMEDIATE based on storage

   as indicated below storage at crest of dam estimated to be 1120 acre-feet

2. Hazard Classification: SIGNIFICANT

   Failure discharge will overtop Manchester St and two dam downstream from Bowers Dam

3. Storage Information

Descriptive Information	Elevation* (feet)	Surface* Area (acres)	Storage* (acre-ft)
190 feet Contour	190	320	3245
Test-fitted elev	185.9	242	2090
Top of Dam	180.9	147	1120
180 feet Contour	180	130	995
Top of 4' dia. spillway structure, approx. elev. normal full pond	177.84	87.3	761
Crest of permanent spillway weir	172.32	51.8	377

* Notes : (1) elevations : NGVD

(2) elevations based on information obtained from Pennichuck W.W. – elevation of 172.32 feet taken to correspond with permanent weir crest.

(3) Surface area at elevation 177.84 obtained from information provided by Pennichuck W.W. Other surface areas obtained from planimetering U.S.G.S. contour and interpolating for intermediate elevations

(4) Storage at elevation 177.84 feet and below obtained from information provided by Pennichuck Water Works

C. Spillway Information

1. Spillway structure located near right abutment. Structure has a series of 10 stop log bays, with stop logs set a various elevations. – avg elev = 177.2

a. for subsequent calculations will use average crest elevations for stop logs

2. Discharge over the spillway given by sharp-crest weir equation – to elevation 180.29 feet

$$Q = C L H^{3/2}$$ (Standard Handbook for CE's Manual)

where: Q = discharge, cfs
L = length of weir, feet
H = head over weir, feet
C = discharge coeff., varies with head over weir

3. Above elevation 180.29 feet, discharge over spillway will be given by orifice discharge equation, since the wooden beams supporting the deck above the spillway creates an orifice discharge condition above elevation 180.29.

$$Q = C a \sqrt{2gh}$$ (Standard Handbook for CE's, Merritt)

where: Q = discharge, cfs
a = area of orifice, sq. feet
g = acceleration due to gravity, 32.2 ft/sec²
h = head on horizontal center line of orifice, feet
C = discharge coefficient = 0.6

4. Above elevation 181.84 feet the discharge over the spillway will be a combination of orifice discharge (as discussed above) and discharge over the wood planking deck. Discharge over the deck will be defined by the broad-crested weir equation

$$Q = CLH^{3/2}$$ (Standard Handbook for CE's, Merritt)

where: Q, C, L and H as defined in I.C.2. with C = 2.6

II Estimate Effect of Surcharge Storage on Maximum Probable Discharge

A. Develop stage-discharge curve for outflow from dam site

1. define sources of outflow

a. discharge over spillway structure - as defined previously in I.C.

b. discharge over various portions of earth embankment and abutments - above elevation 180.9 feet

(1) use broad-crested weir equation with C = 2.6

2. Discharge over spillway

a. weir discharge above average crest elevation of 177.16 feet

Elevation (feet)	C	L (feet)	avg. H (feet)	Q (cfs)
177.2	—	—	0	0
178	3.3	42.6	0.8	109
179	3.4	↓	1.8	350
180	3.5	↓	2.8	699.1

b. orifice discharge above elevation 180.29

Elevation (feet)	C	a (ft²)	h (feet)	Q (cfs)
181	0.6	133	2.27	965
182	↓	↓	3.27	1160
183	↓	↓	4.27	1320
184	↓	↓	5.27	1470
185	↓	↓	6.27	1600
186	↓	↓	7.27	1730
187	↓	↓	8.27	1840
188	↓	↓	9.27	1950
189	↓	↓	10.27	2050
190	↓	↓	11.27	2150
191	↓	↓	12.27	2240
192	↓	↓	13.27	2330
193	↓	↓	14.27	2420

c. discharge over wood planking deck - above elevation 181.84

Elevation (feet)	C	L (feet)	H (feet)	Q (cfs)
181.84	2.6	44	0	0
182	↓	↓	0.16	7
183			1.16	143
184			2.16	363
185			3.16	643
186			4.16	971
187			5.16	1340
188			6.16	1750
189			7.16	2190
190			8.16	2670
191			9.16	3170
192			10.16	3700
193			11.16	4270

d. Summary of discharge over spillway (to 3 significant digits)

Elevation (feet)	Q_{weir}	$Q_{orifice}$	Q_{deck}	$Q_{spillway}$
177.2	0	—	0	0
178	100	—	0	100
179	350	—	0	350
180	699	—	0	699
181	—	965	0	965
182	—	1160	7	1170
183	—	1320	143	1460
184	—	1470	363	1830
185	—	1600	643	2240
186	—	1730	971	2700
187	—	1840	1340	3180
188	—	1950	1750	3700
189	—	2050	2190	4240
190	—	2150	2670	4820
191	—	2240	3170	[illegible]
192	—	2330	3700	[illegible]
193	—	2420	4270	[illegible]

3. Discharge over right abutment

a. between right training wall of spillway and Sta 0+24 (Profile B of Plans and Details)

Elevation (feet)	C	L (feet)	Ave H (feet)	Q (cfs)
181.4	—	—	0	0
182	2.0	14	0.3	6
183	↓	37	0.3	69
184	↓	56	1.3	216
185	↓	79	1.3	496
186	↓	83	2.75	934
187	↓	↓	3.75	1570
188	↓	↓	4.75	2230
189	↓	↓	5.75	2930
190	↓	↓	6.75	3780
191	↓	↓	7.75	4660
192	↓	↓	8.75	5590
193	↓	↓	9.75	6570

b. from Sta. 0+24 to further up slope

Elevation (feet)	C	L (feet)	Ave H (feet)	Q (cfs)
185.1	—	—	0	0
186	2.0	5	2.45	4
187	↓	11	2.95	27
188	↓	13	1.45	82
189	↓	24	1.95	172
190	↓	30	2.45	299
191	↓	36	2.95	474
192	↓	44	3.45	733
193	↓	50	3.95	920

C. Summary of discharge over right abutment (to 3 significant digits)

Elevation (feet)	Q_{3a}	Q_{3b}	$Q_{right\ abut.}$
181.4	0	0	0
182	6	0	6
183	69	0	69
184	216	0	216
185	496	0	496
186	984	4	988
187	1570	27	1600
188	2230	82	2310
189	2980	170	3150
190	3780	299	4080
191	4660	474	5130
192	5590	733	6320
193	6570	1020	7590

4. Discharge over earth embankment

a. between left training wall of spillway to ℄ of penstock

Elevation (feet)	C	L (feet)	Avg H (feet)	Q (cfs)
180.9	2.6	—	0	0
181	↓	5	0.05	<1
182	↓	80	1.2	273
183	↓	↓	2.2	629
184	↓	↓	3.2	1190
185	↓	↓	4.2	1890
186	↓	↓	5.2	2470
187	↓	↓	6.2	3210
188	↓	↓	7.2	4020
189	↓	↓	8.2	4890
190	↓	↓	9.2	5900
191	↓	↓	10.2	6750
192	↓	↓	11.2	7500
193	↓	↓	12.2	8300

4 Discharge over earth embankment – CONTINUED

b. between ℄ Penstock and ≈ Sta 3+30 (PROFILE B - Plans + Details)

Elevation (feet)	C	L (feet)	Ave H (feet)	Q (cfs)
181.1	—	—	0	0
182	2.6	80	0.8	149
183	↓	↓	1.8	502
184			2.8	975
185			3.8	1540
186			4.8	2190
187			5.8	2910
188			6.8	3670
189			7.8	4530
190			8.8	5430
191			9.8	6380
192			10.8	7380
193			11.8	8432

c between ≈ Sta 3+30 (PROFILE B - Plans + Details) and left abutment (≈ Sta 4+20)

Elevation (feet)	C	L (feet)	Ave H (feet)	Q (cfs)
181.1	—	—	0	0
182	2.6	43	0.45	34
183	↓	90	0.95	217
184		↓	1.95	657
185			2.95	1190
186			3.95	1940
187			4.95	2530
188			5.95	3400
189			6.95	4200
190			7.95	5250
191			8.95	6270
192			9.95	7340
193			10.95	8430

d. Summary of discharge over earth embankment

(to 3 significant digits)

Elevation (feet)	Q_{4a}	Q_{4b}	Q_{4c}	$Q_{\text{Earth Embankment}}$
180.9	0	0	0	0
181	<1	0	0	<1
182	273	149	34	456
183	679	502	217	1400
184	1190	975	637	2300
185	1790	1540	1190	4520
186	2470	2190	1840	6500
187	3210	2910	2580	8700
188	4020	3670	3400	11,100
189	4880	4530	4290	13,700
190	5800	5430	5250	16,500
191	6780	6330	6270	19,400
192	7800	7380	7340	22,500
193	8860	8430	8490	25,900

5. Discharge over left abutment

(to 3 significant digits)

Elevation (feet)	C	L (feet)	Ave H (feet)	Q (cfs)
183	—	—	0	0
184	2.6	13	2.5	17
185		35	1.0	91
186		53	1.5	253
187		71	2.0	522
188		89	2.5	915
189		107	3.0	1450
190		125	3.5	2130
191		143	4.0	2970
192		161	4.5	4000
193		179	5.0	5200

6. Summary of discharge from dam site

(to 3 significant digits)

Elevation (feet)	Q spillway	Q Right Abut	Q Earth Embankment	Q net inc.	Q TOTAL
177.2	0	0	0	0	0
178	100	0	0	0	100
179	350	0	0	0	350
180	699	0	0	0	699
181	965	0	<1	0	965
182	1170	6	456	0	1630
183	1460	69	1400	0	2930
184	1830	216	2800	17	4860
185	2240	496	4520	91	7350
186	2700	938	6500	253	10,400
187	3180	1600	8700	522	14,000
188	3700	2310	11,100	915	18,000
189	4240	3150	13,700	1450	22,500
190	4820	4080	16,500	2130	27,500
191	5410	5130	19,400	2970	32,900
192	6030	6320	22,500	4000	38,900
193	6690	7590	25,800	5200	45,300

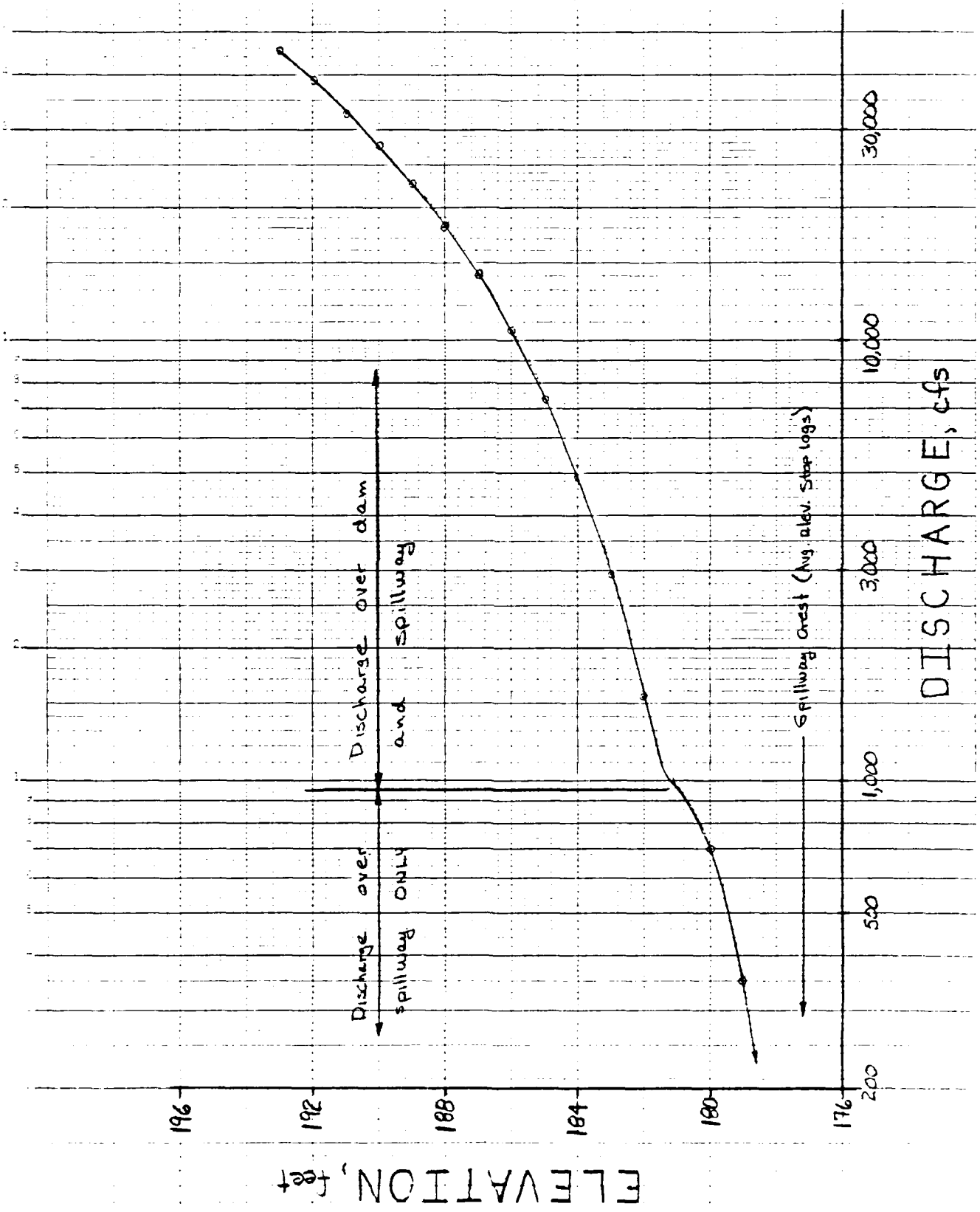
Discharge vs. Elevation shown graphically in Figure 1

Bowers Dam

Job # 274-7901

FIGURE 1

DISCHARGE vs. ELEVATION



B. Effect of surcharge storage on max. prob. discharge

1. Pertinent Data

a. Drainage area = 22.99 square miles

b. Characteristics of basin - combination of rolling and flat use point midway between curves

c. Test flood = use 1/2 PMF (Intermediate size and significant hazard)

d. Follow Army Corps' procedure

2. STEP 1: Determine Peak Inflow Q_{P1} from Guide Curve

a. the maximum probable discharge was estimated to be 1000 cfs/sq. mi

$$\therefore \text{PMF} = (22.99 \text{ square miles})(1000 \text{ cfs/sq.mi})$$

$$= 23{,}000 \text{ cfs}$$

$$1/2 \text{ PMF} = 11{,}500 \text{ cfs}$$

3. STEP 2: Determine surcharge height to pass Q_{P1}, $STOR_1$, and Q_{P2}

a. from Figure 1 determine surcharge height to pass Q_{P1} = 11,500 cfs

Surcharge elevation = 186.5 ft
avg elev Spillway weir crest ≈ 177.2 ft.
Surcharge height = 9.3 feet

b. determine volume of surcharge $STOR_1$ in inches of runoff

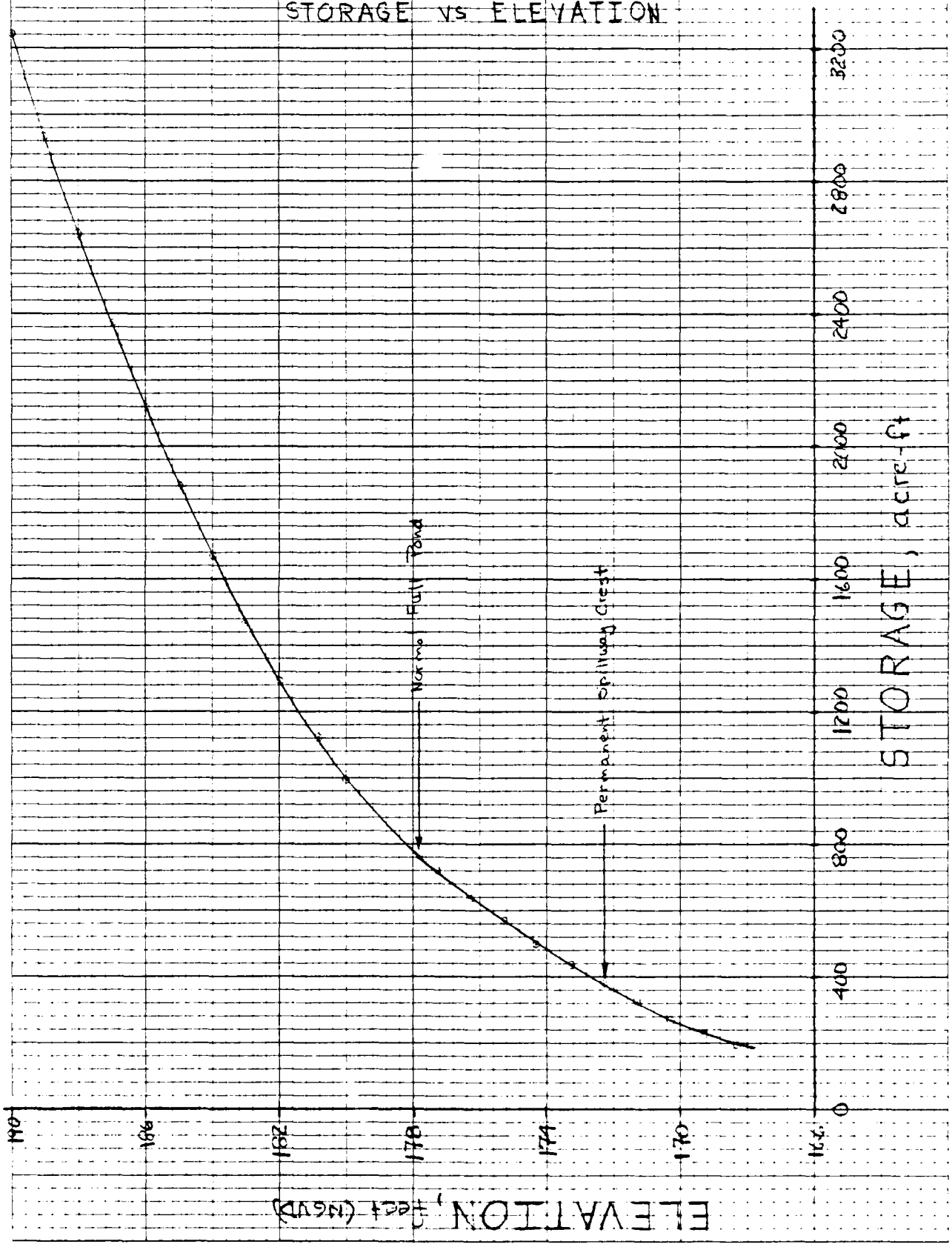
Find storage at surcharge elevation from Figure 2 ≈ 2240 acre-ft

Bowers Dam

Job # 274-7901

FIGURE 2

STORAGE vs ELEVATION



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NO. 341-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

(2) Volume of surcharge storage equals difference between storage at surcharge elevation and storage at spillway crest elevation (≈ 177.2 ft avg elev. of stop logs)

$$STOR_1 = \frac{\text{Volume of storage (as acre-inches)}}{\text{drainage area}}$$

$$STOR_1 = \frac{(2240 \text{ ac-ft} - 761 \text{ ac-ft})(12''/\text{ft})}{(22.99 \text{ sq.mi})(640 \text{ acre/sq.mi})}$$

$$STOR_1 = 1.21 \text{ inches}$$

c. determine Q_{P2}

$$Q_{P2} = Q_{P1}\left(1 - \frac{STOR_1}{9.5''}\right)$$

$$Q_{P2} = (11{,}500 \text{ cfs})\left(1 - \frac{1.21''}{9.5''}\right)$$

$$Q_{P2} = 10{,}000 \text{ cfs}$$

4. STEP 3: Determine surcharge height and $STOR_2$ to pass Q_{P2} and then Q_{P3}

a. From Figure 1 determine surcharge height to pass $Q_{P2} = 10{,}000$ cfs

surcharge elevation	=	185.8 ft
avg elev. spillway weir crest	≈	177.2 ft
surcharge height	=	8.6 feet

Storage @ surcharge elev. ≈ 2070 acre-ft

b. determine $STOR_2$

$$STOR_2 = \frac{(2070\ ac\text{-}ft - 761\ ac\text{-}ft)\ (12''/ft)}{(22.99\ sq.m.)(640\ acres/sq.m.)}$$

$$= 1.07\ inches$$

c. Average $STOR_1$ and $STOR_2$

$$STOR_{AVG} = \frac{STOR_1 + STOR_2}{2}$$

$$STOR_{AVG} = \frac{1.21\ inches + 1.07\ inches}{2}$$

$$STOR_{AVG} = 1.14\ inches$$

d. determine Q_{P3}

$$Q_{P3} = (11,500\ cfs)\left(1 - \frac{1.14''}{9.5''}\right)$$

$$Q_{P3} = 10,100\ cfs$$

5. STEP 4: Determine surcharge height for Q_{P3} and $STOR_3$

a. from Figure 1 surcharge height for Q_{P3} = 10,100 cfs

Surcharge elevation ≈ 185.8 ft
avg. elev. spillway weir crest ≈ 177.2 ft
Surcharge height = 8.6 feet

Storage at surcharge elev. ≈ 2070 acre-ft

b. determine $STOR_3$

$$STOR_3 = \frac{(2070\ ac\text{-}ft - 761\ ac\text{-}ft)\ (12''/ft)}{(22.99\ sq.m.)(640\ acres/sq.m.)}$$

$STOR_3$ = 1.0 inches

c. determine $STOR_{AVG}$

$$STOR_{AVG} = \frac{1.14 \text{ inches} + 1.07 \text{ inches}}{2}$$

$STOR_{AVG}$ = 1.11 inches

d. determine Q_{P4}

$$Q_{P4} = (11{,}500 \text{ cfs})\left(1 - \frac{1.11''}{9.5''}\right)$$

Q_{P4} = 10,200 cfs

6. STEP 5: Determine surcharge height for Q_{P4} and $STOR_4$

a. From Figure 1 surcharge height for Q_{P4} = 10,200 cfs

surcharge elevation ≈ 185.9 feet
avg elev. spillway weir crest ≈ 177.2 feet
Surcharge height = 8.7 feet
storage at surcharge height ≈ 2080 ac-ft

b. determine $STOR_4$

$$STOR_4 = \frac{(2080 \text{ ac-ft} - 761 \text{ ac-ft})(12''/\text{ft})}{(22.99 \text{ sq.mi})(640 \text{ acres/sq.mi})}$$

$STOR_4$ = 1.07 inches

c. determine $STOR_{AVG}$

$$STOR_{AVG} = \frac{1.11 \text{ inches} + 1.07 \text{ inches}}{2}$$

= 1.09 inches

$STOR_4$ and $STOR_{AVG}$ agree to within 2%, therefore accept routed test flood outflow equal to 10,200 cfs at surcharge elevation of 185.9 feet

7. In Conclusion

a. Routed test flood outflow = 10,200 cfs will overtop dam by 5 feet

b. Spillway capacity

(1) water surface at crest of dam - elevation = 180.9 feet - orifice discharge condition

(a) normal avg. stop log elevation = 177.2 ft

$$Q = (0.6)(133\ ft^2)\left[(2)(32.2)(180.9' - 178.7')\right]^{1/2}$$

$$Q \approx 950\ cfs$$

(b.) all stop logs removed - weir crest = 172.32 ft

$$Q = (0.6)\left[(42.6')(7.97')\right]\left[(2)(32.2)(180.9' - 176.31')\right]^{3/2}$$

$$Q \approx 3,500\ cfs$$

(2) water surface at routed test flood elevation elevation = 185.9 feet

(a) will have a combination of orifice discharge and discharge over wood pinnacle decks

(b) normal avg. stop log elevation = 177.2 ft.

(1) orifice discharge

$$Q = (0.6)(133\ ft^2)\left[(2)(32.2)(185.9' - 178.7')\right]^{1/2}$$

$$Q \approx 1{,}720\ cfs$$

(2) discharge over deck

$$Q = (2.6)(44\ feet)(185.9' - 181.84')^{3/2}$$

$$Q \approx 940\ cfs$$

(3) Total discharge

$$Q_{TOTAL} = 1{,}720\ cfs + 940\ cfs$$

$$Q_{TOTAL} = 2{,}660\ cfs$$

(c) all stop logs removed - weir crest = 172.32 ft

(1) orifice discharge

$$Q = (0.6)(42.6\ ft)(7.97\ ft)\left[(2)(32.2)(185.9' - 176.32')\right]^{1/2}$$

$$Q \approx 5{,}060\ cfs$$

(2) discharge over deck

$$Q = (2.6)(44\ feet)(185.9' - 181.84')^{3/2}$$

$$Q \approx 940\ cfs$$

(3) Total discharge

$$Q_{TOTAL} = 5{,}060\ cfs + 940\ cfs$$

$$Q_{TOTAL} = 6{,}000\ cfs$$

III. Using "Rule of Thumb" Guidance for Estimating Downstream Dam Failure Hydrographs examine impact of dam failure

1. Pertinent Data

a. Failure occurs when reservoir level at crest of dam - elevation = 180.9 feet

b. Storage at crest elevation estimated to be approximately 1120 acre-feet. Storage below normal elevation of Harris Pond ≈ 180 acre-feet. Therefore storage above normal elevation of Harris Pond = 940 acre-feet.

A. Reach 1

1. STEP 1: Determine reservoir storage at time of failure

from previous calcs. storage = 940 acre-ft

2. STEP 2: Determine Peak Failure Outflow Q_{P1}

$$Q_{P1} = (8/27)\, W_b \sqrt{g}\, Y_o^{3/2}$$

where: W_b = Breach width (use 40% of total length)
= (0.4)(420 feet)
= 168 feet

Y_o = Total height from tailwater to pool level at failure

elev top of dam = 190.9 ft
typ. tailwater elev. ≈ 178.3 ft
12.6 ft

≈ 12.6 feet

$$Q_{P1} = (8/27)(168\text{ feet})(32.2)^{1/2}(12.6\text{ feet})^{3/2}$$

$$Q_{P1} \approx 12{,}600\text{ cfs}$$

Spillway discharge is small compared to failure discharge, therefore effect of tailwater need not be analyzed. Also if failure occurs most probably will include entire length of spillway therefore no additional discharge needs to be added to failure discharge

3. Step 3: Prepare stage - discharge curve for Reach 1

a. Pertinent Data

(1) discharge through Reach 1 will be controlled by the road culvert at Manchester Street

(2) discharge calculations through culvert and over roadway have been included in Section IV of the Hydrologic Calculations

b. see Figure 3 for Stage - Discharge curve

4. STEP 4: Estimate Reach Outflow

a. Determine stage for Q_{P_1} = 12,600 cfs from Figure 3 and find volume in reach

(1) stage = 6.7 feet (elevation ≈ 174.7 feet)

(2) volume in reach = (stage)(Average surface* area of pond)

*see Figure 5 in Section IV of the Hydrologic Calcs for pond surface areas at various elevation

$$\text{Volume} = V_1 = (2.0\text{ ft})\left(\frac{45.8\text{ acres} + 50.9\text{ acres}}{2}\right)$$

$$\rightarrow + (4.7\text{ ft})\left(\frac{56.9\text{ acres} + 78\text{ acres}}{2}\right)$$

$$V_1 = 420 \text{ acre-ft}$$

b. Determine $Q_{P2(TRIAL)}$

$$Q_{P2(TRIAL)} = Q_{P1}\left(1 - \frac{V_1}{S}\right)$$

$$Q_{P2(TRIAL)} = (12{,}600 \text{ cfs})\left(1 - \frac{420 \text{ ac-ft}}{940 \text{ ac-ft}}\right)$$

$$Q_{P2(TRIAL)} = 6{,}970 \text{ cfs}$$

c. Compute V_2 using $Q_{P2(TRIAL)}$

From Figure 3 determine stage for $Q_{P2(TRIAL)}$

Stage = 5.0 feet (elevation ≈ 173.0 ft)

$$V_2 = (2.0 \text{ ft})\left(\frac{45.8 \text{ ac} + 56.9 \text{ ac}}{2}\right) + (3.0 \text{ ft})\left(\frac{56.9 \text{ ac} + 70.0 \text{ ac}}{2}\right)$$

$$V_2 = 293 \text{ acre-ft}$$

d Average V_1 and V_2 and compute Q_{P2}

(1) $$V_{avg} = \frac{V_1 + V_2}{2}$$

$$V_{avg} = \frac{420 \text{ ac-ft} + 293 \text{ ac-ft}}{2}$$

$$V_{avg} = 357 \text{ acre-ft}$$

(2) $$Q_{P2} = Q_{P1}\left(1 - \frac{V_{avg}}{S}\right)$$

$$Q_{P2} = (12{,}600 \text{ cfs})\left(1 - \frac{357}{940}\right)$$

$$Q_{P2} = 7{,}820 \text{ cfs}$$

B. Reach 2

1. STEP 3. Prepare stage-discharge curve for Reach 2

a. Pertinent Data

(1) discharge through reach will be controlled by Harris Pond Dam

(2) discharge calculations for Harris Pond Dam have been included in Section IV of the Hydrologic Calculations

b. see Figure 3 for Stage-Discharge curve

2. STEP 4: Estimate Reach Outflow

a. Determine stage for Q_{P2} = 7,820 cfs from Figure 3 and determine volume in reach

(1) stage = 7.8 feet (elevation ≈ 175.5 ft)

(2) volume in reach = (stage)(Average surface* area of pond)

* see Figure 8 in Section IV of the Hydrologic Calcs for pond surface areas at various elevations

$$\text{Volume} = V_1 = (2.0\,ft)\left(\frac{37.5\,acres + 41.3\,acres}{2}\right) + (5.8\,ft)\left(\frac{41.3\,acres + 52.5\,acres}{2}\right)$$

$$V_1 = 351 \text{ acre-ft}$$

b. Determine $Q_{P3(TRIAL)}$

$$Q_{P3(TRIAL)} = Q_{P2}\left(1 - \frac{V_1}{S}\right)$$

$$Q_{P3(TRIAL)} = (7{,}820\,cfs)\left(1 - \frac{351}{940}\right)$$

$$Q_{P3(TRIAL)} = 4{,}900\ cfs$$

c. Compute V_2 using $Q_{P2\,(TRIAL)}$

From Figure 3 determine stage for $Q_{P3(TRIAL)}$

Stage = 6.4 feet (elevation ≈ 174.1 ft)

$$V_2 = (2.0\,ft)\left(\frac{37.5\,ac + 41.3\,ac}{2}\right) + (4.4\,ft)\left(\frac{41.3\,ac + 49.5\,ac}{2}\right)$$

$$V_2 = 279\ acre\text{-}ft$$

d. Average V_1 and V_2 and compute Q_{P2}

(1) $$V_{avg} = \frac{V_1 + V_2}{2}$$

$$V_{avg} = \frac{351\ ac\text{-}ft + 279\ ac\text{-}ft}{2}$$

$$V_{avg} = 315\ acre\text{-}ft$$

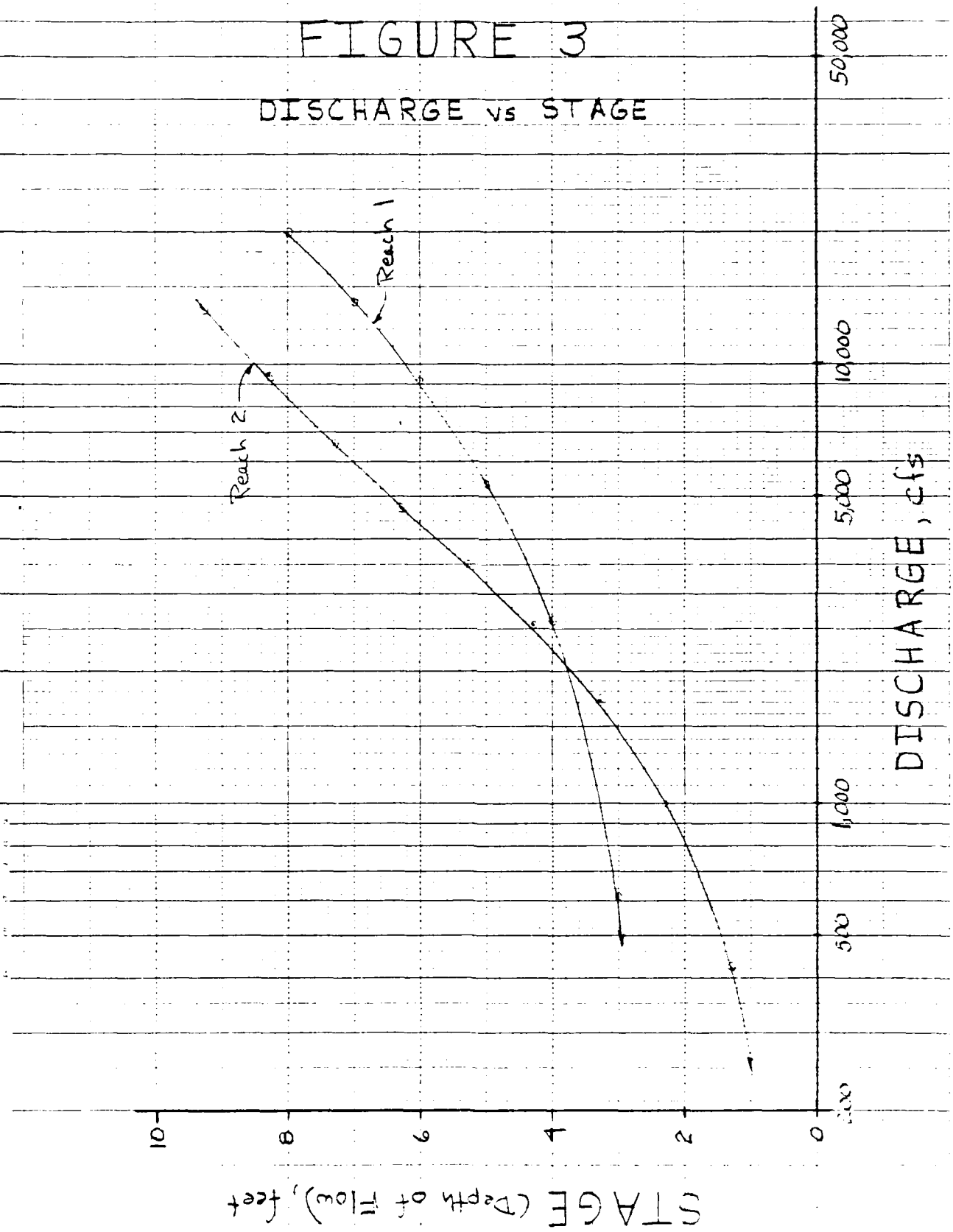
(2) $$Q_{P3} = Q_{P2}\left(1 - \frac{V_{avg}}{S}\right)$$

$$Q_{P3} = (7{,}820\,cfs)\left(1 - \frac{315}{940}\right)$$

$$Q_{P3} = 5{,}200\ cfs$$

FIGURE 3

DISCHARGE vs STAGE



IV Stage-Discharge Calculations for Reaches

A. Reach 1 – Stage-Discharge Calculations – Harris Pond @ Manchester Street Crossing

1. DISCHARGE THROUGH BOX CULVERT WITH SUBMERGED INLET (ABOVE ELEVATION 170.5)

$$Q = \left(\frac{2g\, R^{4/3} A^2 H}{29\, n^2 L}\right)^{1/2} = \left(\frac{(2)(32.2)(1.11)^{1.333}(50)^2 H}{29(0.029)^2(20)}\right)^{1/2} = 616\, H^{1/2}$$

WHERE: $g = 32.2$ $R = 1.11$ $L = 20$ ft
$A = 50$ ft^2 $n = 0.029$ H = height above crown

ELEVATION (FT)	CONSTANT	$H^{1/2}$ (FT)	Q (CFS)
171	616	0.71	440
172	↓	1.23	760
173	↓	1.58	970
174	↓	1.87	1150
175	↓	2.12	1310
176	↓	2.35	1450

2. Discharge over Manchester Street (above Elev. 172.5)

use formula for broad-crested weir $Q = CLH^{3/2}$

a. Discharge over "flat" portion of road surface profile

Elevation (feet)	C	L (feet)	H feet	Q (cfs)
170.5	2.6	160	0	0
171	↓	↓	0.5	150
172	↓	↓	1.5	1530
173	↓	↓	2.5	3290
174	↓	↓	3.5	5450
175	↓	↓	4.5	7940
176	↓	↓	5.5	10 700

b. Discharge over "sloped" portion of road surface profile

Elevation (feet)	C	Total L (feet)	Avg H (feet)	Q (cfs)
170.5	2.6	0	0	0
171	↓	60	0.25	20
172	↓	180	0.75	300
173	↓	300	1.25	1090
174	↓	420	1.75	2530
175	↓	540	2.25	4740
176	↓	660	2.75	7830

3 Total Discharge @ Manchester Street

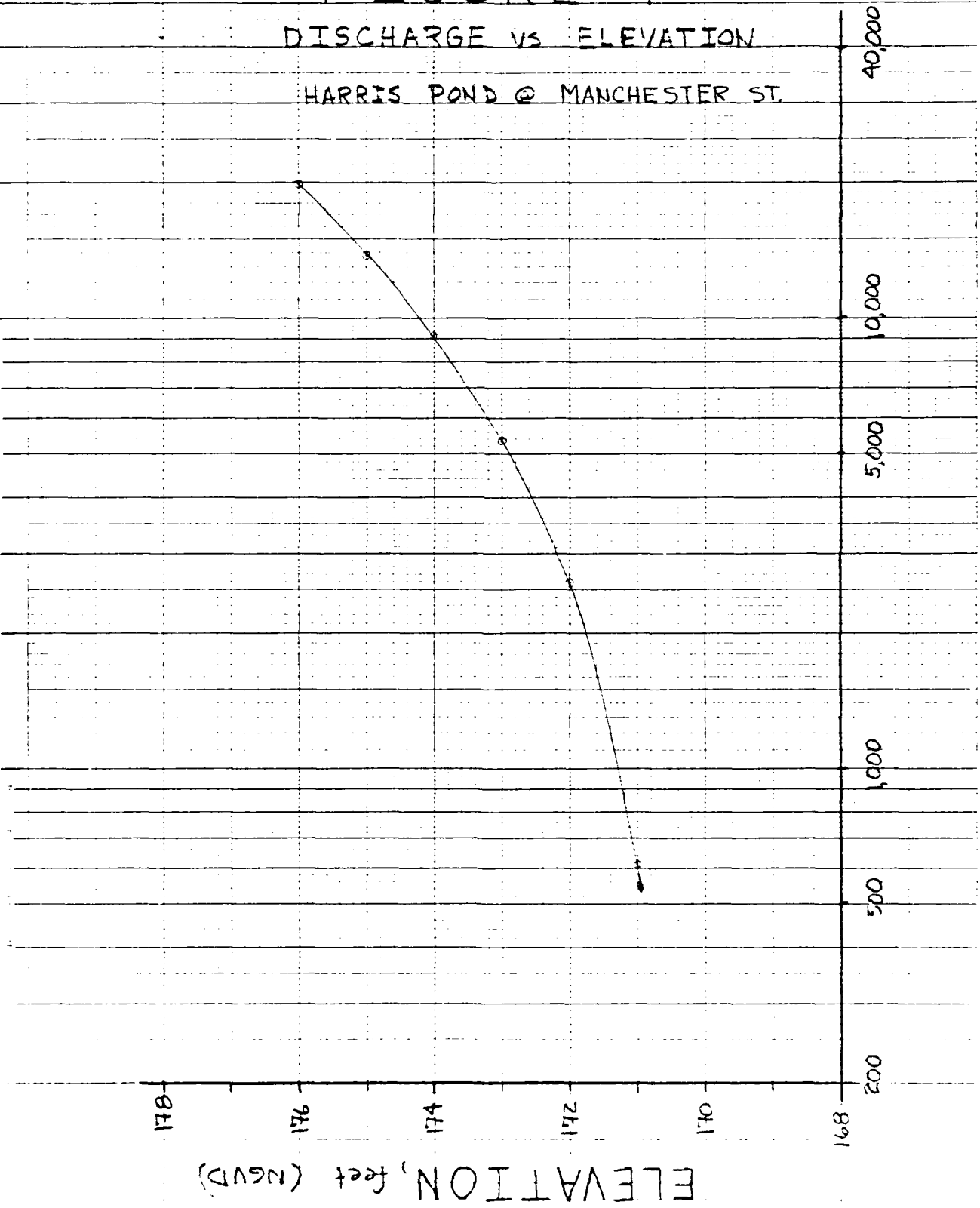
Elevation (feet)	Q culvert	Q flat portion road	Q sloped portion road	Q TOTAL
171	440	150	20	610
172	760	1530	300	2590
173	970	3290	1090	5350
174	1150	5450	2530	9130
175	1310	7940	4740	13,990
176	1450	10,700	7830	19,980

Bowers Dam Job # 274-7901

FIGURE 4

DISCHARGE vs ELEVATION

HARRIS POND @ MANCHESTER ST.



Bowers Dam Job No. 274-7301 4/1/80 KMS

FIGURE 5

SURFACE AREA vs ELEVATION

HARRIS POND ABOVE MANCHESTER STREET

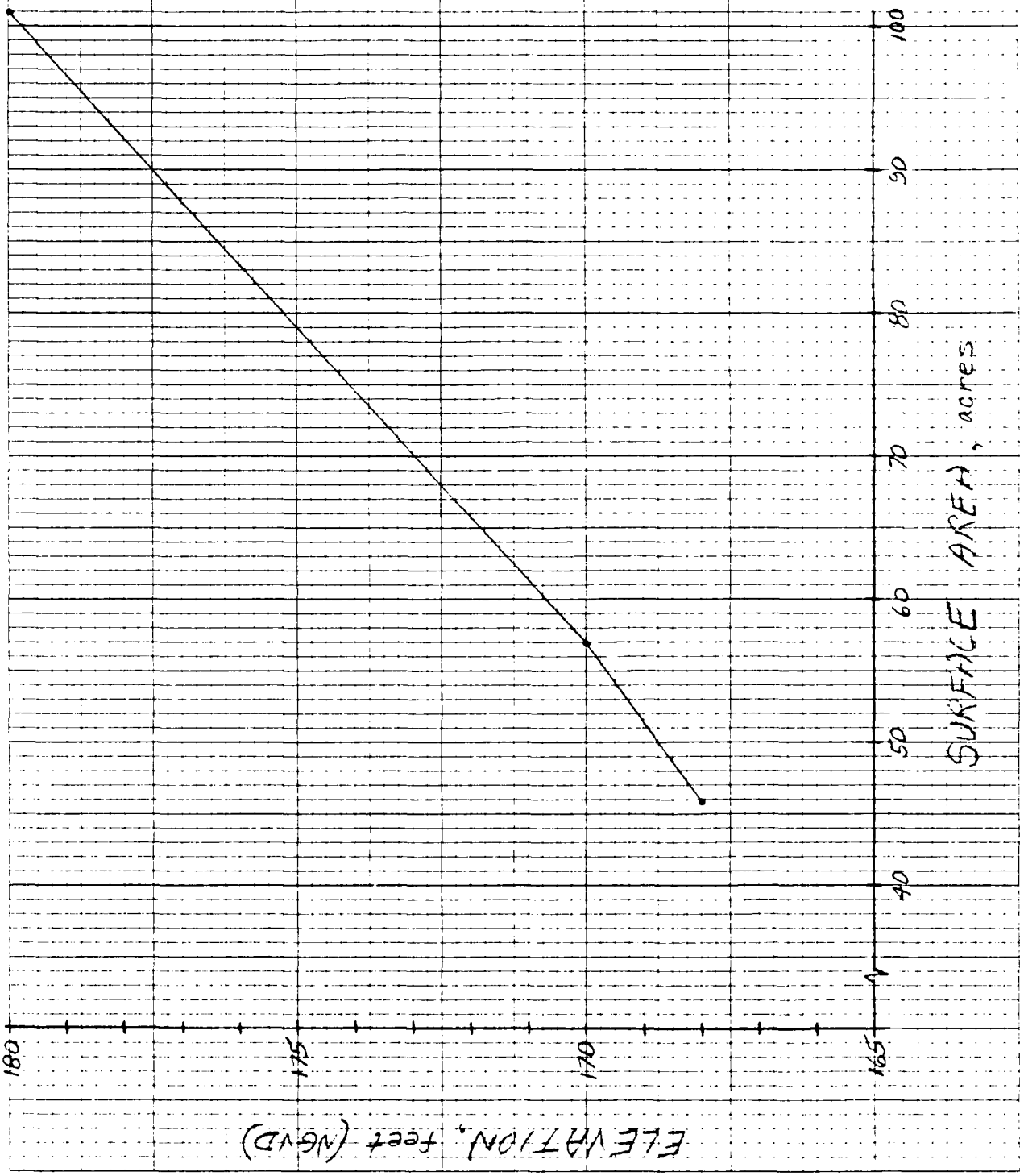


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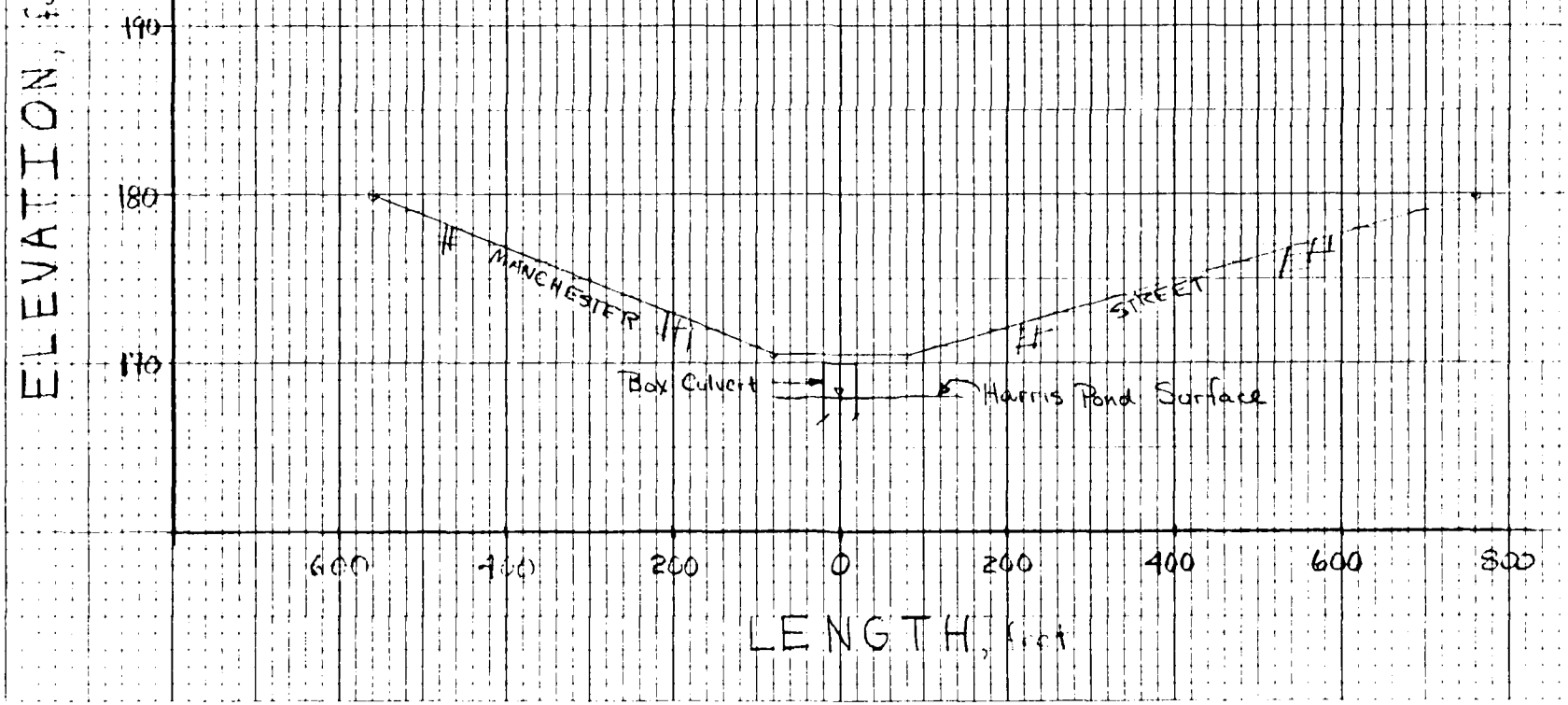
FIGURE 6

CHANNEL CROSS-SECTION

HARRIS POND @ MANCHESTER ST.

(VIEW LOOKING UPSTREAM)



B. Reach 2 - Stage-discharge calculations - Harris Pond Dam

1. Discharge over spillway - using sharp-crested weir equation

Elevation (feet)	C	L (feet)	H (feet)	Q spillway (cfs)
167.7	3.33	85	0	0
168	↓	↓	0.3	47
169	↓	↓	1.3	420
170	↓	↓	2.3	987
171	↓	↓	3.3	1700
172	↓	↓	4.3	2520
173	↓	↓	5.3	3450
174	↓	↓	6.3	4480
175	↓	↓	7.3	5580
176	↓	↓	8.3	6770
177	↓	↓	9.3	8030

2. Discharge over dam crest to left of spillway - using broad-crested weir equation

Elevation (feet)	C	L (feet)	H (feet)	Q left crest (cfs)
173.4	2.6	≈ 100	0	0
174	↓	↓	0.6	121
175	↓	↓	1.6	526
176	↓	↓	2.6	1090
177	↓	↓	3.6	1730

3. Discharge over left abutment

Elevation (feet)	C	L (feet)	Avg. H (feet)	Q left abut (cfs)
173.4	2.6	0	0	0
174	↓	15	0.3	6
175	↓	40	0.8	74
176	↓	65	1.3	250
177	↓	90	1.8	565

4. Discharge over dam crest and abutment to right of spillway

Elevation (feet)	C	L (feet)	Avg. H (feet)	Q right (cfs)
173.4	2.6	0	0	0
174	↓	80	0.3	34
175		210	0.8	39
176		340	1.3	1310
177		470	1.8	2950

5. Summary of discharge from dam site

Elevation (feet)	Q spillway	Q left abutment	Q [illegible] abutment	Q right	Q TOTAL
167.7	0	0	0	0	0
168	47	0	0	0	47
169	420	0	0	0	420
170	987	0	0	0	987
171	1700	0	0	0	1700
172	2520	0	0	0	2520
173	3450	0	0	0	3450
174	4480	121	6	34	4640
175	5580	526	74	391	6570
176	6770	1090	250	1310	9420
177	8030	1780	565	2950	13,325

BOWERS DAM JOB NO. 274-7701 4/8/80 KMS

ZUP

FIGURE 7

DISCHARGE VS. ELEVATION

HARRIS POND DAM

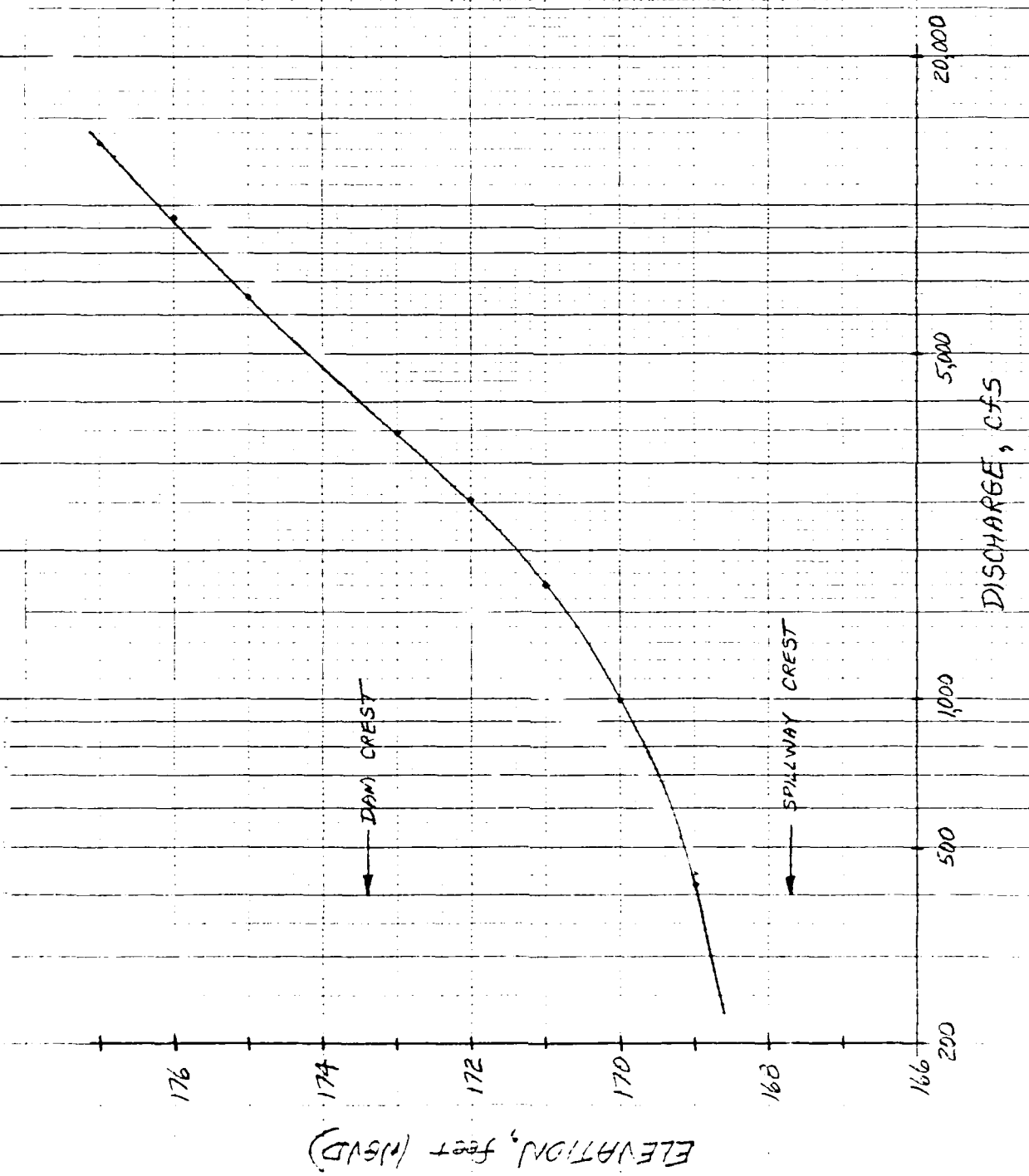


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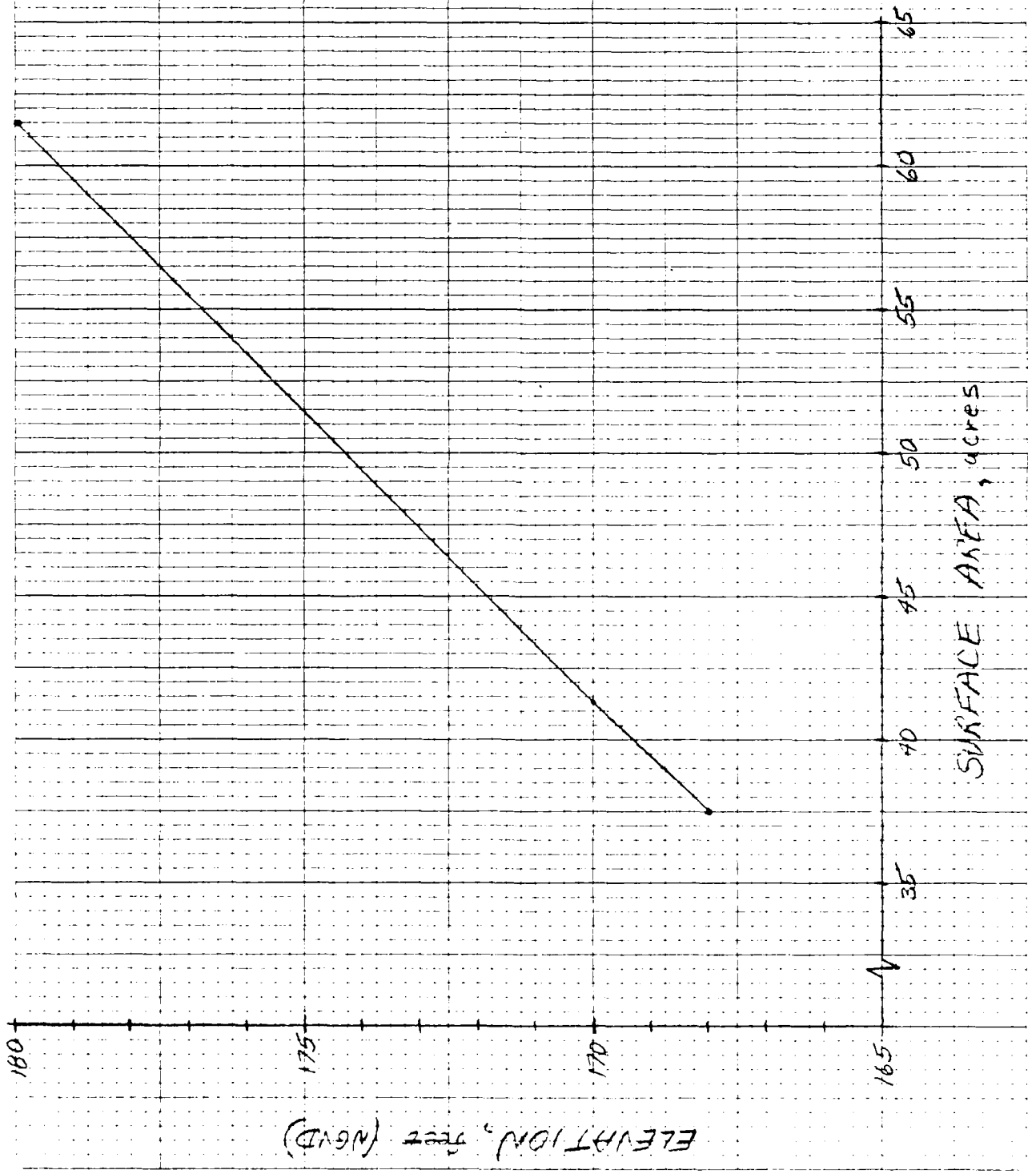
FIGURE 8

SURFACE AREA VS ELEVATION

HARRIS POND BELOW MANCHESTER STREET



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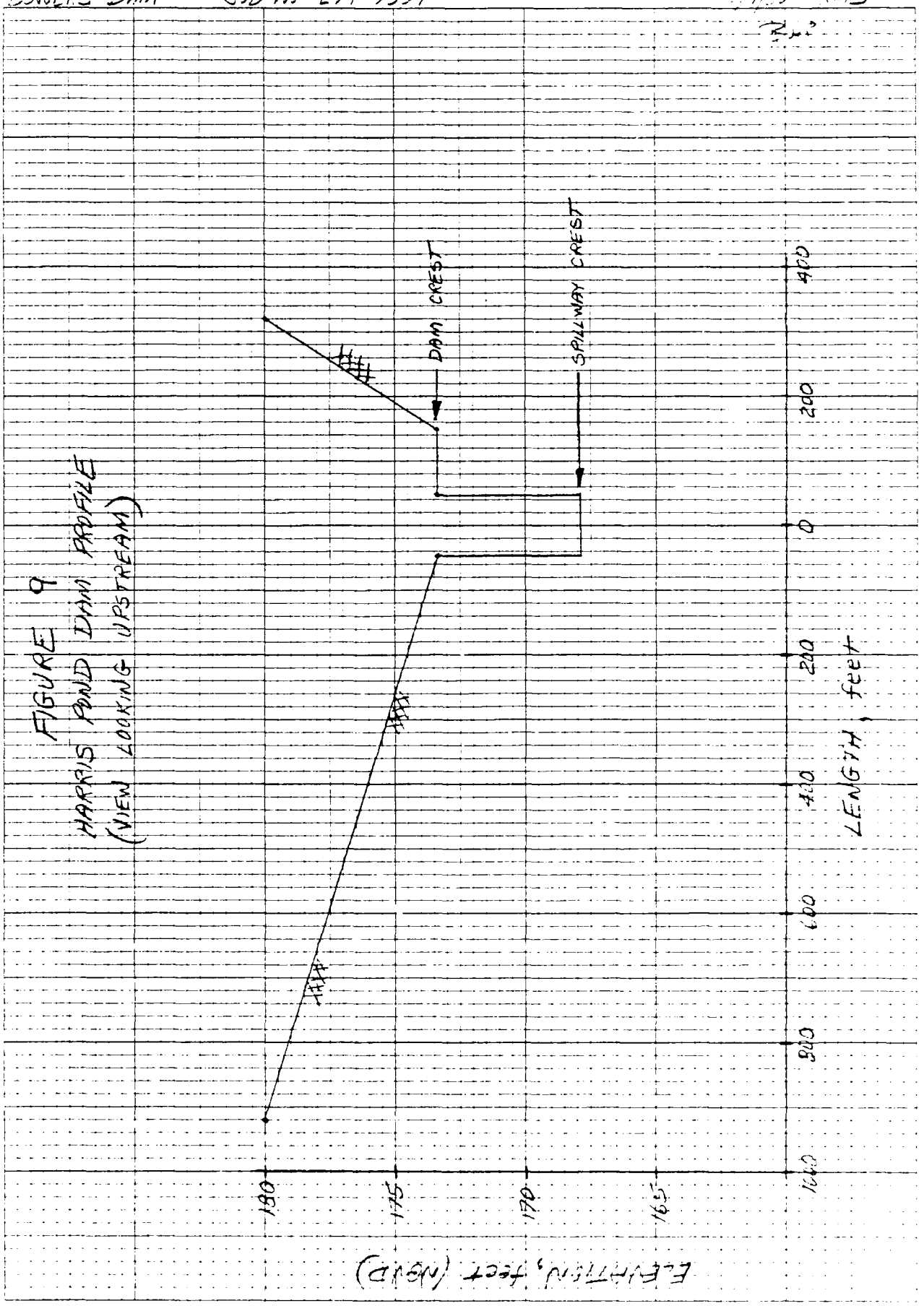

FIGURE 9
HARRIS POND DAM PROFILE
(VIEW LOOKING UPSTREAM)

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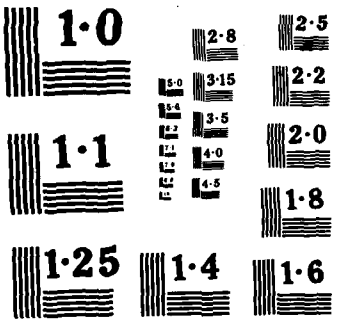
AD-A156 405 NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS 2/2
BOWERS DAM (NH 00330)..(U) CORPS OF ENGINEERS WALTHAM
MA NEW ENGLAND DIV MAY 80

UNCLASSIFIED F/G 13/13 NL



NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

V Determine discharge Through penstock

A. Use culvert headloss equation -

$$Q = \left(\frac{2g\ R^{1.33}\ A^2\ H}{29\ n^2\ L} \right)^{1/2}$$

$g = 32.2$ ft/sec² $\quad A = 19.63$ ft² $\quad L = 58$ ft

$R = 1.25 \quad n = 0.017 \quad H$ = height above crown of outlet, feet

$$Q = \left(\frac{(2)(32.2)(1.25)^{1.33}(19.63)^2\ H}{29(0.017)^2(58)} \right)^{1/2}$$

$$Q = 262\ H^{1/2}$$

1. Water surface at crest of dam - elevation = 190.9 ft

$$Q = 262(180.9 - 173.26)^{1/2}$$

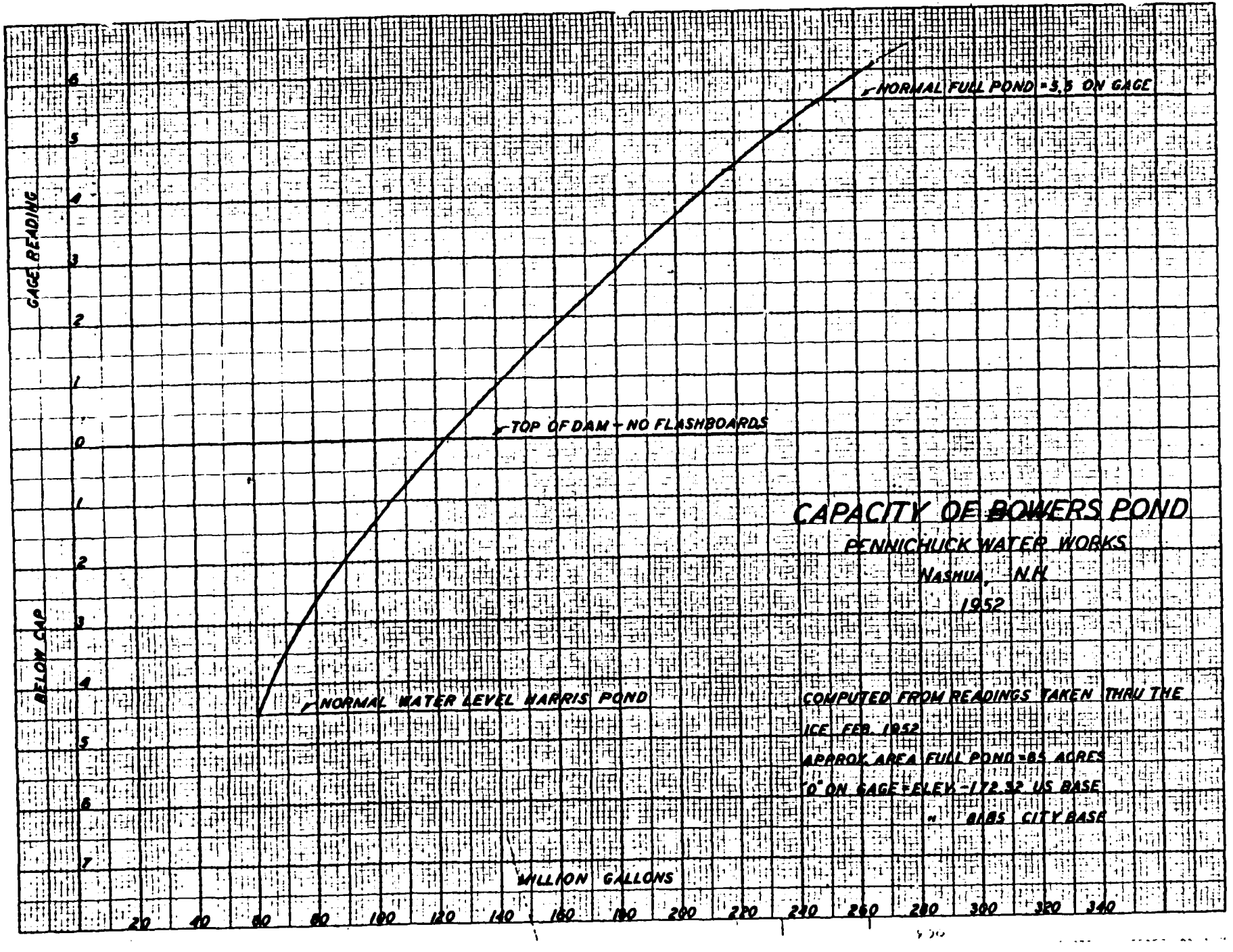
$$Q \approx 725 \text{ cfs}$$

2. Water surface at test flood elevation - elev = 185.9 ft

$$Q = 262(185.9 - 173.26)^{1/2}$$

$$Q \approx 930 \text{ cfs}$$

VI Information provided by Pendleton Water Works


CAPACITY OF BOWERS POND
PENNICHUCK WATER WORKS
NASHUA, N.H.
1952
COMPUTED FROM READINGS TAKEN THRU THE ICE FEB. 1952
APPROX. AREA FULL POND = 85 ACRES
"0" ON GAGE = ELEV. - 172.32 US BASE
" 81.85 CITY BASE
NORMAL FULL POND = 3.5 ON GAGE
TOP OF DAM - NO FLASHBOARDS
NORMAL WATER LEVEL HARRIS POND
GAGE READING
BELOW CAP
MILLION GALLONS
6
5
4
3
2
1
0
1
2
3
4
5
6
7
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340

Summary of Spillway Capacity at Dams

	Drainage Area in Sq. Mi.	Length of Spill-way in feet	Ht. of Top of Embkt above spill-way in feet	Corresp. Discharge c.f.s.	c.f.s. per sq. mile	Remarks
Holt	21.12	38.7	2.67'	560	26	No flash-boards
Bowers	22.99	44 net				
Max. ht. with 5.5' of flashboards			2.0	532	23	Waste gate also forms cir. overflo 4' in dia. included
With 4' of flash boards			3.5	1079	47	
Without flashboards			7.5	3280	143	
Harris (with 2' of flashboards)	24.71	85	5.7	3920	155	
Without flashboards			7.7	6050	242	
Supply Pond Without Flashboards	25.36	30	3.7	710	28	No deduction for obstructi caused by bri

Discharge capacity of the penstock approx. 300 c.f.s.

Flood discharges of streams as small as that of Pennichuck Brook (approximately 25 sq. miles) have frequently been observed exceeding 150 c.f.s. per sq. mile and in some cases exceeding 200 or even 250 c.f.s. per square mile.

PONDS ON THE WATERSHED OF THE PENNICHUCK WATER WORKS

Pond	Location	Storage Capacity Million Gals.	Surface Area Acres	Drainage Area Sq. Miles	Elevation U.S.G.A.
(a) SUPPLY	Nashua & Merrimack	54.3	17.9	25.36	136.75
(a) HARRIS	Merrimack	375.4	83.3	24.71	167.71
(a) BOWERS	"	248.	87.3	22.99	177.84
(a) HOLT	"	15.	35.+	21.12	183.03
(b) OLD PENNICHUCK	Nashua & Hollis		50.+		186.+
(c) STUMP	Merrimack		12.+	1.65	194.+
(c) DUNCKLEE	Hollis		5.+	1.75	
(d) LONG	"		32.77		274.+
(d) PARKERS	"		6.8		230.+
(d) HAYDEN'S MILL	"		4.+		

(a) Ponds and dams owned, controlled, and maintained by the Pennichuck Water Works.

(b) Owned in part by Pennichuck Water Works.

(c) Dam site and water rights owned by Pennichuck Water Works.

(d) No control by P. W. W. Data shown from State Planning Board.

REPRODUCED AT GOVERNMENT EXPENSE

END

FILMED

8-85

DTIC