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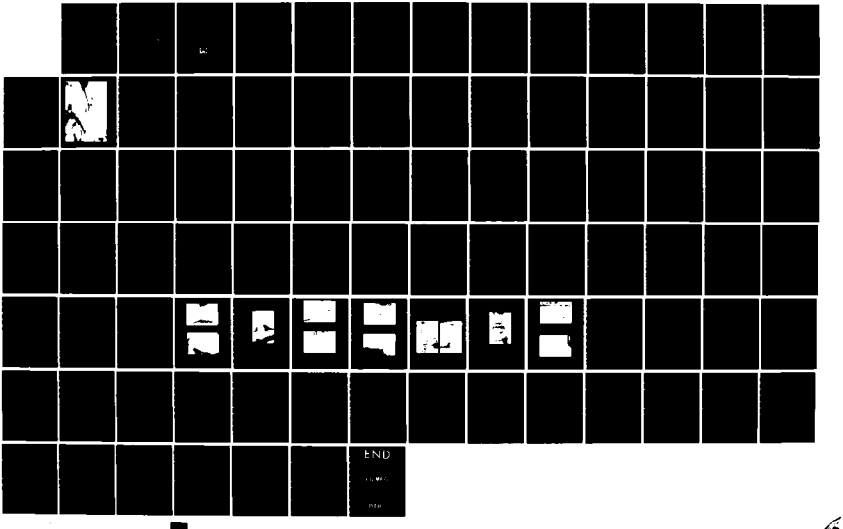

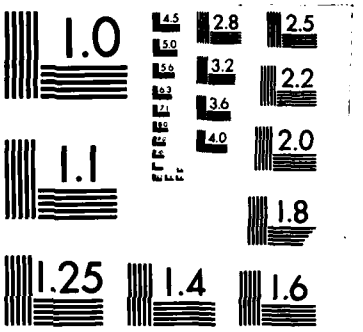

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LAKE MEMPHREMAGOG BASIN
BARTON, VERMONT

CRYSTAL LAKE DAM
VT 00008

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

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

JUNE, 1980

REPRODUCED AT GOVERNMENT EXPENSE
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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,
Lake Memphremagog Basin
Barton, VT.
Crystal Lake Outlet

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

TXe dam is an ashlar masonry and concrete buttress structure about 65 ft. long and 16.9 ft. high. The dam is in fair condition. No evidence of structural instability was observed, but two adjacent conditions which could indirectly affect dam stability were noted. It is intermediate in size with a high hazard potential. There are various remeidal measures which should be undertaken by the owner.

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CRYSTAL LAKE DAM

VT 00008

LAKE MEMPHREMAGOG BASIN
BARTON, VERMONT

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

LETTER OF TRANSMITTAL

FROM THE CORPS OF ENGINEERS TO THE STATE

TO BE SUPPLIED BY THE CORPS OF ENGINEERS

BRIEF ASSESSMENT

PHASE I INSPECTION REPORT

NATIONAL PROGRAM OF INSPECTION OF DAMS

Identification Number:	VT 00008
Name of Dam:	CRYSTAL LAKE DAM
Town:	BARTON
County and State:	ORLEANS COUNTY, VERMONT
Stream:	CRYSTAL LAKE OUTLET
Date of Inspection:	MAY 7, 1980

The dam, originally constructed about 1860 and extensively reconstructed in 1966, is an ashlar masonry and concrete buttress structure approximately 65 feet long and 16.9 feet in height. Both upstream and downstream faces are vertical. The dam has two broad crested drop spillways; the primary 23.5 feet long located at the central portion, the secondary 21.5 feet long to the left of and 6 inches higher than the primary. The manually operated gated low level outlet, located on the left side, is approximately 2 feet wide by 4 feet high and is reported to be operable.

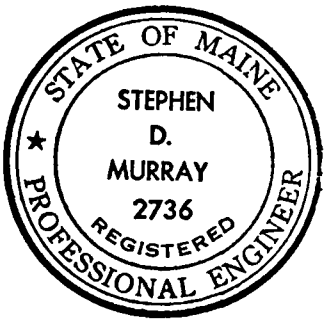
The dam impounds Crystal Lake and the discharge flows in a northwesterly direction approximately 1800 feet to its confluence with the Barton River. Originally constructed as a mill dam, the structure is now used to maintain the level of Crystal Lake. The lake is 14,300 feet in length with a surface area of 702 acres. Normal storage capacity is about 2808 acre-ft.

Based upon the visual inspection and the review of available data regarding this facility, the dam is considered to be in FAIR condition. No evidence of structural instability was observed, but two adjacent conditions which could indirectly affect dam stability were noted as follow: failure of a cracked and displaced retaining wall upstream of the right abutment could reduce the integrity of the building foundation against which the right end of the dam abuts, and a crumbling foundation wall downstream of the right abutment could induce a chain reaction weakening the right dam abutment.

In accordance with the Corps of Engineers Guidelines and the size (INTERMEDIATE) and hazard (HIGH) classification of the dam, the Test Flood is equivalent to the Probable Maximum Flood (PMF). Peak inflow to Crystal Lake is 40,033 cfs; routed peak outflow from the dam is 9000 cfs with the water elevation 5.6 feet over the dam crest. The spillway capacity is 1700 cfs, which is equivalent to 19% of the routed Test Flood outflow from the dam.

It is recommended that the owner engage a qualified, registered engineer to inspect the spillways and dam face under no-flow conditions, investigate the necessity to repair deteriorated concrete upstream and downstream of the right abutment and to perform a detailed hydrologic and hydraulic investigation to further assess the need for and means to increase the project discharge capacity. These and remedial measures which are discussed in Section 7 should be instituted within one year of the owner's receipt of this report.

Stephen D. Murray, P.E.
Project Manager
James W. Sewall Company



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

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

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

SAUL COOPER, Member
Chief, Water Control Branch
Engineering Division

APPROVAL RECOMMENDED:

JOE B. FRYAR
Chief, Engineering Division

THIS SHEET TO BE FURNISHED BY THE CORPS OF ENGINEERS

PREFACE

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

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

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

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

The Phase I Investigation does <u>not</u> 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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SECTION 5: EVALUATION OF HYDRAULIC/HYDROLOGIC FEATURES

5.1 GENERAL

The project is basically a low surcharge storage-high spillage gravity dam, currently used to impound water for recreational use only.

The tributary watershed consists of 23.9 square miles of relatively undeveloped steep terrain, approximately 90% wooded and containing no significant storage other than Crystal Lake. Crystal Lake has a surface area of 702 acres constituting less than 5% of the total drainage area.

Approximately 100 yards upstream of the dam is a crossing of the Canadian Pacific Railroad. The tracks are carried about 10 feet above the streambed by a deck plate girder bridge with a 20 foot span.

U.S. Route 5 crosses the stream approximately 50 yards upstream of the dam at a height of 14.5 feet above the streambed. The stream passes beneath the road through two 6 foot wide by 9 foot high granite box culverts.

Our hydraulics computations indicate that Crystal Lake Dam would control the streamflow at water levels below spillway elevation but the U.S. Route 5 crossing would restrict the flow at higher water levels. Once U.S. Route 5 is overtopped, a portion of the flow would be directed northward along Route 5 bypassing Crystal Lake Dam and rejoining the main stream just below the West Street Bridge. Approximately 46% of the routed test flood outflow from Crystal Lake would be diverted at the U.S. Route 5 crossing. The spillways would accommodate 19% of the routed test flood outflow from the dam with the dam overtopped by 5.6 feet.

5.2 DESIGN DATA

No design data are known to exist for this project.

5.3 EXPERIENCE DATA

The maximum known flood at the dam site had an approximate recurrence interval of 30 years and occurred in November, 1927. Maximum flow during this event is estimated at (±) 800 cfs and would not have been sufficient to overtop Crystal Lake Dam.

5.4 TEST FLOOD ANALYSIS

The Test Flood for this high hazard, intermediate size dam is the Probable Maximum Flood (PMF). The PMF is equal to 40,033 cfs and was determined using the "mountainous" guide curve from the "Preliminary Guidance for Estimating Maximum Probable Discharge", dated March, 1978.

SECTION 4: OPERATIONAL AND MAINTENANCE PROCEDURES

4.1 OPERATIONAL PROCEDURES

a. General - No operating procedure, as such, is known to exist. A local firm, E. M. Brown and Son, are reported to have rights to draw down the lake to a maximum of one foot. These rights are not currently being exercised.

b. Warning System - No warning system is known to exist.

4.2 MAINTENANCE PROCEDURES

a. General - The dam receives no regular maintenance.

b. Operating Facilities - The gate stem and operating handle appear in good condition and show no sign of misuse.

4.3 EVALUATION

The operation and maintenance procedures at this 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 a warning system to follow in the event of flood flow conditions or imminent dam failure.

Immediately upstream from the right abutment of the dam is a building on a foundation wall which forms the right side of the dam approach channel. This wall has several serious cracks, one, visible in Photo 4, about 20 feet upstream from the dam, about 1/2 inch wide and extending below the water line; others shown in Photo 5 just upstream of the building at a bend in the wall. Upstream of the building the wall is cracked and tilted toward the stream approximately 3 inches. Our examination indicates the above damage occurred some time ago, and there is no visible indication of recent movement.

Upstream of the U.S. Route 5 bridge crossing, as shown in Photo 6, the left bank is a granite block retaining wall in good condition and the right bank is natural ground.

About 50 yards upstream of the roadway crossing, a deck plate girder bridge carries the Canadian Pacific railroad tracks over the stream. The downstream face of the bridge, and its granite block abutments, are shown in Photo 7 with Crystal Lake in the background.

e. Downstream Channel

The channel below the dam is shown in Photos 8 and 9. A considerable quantity of debris, visible in Photo 8, lies at the base of the dam. On the right side, also shown in Photo 8, is a badly cracked building foundation on piers about 60 feet downstream of the right abutment. The West Street bridge, shown in Photo 8, is about 110 feet below the dam. Below this bridge the channel is extremely steep and contains the remains of three old dams. There are bedrock outcrops along the channel floor.

Photo 10, looking upstream, shows the remnants of two old dams and the buildings abutting the channel.

The second roadway crossing below the dam is the Vt. Route 16 bridge located about 500 yards downstream. This bridge contains some debris as shown in Photo 11. As shown in Photo 12, the channel is less steep at this location with low banks and residences in close proximity.

3.2 EVALUATION

On the basis of visual examination the dam is considered to be in fair condition.

A failure of the retaining wall shown in Photo 5, if uncorrected, could reduce the integrity of the building foundation against which the right end of the dam abuts.

A crumbling foundation wall, shown on the right side of Photo 8 could, upon failure, induce a chain reaction weakening the right dam abutment.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General - At the time of inspection on May 7, 1980, the water level in Crystal Lake, impounded by the dam, was 6 inches over the primary spillway with a minor flow over the secondary spillway as shown in Photo 1. The weather was cloudy and cool with light showers. The general condition of this dam is fair.

b. Dam - The dam is constructed of ashlar masonry with a reinforced concrete cap on the crest of the masonry. The cap is deflected downstream at a point between the left abutment and the middle buttress. It appears this downstream deflection was a result of form movement during construction, rather than being indicative of dam movement. Three concrete buttresses extend from the vertical downstream face to the bedrock floor of the channel. Two of the buttress walls are integral with the dam abutments, and the third buttress is in the approximate center of the dam. The ashlar masonry is visible through the water in Photo 2. All visible masonry and concrete components of the dam appeared in good condition.

The dam is founded on bedrock which is exposed along the entire base of the dam. Photo 3 is a view of the right abutment showing the contact between the concrete buttress and the bedrock foundation.

c. Appurtenant Structures

Spillway

As shown in Photo 1, virtually the entire top of the dam is a spillway section. As far as could be observed, the spillway concrete is in good condition. No debris or other obstructions to flow were visible. No provision for flashboard attachment exists.

Outlet Structure

A low level outlet was constructed as an integral part of the left abutment concrete section. As shown in Photo 1, the outlet was partially open at the time of our inspection. The outlet is sufficiently low to relieve hydrostatic pressure from the dam and to facilitate dam repair. The mechanism appears in good condition and the outlet is reported to be operable.

d. Reservoir Area

The left shoreline immediately upstream of the dam is formed by a sloping glacial till surface. Upstream from this is an old frame mill building visible in Photo 1, founded on a reinforced concrete retaining wall forming the edge of the stream. This wall is severely eroded at water level and displays some minor cracking. The retaining wall located immediately upstream of the building and extending to the U.S. Route 5 highway bridge, is granite block in good condition.

SECTION 2: ENGINEERING DATA

2.1 DESIGN

a. Available Data - Available data consists of three sheets by Dubois and King, Engineers; Sheet 1, "Existing Dam" June, 1966; Sheet 2A "Proposed Dam Improvements - 'As-built'", October, 1966 and Sheet 3, "Misc. Details", June, 1966. Also available were Sheets 1 and 2, "Outlet Structure - Crystal Lake", Vermont State Water Conservation Board, October, 1954.

b. Design Features - The drawings, computations and inspection reports indicate the design features stated in Section 1.

c. Design Data - Design data consists of information on the drawings by Dubois and King and the two sheets by the Vermont State Water Conservation Board as listed in "Available Data".

2.2 CONSTRUCTION

a. Available Data - Information as contained in any plans, drawings, or specifications previously listed in "Design Data" or Appendix B.

b. Construction Considerations - Minor variations were noted in the dam as-built compared to the "As-built" drawing dated October, 1966. On the upstream face are two blocks of concrete, at and below the water level, on both the left and right sides which are not shown in the drawing. On the down-stream face, left of the left buttress, the concrete cap extends down to approximately the spillway elevation, and the ground at this point is at spillway elevation rather than at the outlet elevation.

2.3 OPERATION

Pond level readings are not taken on any regular schedule. No formal operation procedures are known to exist.

2.4 EVALUATION

a. Availability - Existing data was provided by the State of Vermont Agency of Environmental Conservation.

b. Adequacy - Detailed hydrologic/hydraulic data were not available. Design data and field measurements were utilized in conjunction with New England Division - Army Corps of Engineers "Preliminary Guidance for Estimating Maximum Probable Discharges" to perform the computations of outflow capacity.

The detailed engineering data required to perform an in-depth stability analysis of the dam was not available. The final assessment of the dam, therefore, must be based primarily on visual inspection, performance history, and spillway capacity computations.

c. Validity - A comparison of records, data, and visual observations reveals no significant discrepancies, other than those noted above, between design and as-built dimensions.

6.	Downstream channel:	30± ft wide channel bounded by masonry and concrete building foundation on one side
7.	General:	N/A

j. Regulating Outlets

1.	Invert:	938.8
2.	Size:	2'x4'
3.	Description:	Rectangular orifice in concrete section of crest wall (±) 3 ft thick
4.	Control mechanism	Manually operated outlet gate
5.	Other:	N/A

f.	Reservoir Surface	
1.	Normal pool	702 acres
2.	Flood control pool	N/A
3.	Spillway crest	702 acres
4.	Test flood pool	702± acres
5.	Top of dam	702± acres
g.	Dam	
1.	Type:	masonry & concrete gravity
2.	Length:	65± ft
3.	Height:	16.9± ft
4.	Top Width:	3 ft
5.	Side Slopes:	vertical
6.	Zoning:	N/A
7.	Impervious Core:	N/A
8.	Cutoff:	N/A
9.	Grout Curtain:	N/A
10.	Other:	N/A
h.	Diversion and Regulating Tunnel	N/A
i.	Spillway	
1.	Type:	masonry & concrete free overfall
2.	Length of weir:	45± ft
3.	Crest el.	23.5± ft @ 944.8 21.5± ft @ 950.3
4.	Gates:	N/A
5.	Upstream channel:	75± ft wide approach channel bounded by concrete building foundation on one side

8.	Total project discharge at top of dam el. 950.4:	1810 cfs
9.	Total project discharge at test flood el. 956.0:	9000 cfs

c. Elevation (Feet, NGVD)

1.	Streambed at toe of dam	933.5±
2.	Bottom of cutoff	N/A
3.	Maximum tailwater	942
4.	Recreation pool	945±
5.	Full flood control pool	N/A
6.	Spillway crest (Ungated)	944.8 primary 945.3 secondary
7.	Design surcharge (original design)	N/A
8.	Top of dam	950.4
9.	Test flood surcharge	956

d. Reservoir

1.	Length of normal pool	14300± ft.
2.	Length of flood control pool	N/A
3.	Length of spillway crest pool	14300± ft.
4.	Length of pool at top of dam	14300± ft.
5.	Length of test flood pool	14300± ft.

e. Storage

1.	Normal pool	2808 acre-ft
2.	Flood control pool	N/A
3.	Spillway crest pool	2808 acre-ft
4.	Top of dam	6740 acre-ft
5.	Test flood pool	10671 acre-ft

g. Purpose of Dam - Originally water power, currently recreational water level control.

h. Design and Construction History - The following information is believed to be accurate based upon plans and correspondence available and from conversations with persons familiar with the history of the dam. The dam is believed to have been originally constructed about 1860 to provide water power for a textile mill at the site. There is no record of post-construction changes until the dam was redesigned in 1966 by Dubois and King Engineers for the Vermont Department of Water Resources and reconstructed at that time by Murray and Blake Construction.

i. Normal Operational Procedures - The gated outlet is reported operable and remains partially open under normal operation. There are no regular operational procedures other than occasional checking.

1.3 PERTINENT DATA

a. Drainage Area - 23.9 square miles of steep relatively undeveloped terrain which is 10% open and 90% wooded.

b. Discharge at Dam Site - Discharge is from over the primary and secondary spillways and through the 2'x4' gated outlet. Elevations are referenced to NGVD datum.

1.	Outlet Works (conduits):	
	One 2'x4' gated outlet, invert el. 938.8, discharge capacity	110 cfs
2.	Maximum known flood at dam site: November, 1927, Magnitude estimated from information presented in June, 1977 HUD Flood Insurance Study	800 ± cfs
3.	Ungated spillway capacity at top of dam el. 950.4:	1700 cfs
4.	Ungated spillway capacity at test flood el. 956.0:	5000 cfs
5.	Gated spillway capacity at normal pool el. 945.0:	N/A
6.	Gated spillway capacity at test flood el. 956.0:	N/A
7.	Total spillway capacity at test flood el. 956.0:	5000 cfs

The 3 foot broad crest wall has a top elevation of 950.42 and is approximately 16.9 feet in height above the streambed. The primary and secondary spillways are straight drop spillways with breadths of 3 feet and 5 feet and crest elevations of 944.82 and 945.32, respectively.

The outlet structure consists of a rectangular orifice in the concrete portion of the crest wall, approximately 2 feet wide by 4 feet high with the bottom elevation at approximately 938.8. Control is achieved by a manually operated gate mechanism on the upstream side. The control mechanism is accessed from the left side via a railed walkway on the dam crest.

Two 1 foot wide concrete buttress walls with downstream slopes of 1 horizontal to 1 vertical extend from the left and right sides of the secondary spillway. An equivalent third downstream buttress wall extends from the crest wall at the left of the outlet works. Two massive concrete blocks are located on both the left and right sides of the upstream face of the dam. There appears to be a concrete and masonry core wall, top elevation 950.17, extending 25 feet to the left of the crest wall and then approximately 19 feet in an upstream direction. This may at one time have been an exposed portion of the dam which was subsequently backfilled.

Elevations are referenced to NGVD datum.

No instrumentation exists at this dam.

c. Size Classification - INTERMEDIATE - The dam impounds 6740 acre-feet of water with the water level at the top of the dam, which at elevation 950.42 is approximately 16.9 feet above the streambed elevation. According to the Recommended Guidelines, the dam is classified as intermediate in size since its impoundment is between 1000 acre-ft and 50,000 acre-ft.

d. Hazard Classification - HIGH - If the dam were to be breached, there is potential for considerable downstream damage and the loss of more than a few lives. Vermont Route 16, approximately 1500 feet downstream and 11 feet above the streambed would be inundated prior to dam failure, and 10 to 20 residential structures having sills ranging from 11 to 15 feet above the streambed would suffer prefailure damage. The rapid rise in flood stage from 17 feet to 23 feet due to the breach would inflict very considerable additional damage on structures already flooded, and flood approximately 5 additional residences with sills from 17 to 22 feet above streambed.

e. Ownership - Department of Water Resources
Agency of Environmental Conservation
Sate of Vermont
Montpelier, Vermont 05602
(802) 828-3361

f. Operator - Mr. A. Peter Barranco, Dam Safety Engineer
Water Quality Division
Department of Water Resources
Agency of Environmental Conservation
State of Vermont
Montpelier, Vermont 05602
(802) 828-2761

PHASE 1 INSPECTION REPORT

CRYSTAL LAKE DAM

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority - Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a National Program of Dam Inspection throughout the United States. 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. James W. Sewall Company has been retained by the New England Division to inspect and report on selected dams in the State of Vermont. Authorization and notice to proceed were issued to James W. Sewall Company under a letter of April 2, 1980 from William E. Hodgson, Jr. Colonel, Corps of Engineers. Contract No. DACW 33-80-C-0051 has been assigned by the Corps of Engineers for this work.

b. Purpose of Inspection Program - The purposes of the program are to:

1. Perform technical inspection and evaluation of non-federal dams to identify conditions requiring correction in a timely manner by non-federal interests.

2. Encourage and prepare the States to quickly initiate effective dam inspection programs for non-federal dams.

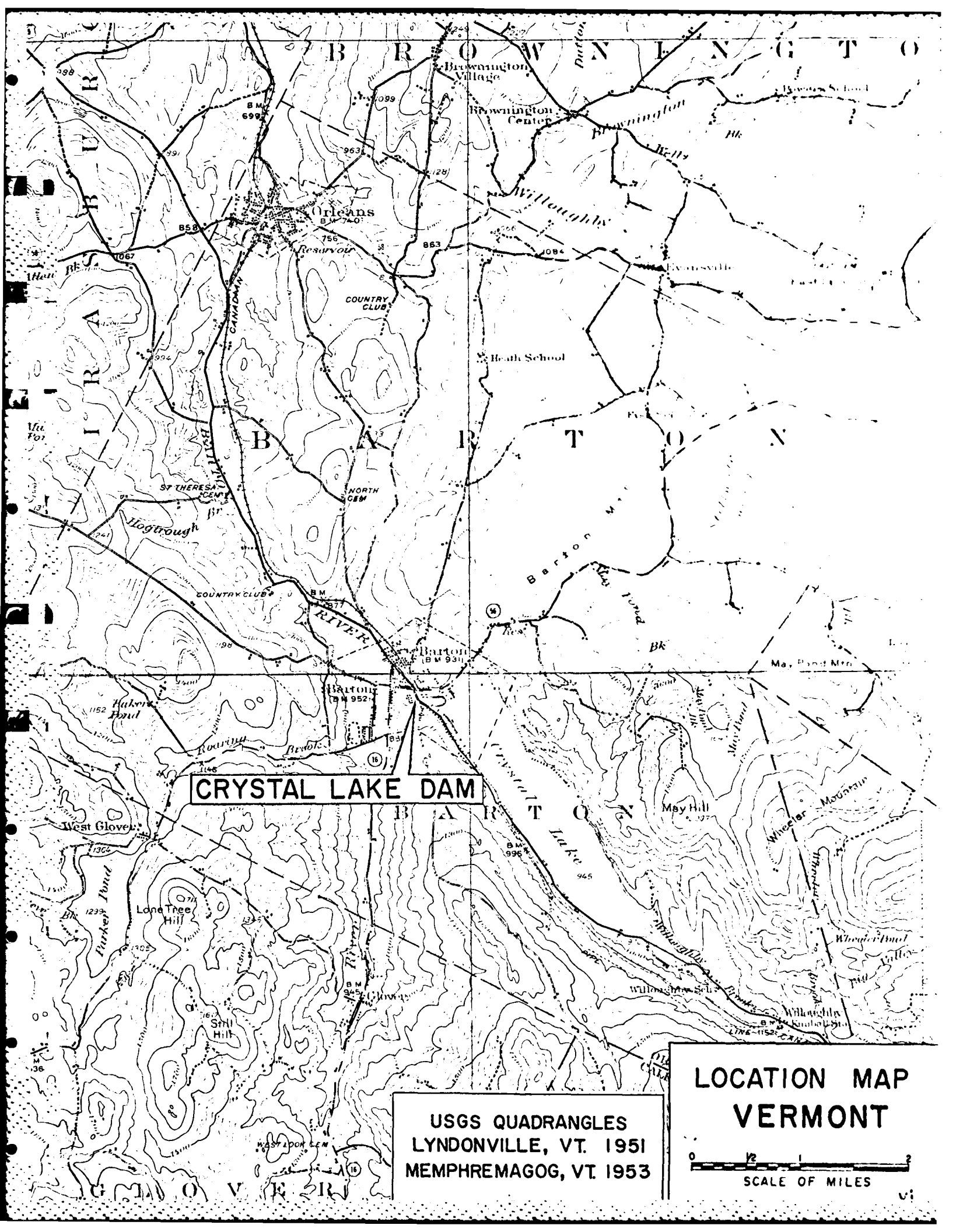
3. To update, verify and complete the National Inventory of Dams.

1.2 DESCRIPTION OF PROJECT

a. Location - The dam is located at the outlet of Crystal Lake in the Village of Barton, Town of Barton, County of Orleans, State of Vermont. The dam is shown on the Lyndonville USGS Quadrangle Map having coordinates latitude N 44° 44.8' and longitude W 72° 10.6'.

b. Description of Dam and Appurtenances - The dam, initially constructed about 1860 and reconstructed in 1966, has a total length of approximately 65 feet, including a 23.5 foot long primary spillway at the central portion of the dam, a 21.5 foot long secondary spillway at the right side of the dam, and a 20 foot long crest wall with outlet works at the left side of the primary spillway. Maximum dam height from bottom of downstream channel is 16.9 feet. The primary spillway is 11.3 feet above the downstream channel; the secondary spillway is 0.5 feet higher.

The dam is constructed mainly of ashlar masonry with a concrete cap on the crest. A full concrete section spans the leftmost 12 feet of the primary spillway and approximately 5.5 feet of the crest wall housing the outlet works.



USGS QUADRANGLES
LYNDONVILLE, VT. 1951
MEMPHREMAGOG, VT. 1953

LOCATION MAP
VERMONT

0 1/2 1 2
SCALE OF MILES

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

JAMES W. SEWALL COMPANY
CONSULTANTS
OLD TOWN, MAINE

NATIONAL PROGRAM OF
INSPECTION OF
NON-FED. DAMS

Crystal Lake Dam - VT 00008

Barton, Vermont

April 22, 1980

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APPENDIX

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With the level of Crystal Lake initially at spillway crest (el. 944.82 NGVD) the routed Test Flood outflow is 16,750 cfs with 7750 cfs bypassing the dam after being diverted by Route 5. The remaining 9000 cfs would reach Crystal Lake Dam and overtop it by 5.6 feet. Based upon our hydraulics computations, the spillway capacity is 1700 cfs which is approximately 19% of the routed Test Flood outflow from Crystal Lake Dam.

5.5 DAM FAILURE ANALYSIS

Utilizing the April, 1978, "Rule of Thumb Guidance for Estimating Downstream Dam Failure Hydrographs", the peak failure outflow with the pool initially at the top of the dam (el. 950.4 NGVD) would be approximately 3600 cfs. The portion of the flow diverted at U.S. Route 5 would rejoin the stream below the West Street Bridge and increase the failure flow to 3700 cfs. Storage downstream of the dam would not significantly attenuate the peak failure discharge until the confluence with the Barton River approximately 1800 feet downstream of the dam.

The prefailure flood would overtop Route 16 by 6 feet and cause extensive damage to 10 to 20 residential structures with a maximum depth at the houses of 6 feet. Although the prefailure flood would cause major damage, the failure flood would increase the stage at these houses by an additional 6 feet and flood approximately 5 more residences to depths of less than 5 feet. Vermont Route 16 would be overtopped by 12 feet and the private drive between the second and third dams downstream of Crystal Lake Dam would also suffer severe damage. There is a potential for the loss of more than a few lives and thus Crystal Lake Dam has been classified as a "High Hazard" dam.

SECTION 6: EVALUATION OF STRUCTURAL STABILITY

6.1 VISUAL OBSERVATION

The visual inspection indicates the following potential structural problems:

1. A failure of a cracked and displaced retaining wall, upstream of the right abutment shown in Photo 5, could, if uncorrected, reduce the integrity of the building foundation against which the right end of the dam abuts.

2. A crumbling foundation wall downstream of the right abutment shown in Photo 8 could, upon failure, induce a chain reaction weakening the right dam abutment.

6.2 DESIGN AND CONSTRUCTION DATA

No original design and construction data are available for the dam.

6.3 POST-CONSTRUCTION CHANGES

It is reported that the original masonry dam was constructed to provide water power for a mill at the site, probably around 1860. There is no record of post-construction changes until 1966. At that time the original operating mechanism and sluiceway were removed, the three buttresses added, the dam was capped to establish the new spillway, and the new outlet gate was installed.

6.4 SEISMIC STABILITY

The dam is located in Seismic Zone 2, and in accordance with the recommended Phase 1 guidelines does not warrant seismic investigation.

SECTION 7: ASSESSMENT, RECOMMENDATIONS AND REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Condition - Based upon the visual inspection, the dam is judged to be in fair condition.

b. Adequacy of Information - Due to the lack of design and construction data for this dam, the assessment of safety is based solely on the visual inspection.

c. Urgency - The remedial measures and recommendations presented below should be implemented by the owner within 1 year after receipt of this Phase I Inspection Report.

7.2 RECOMMENDATIONS

The owner should engage a qualified registered engineer to undertake further investigations as follow:

a. Inspect the spillways and dam face under no-flow conditions.

b. Assess the need to repair the cracked and crumbling concrete in the retaining wall and foundation upstream and downstream of the right abutment.

c. Perform a detailed hydraulic and hydrologic study to further assess the need for and means to increase the project discharge capacity. The owner should implement all recommendations by the engineer.

7.3 REMEDIAL MEASURES

a. A program of biennial technical inspection, with repairs as necessary, should be instituted by the owner.

b. A formal downstream warning system to be implemented in the event of flood flow or imminent dam failure conditions should be developed by the owner.

c. A formal program of operation and maintenance procedures should be instituted and fully documented to provide accurate records for future reference.

d. The owner should arrange for removal of debris from the downstream channel.

7.4 ALTERNATIVES

This study has identified no practical alternative to the above recommendations.

APPENDIX A

VISUAL CHECK LIST WITH COMMENTS

VISUAL INSPECTION CHECKLIST
PARTY ORGANIZATION

PROJECT Crystal Lake Dam

DATE May 7, 1980

TIME 9:00

WEATHER Cloudy 50°

W.S. ELEV. _____ U.S. _____ DN.S.

PARTY:

1. Stephen D. Murray S.D.M.
2. Rodney L. Hanscom R.L.H.
3. Charles A. Heney C.A.H.
4. Daniel P. LaGatta D.P.L.
5. Peter Barranco
6. _____
7. _____
8. _____
9. _____
10. _____

	PROJECT FEATURE	INSPECTED BY	REMARKS
1.	Granite and Concrete Dam	SDM, RLH, CAH, DPL	
2.	Retaining and Foundation Walls	SDM, RLH, CAH,	
3.	Intake Structure	SDM, RLH, CAH, DPL	
4.	Outlet Channel	SDM, RLH, CAH, DPL	
5.	Spillway Weir and Discharge Channel	SDM, RLH, CAH, DPL	
6.			
7.			
8.			
9.			
10.			

PERIODIC INSPECTION CHECKLIST

PROJECT Crystal Lake Dam DATE May 7, 1980

PROJECT FEATURE Granite and Concrete Dam NAME SDM, RLH,

DISCIPLINE James W. Sewall Co. NAME CAH, DPL
Geotechnical Engineers Inc.

AREA EVALUATED	CONDITION
DAM EMBANKMENT	Granite masonry dam with concrete cap and two concrete buttresses which appear to have been added after original dam was built.
Crest Elevation	
Current Pool Elevation	
Maximum Impoundment to Date	
Surface Cracks	None observed - water flowing over entire dam
Pavement Condition	No pavement
Movement or Settlement of Crest	None observed
Lateral Movement	Concrete cap on crest is not straight but misalignment appears to be result of construction
Vertical Alignment	
Horizontal Alignment	
Condition at Abutment and at Concrete Structures	Good
Indications of Movement of Structural Items on Slopes	None
Trespassing on Slopes	None
Sloughing or Erosion of Slopes or Abutments	None
Rock Slope Protection - Riprap Failures	N. A.
Unusual Movement or Cracking at or Near Toe	None observed. Water spilling over entire dam crest
Unusual Embankment or Downstream Seepage	Foundation below dam could not be observed due to spilling water
Piping or Boils	N.A.
Foundation Drainage Features	N.A.
Toe Drains	N.A.
Instrumentation System	N.A.
Vegetation	N.A.

PERIODIC INSPECTION CHECKLIST

PROJECT Crystal Lake Dam DATE May 7, 1980

PROJECT FEATURE Retaining and Foundation Walls NAME SDM, RLH

DISCIPLINE James W. Sewall Co. Geotechnical Engineers Inc. NAME CAH, DPL

AREA EVALUATED	CONDITION
DIKE EMBANKMENT 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 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 Vegetation	There is no dike as such on this project. Two building foundation walls and a retaining wall form the pool between the dam and U.S. Route 5. The foundation wall on the left is badly eroded at the water level with some minor cracking of the wall. The foundation wall on the right has several vertical cracks top to water level. The retaining wall on the right also has several cracks extending top to water level. This wall is tilted 3" out of plumb. There is no visible indication of recent movement of any of these walls.

PROJECT Crystal Lake Dam DATE May 7, 1980

PROJECT FEATURE Intake Structure NAME SDM, RLH

DISCIPLINE James W. Sewall Co. Geotechnical Engineers Inc. NAME CAH, DPL

AREA EVALUATED	CONDITION
OUTLET WORKS - INTAKE CHANNEL AND INTAKE STRUCTURE	
a. Approach Channel	Intake is below water surface on left abutment. There is no approach channel.
Slope Conditions	
Bottom Conditions	
Rock Slides or Falls	
Log Boom	
Debris	
Condition of Concrete Lining	
Drains or Weep Holes	
b. Intake Structure	
Condition of Concrete	Good
Stop Logs and Slots	None

PERIODIC INSPECTION CHECKLIST

PROJECT Crystal Lake Dam DATE May 5, 1980

PROJECT FEATURE _____ NAME SDM, RLH

DISCIPLINE James W. Sewall Co. Geotechnical Engineers Inc. NAME CAH, DPL

AREA EVALUATED	CONDITION
OUTLET WORKS - CONTROL TOWER	There is no control tower
a. Concrete and Structural	N.A.
General Condition	
Condition of Joints	
Spalling	
Visible Reinforcing	
Rusting or Staining of Concrete	
Any Seepage or Efflorescence	
Joint Alignment	
Unusual Seepage or Leaks in Gate Chamber	
Cracks	
Rusting or Corrosion of Steel	
b. Mechanical and Electrical	N.A.
Air Vents	
Float Wells	
Crane Hoist	
Elevator	
Hydraulic System	
Service Gates	
Emergency Gates	
Lightning Protection System	
Emergency Power System	
Wiring and Lighting System	

PERIODIC INSPECTION CHECKLIST

PROJECT Crystal Lake Dam DATE May 7, 1980

PROJECT FEATURE _____ NAME SDM, RLH

DISCIPLINE James W. Sewall Co. NAME CAH, DPL
Geotechnical Engineers Inc.

AREA EVALUATED	CONDITION
OUTLET WORKS - TRANSITION AND CONDUIT	There is no conduit
General Condition of Concrete	
Rust or Staining on Concrete	
Spalling	
Erosion or Cavitation	
Cracking	
Alignment of Monoliths	
Alignment of Joints	
Numbering of Monoliths	

PERIODIC INSPECTION CHECK

PROJECT Crystal Lake Dam DATE May 7, 1980

PROJECT FEATURE Outlet Channel NAME SDM, RLH,

DISCIPLINE James W. Sewall Co. NAME CAH; DPL
Geotechnical Engineers Inc.

AREA EVALUATED	CONDITION
OUTLET WORKS - OUTLET STRUCTURE AND OUTLET CHANNEL	
General Condition of Concrete	
Rust or Staining	
Spalling	
Erosion or Cavitation	
Visible Reinforcing	
Any Seepage or Efflorescence	
Condition at Joints	
Drain holes	None
Channel	Channel is within natural stream boundaries.
Loose Rock or Trees Overhanging Channel	No loose rock or trees for a distance of 50 yards to highway bridge. Below highway bridge the streambed is very steep. There are remnants of several old dams in the stream channel.
Condition of Discharge Channel	

PERIODIC INSPECTION CHECKLIST

PROJECT Crystal Lake Dam DATE May 7, 1980

PROJECT FEATURE Spillway Weir and Discharge Channel NAME SDM, RLH,

DISCIPLINE James W. Sewall Co. NAME CAH, DPL
Geotechnical Engineers Inc.

AREA EVALUATED	CONDITION
OUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS	
a. Approach Channel	There is no separate approach channel. Reservoir spills directly over dam.
General Condition	
Loose Rock Overhanging Channel	
Trees Overhanging Channel	
Floor of Approach Channel	
b. Weir and Training Walls	
General Condition of Concrete	Good
Rust or Staining	Minor rust stains
Spalling	None visible
Any Visible Reinforcing	No
Any Seepage or Efflorescence	None visible.
Drain Holes	None
c. Discharge Channel	Same as outlet channel.
General Condition	
Loose Rock Overhanging Channel	
Trees Overhanging Channel	
Floor of Channel	
Other Obstructions	

PERIODIC INSPECTION CHECK LIST

PROJECT Crystal Lake Dam DATE May 7, 1980

PROJECT FEATURE _____ NAME SDM, RLH

DISCIPLINE James W. Sewall Co. NAME CAH, DPL
Geotechnical Engineers Inc.

AREA EVALUATED	CONDITION
OUTLET WORKS - SERVICE BRIDGE	There is no service bridge
a. Super Structure	N.A.
Bearings	
Anchor Bolts	
Bridge Seat	
Longitudinal Members	
Underside of Deck	
Secondary Bracing	
Deck	
Drainage System	
Railings	
Expansion Joints	
Paint	
b. Abutment & Piers	N.A.
General Condition of Concrete	
Alignment of Abutment	
Approach to Bridge	
Condition of Seat & Backwall	

APPENDIX B

ENGINEERING DATA

D/S Hagadi

1) Bridges (Rly. & CRR) may control

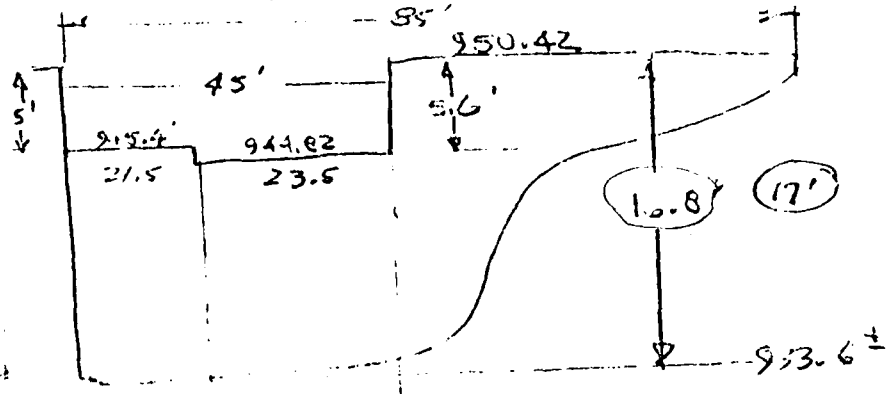
2) Based on EP. work ways
some structures within 100-500 m
Hood bdy.

until verified by Class 2

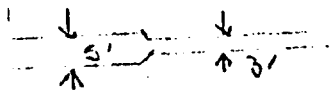
4-4-83

CRYSTAL LAKE DAM

DA = 24 MI² (ANCO) SA = 77 A. (DNR)



$L = 85'$ $\Delta h = \Delta H = 17'$



$H_1 = 5'$ $H = 5.6'$

$C = 2.8$ $C = 3.3$

$Q = CLH^{3/2} = (2.8)(21.5)(5)^{1.5} + (3.3)(21.5)(5.6)^{1.5}$

$= 673 + 1028$

$\therefore Q = 1701$ (1700)

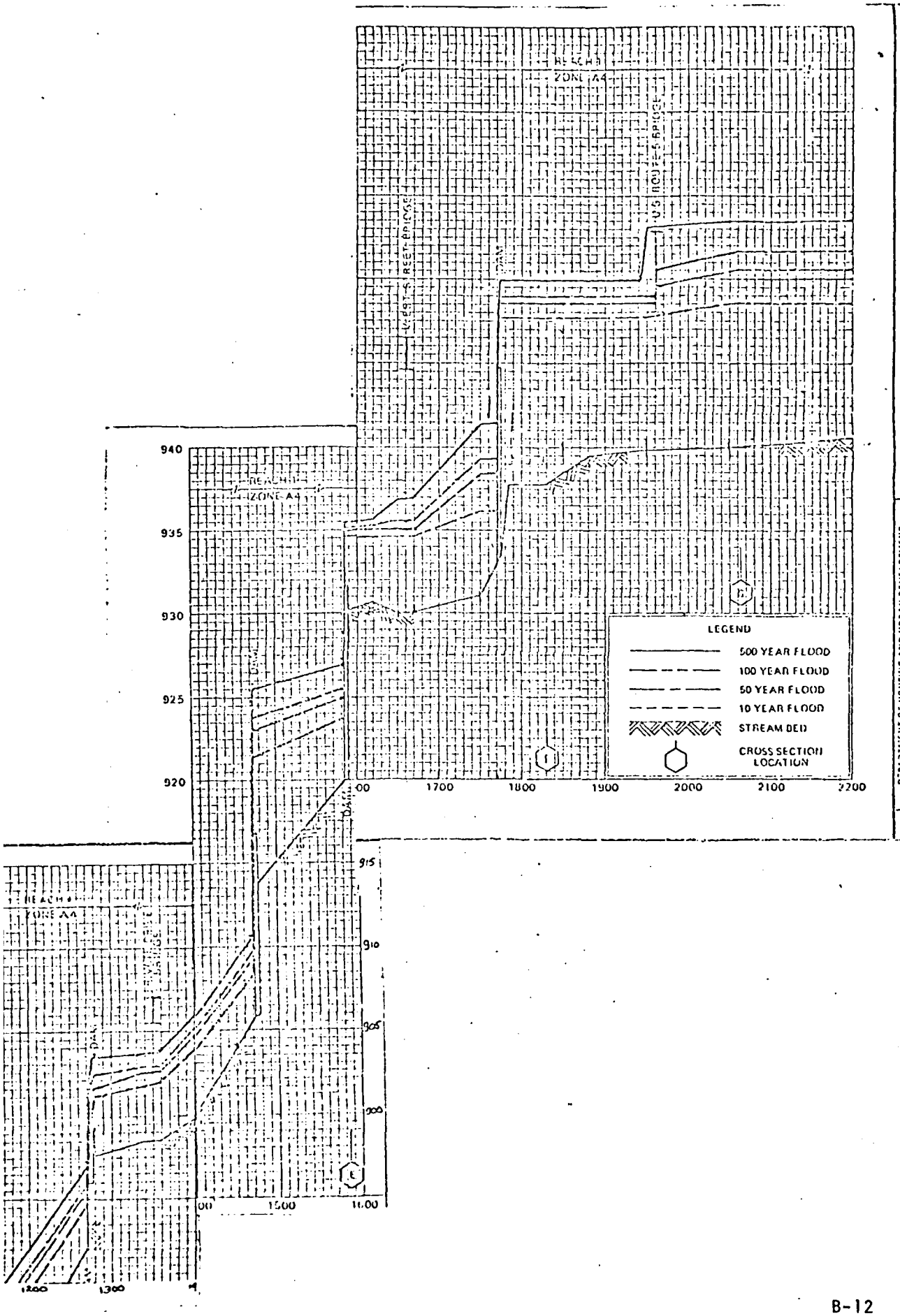
Storage

NOL assume dam controls 1' surcharge (no flow on lake CFS + condition of outlet)

$V_{OL} = (77)(4) = 3108$ (3100)

CREST

$3108 + (5)(771) = 6963$ (7000)


FLOOD PROFILES
OUTLET TO CRYSTAL LAKE
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Federal Insurance Administration
TOWN OF BARTON AND
VILLAGES OF BARTON AND ORLEANS, VT
31P
ZONE A4
940
935
930
925
920
915
910
905
900
1700
1800
1900
2000
2100
2200
1200
1300
1500
LEGEND
500 YEAR FLOOD
100 YEAR FLOOD
50 YEAR FLOOD
10 YEAR FLOOD
STREAM BED
CROSS SECTION LOCATION

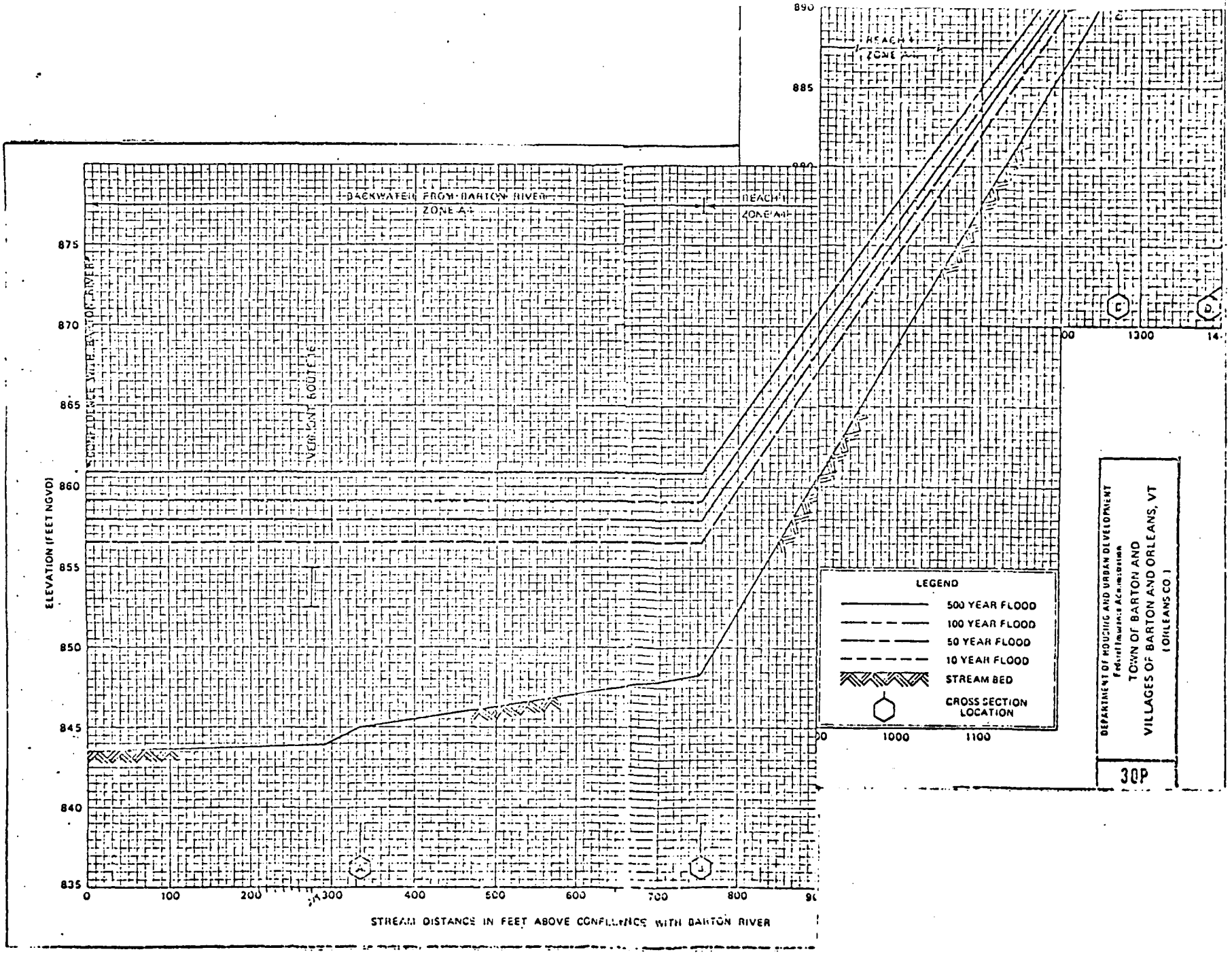

BACKWATER FROM BARTON RIVER
ZONE AH
REACH I
ZONE AH
CONFLUENCE WITH BARTON RIVER
VERMONT ROUTE 16
ELEVATION (FEET NGVD)
STREAM DISTANCE IN FEET ABOVE CONFLUENCE WITH BARTON RIVER
LEGEND
500 YEAR FLOOD
100 YEAR FLOOD
50 YEAR FLOOD
10 YEAR FLOOD
STREAM BED
CROSS SECTION LOCATION
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Federal Insurance Administration
TOWN OF BARTON AND
VILLAGES OF BARTON AND ORLEANS, VT
(ORLEANS CO.)
30P

Table 1. Summary of Discharges (2 of 2)

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (Cubic Feet per Second) 10-Year	50-Year	100-Year	500-Ye
Outlet to Crystal Lake					
Junction With Barton River	24.15	681	1,066	1,257	1,74
at Vermont Water Resources Dam	23.92	630	980	1,150	1,60
Willoughby Brook					
Junction With Crystal Lake	11.21	1,385	1,967	2,285	3,18
Downstream Junction With Tributary 23,300 Feet Above Barton River	9.92	1,343	1,909	2,201	2,8:
Upstream Junction With Tributary 23,300 Feet Above Barton River	8.79	1,168	1,668	1,926	2,7:
Upstream Limit	7.83	996	1,438	1,675	2,2:
Roaring Brook					
Junction With Barton River	11.27	978	1,420	1,658	2,2(
Upstream Limit at Roaring Brook Road	11.11	978	1,420	1,658	2,2(

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION		
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	WITH FLOODWAY	WITHOUT FLOODWAY (FEET NGVD)	DIFFERENCE
Outlet to Crystal Lake							
A	335	140	855	1.5	855.5	855.2[2]	0.3
B	755	20	125	10.1	855.5	855.2[2]	0.3
C	1,272	30	110	11.4	896.0	896.0	0.0
D	1,400	20	100	12.7	905.7	905.0	0.7
E	1,585	20	100	12.6	925.6	925.6	0.0
F	1,830	80	675	1.7	949.1	949.0	0.1
G	2,065	65	650	1.8	951.8	951.7	0.1
H	2,305	85	665	1.7	952.8	952.7	0.1

[1]Feet Above Confluence With Barton River

[2]Water-Surface Elevations Without Considering Barton River Backwater

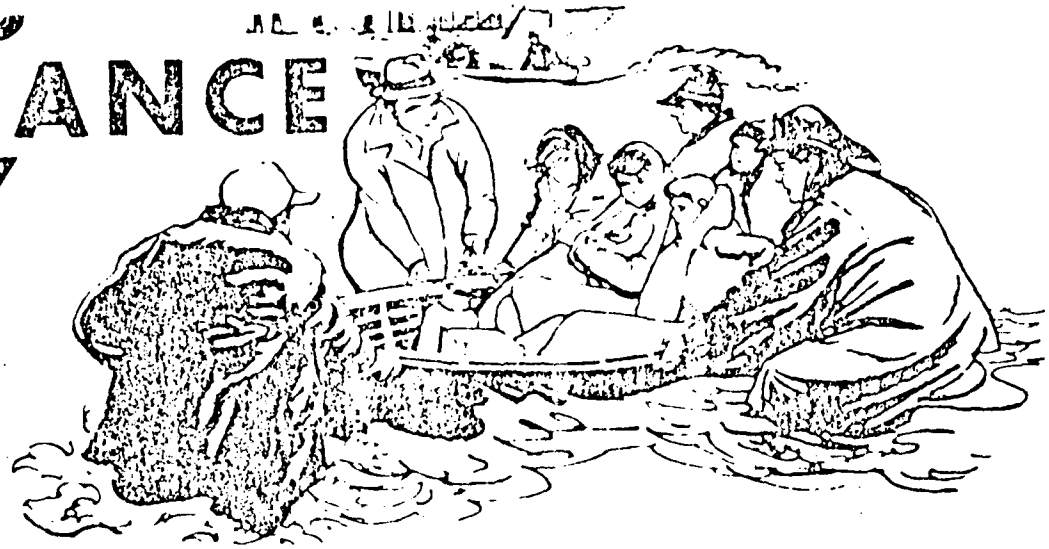
TABL

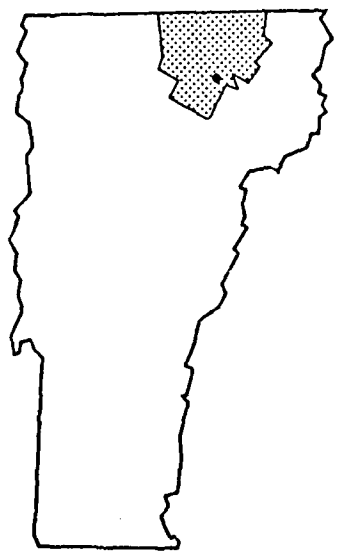
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Federal Insurance Administration
TOWN OF BARTON AND
[illegible] OF BARTON AND ORLEANS, VT

FLOODWAY DATA

OUTLET TO CRYSTAL LAKE

FLOOD INSURANCE STUDY





TOWN OF BARTON AND VILLAGES OF BARTON AND ORLEANS, VERMONT

ORLEANS COUNTY

JUNE 1977

U.S. DEPARTMENT of HOUSING & URBAN DEVELOPMENT
FEDERAL INSURANCE ADMINISTRATION

run the gate recently. He said they have left it as is for the past two or three years. The writer asked if Mr. Brown would object to running it through a cycle once or allowing the Department to do so it. He said there was no objection to Water Resources operating the gate.

DM dfr. 5/18/77
AR ADR 5/10

AA-PUR 307 100M 11-76

STATE OF VERMONT

OFFICE MEMO

TO: File

FROM: Don Spies

DATE: 5-17-77

SUBJECT: Crystal Lake Dam - Barton

☐ APPROVAL	☐ NOTE AND SEE ME	☐ PER CONVERSATION
☐ SIGNATURE	☐ NOTE AND RETURN	☐ AS REQUESTED
☐ COMMENT	☐ NOTE AND FILE	☐ NECESSARY ACTION
☐ REVIEW	☐ FOR YOUR INFORMATION	☐ GIVE ME THE FACTS
☐ PREPARE REPLY FOR MY SIGNATURE		☐ SUGGESTIONS REQUESTED
☐ YOUR ACTION REQUESTED BY THIS DATE		

REMARKS: The writer stopped by this dam on May 5th. The dam and adjacent land appear to be in good condition. There was no debris on the dam.

The slide doesn't appear to have been operated recently and should be run through its cycle once or twice. On May 17th the writer called John F. Brown and asked if they had

Memo

6-11-75
DH - dlm 6/12/75
AR — 6/12
DHS [illegible] 6-12-75
DM dlm 6/13/75

To: File
From: Don Spies
Re: Crystal Lake Dam - Barton

Pete Barranco and the writer checked the subject structure on June 5, 1975. Everything is in good shape with the dam. However, the grass hasn't been mowed and someone has had a backhoe on the site apparently to dig up a water main.

The drain gate was partially open at the time of inspection.

6/12/75
Ann J. - We noted last year on our tour with Andy & Jim C. — "add concrete - concrete wingwall by buildings west gate." —

Don - See if you can finish this
ASR

Will go up w/ Guido & company some day and take care of. Also will check w/ Village on back hoe work.

B-5

VERMONT DEPARTMENT OF WATER RESOURCES

INFORMATION SHEET

Name of Dam Crystal Lake Town Barton

Owner Dep't of Water Resources Name of Stream Trib to Barton River

Address Court Street Classification I

Montpelier, Vt.

U.S.G.S. Coordinates: Lat. 44°-44' 49" Long. 72°-10'-36"

U.S.G.S. Map Lyndenville Aerial Photos VT-62-H 45-214 to 215

U.S.G.S. Elev. @ Spillway 944.82

Total Length of Dam 82 ft. Crest Width of Emergency Spillway 44 ft.

Width of Top 2 ft. Maximum Height 14 ft.

Spillway Capacity: Principal 990 cfs ** Emergency

Pond Area 712 Acres Drainage Area 25 Sq Mi.

Pond Volume: Normal Water Level Design High Water Level

Maximum Water Depth: Normal Water Level Design High Water Level

Storage Before Emergency Spillway is Used None

Use of Reservoir Recreation

Description of Dam: Stone Masonry with Concrete cap

Description of Spillway(s): Concrete weir

Designed by Dubois & King * Year Built 1966 *

Hearing Date June 23, 1966 * Order Date July 14 1966 *

Additional Remarks: * Reconstruction only Additional Plans in PF #6

** With 3½ ft of water over the spillway Note: there are two culverts upstream from the dam that may serve as CONTROL POINTS FOR THE FLOW

SUMMARY OF DATA AND CORRESPONDENCE

DATE	TO	FROM	SUBJECT	PAGE
-	-	-	Vt. Dept. of Water Resources Information Sheet	B-4
6/11/75	File	Don Spires Vt. Dept. Water Resources	Inspection Report	B-5
5/12/77	File	Don Spires Vt. Dept. Water Resources	Inspection Report	B-5,B-7
6/77	-	-	HUD Flood Ins. Study Flow Information	B-8,B-12
4/80	-	-	Vt. Dept. of Water Resources Comp.	B-13,B-14
4/77	-	-	Vt. Geological Survey Crystal Lake Depth Map	B-15

CRYSTAL LAKE DAM

EXISTING PLANS

On file with the Vermont Department of Water Resources:

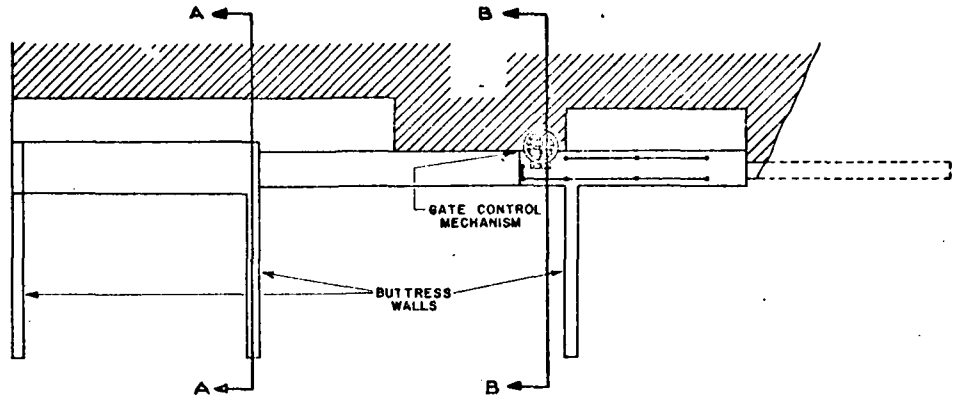
1. Vermont Department of Water Resources
   Crystal Lake Dam
   Dubois and King, Engineers, Randolph, Vermont
   Sheet 1 - Existing Dam, June, 1966
   Sheet 2 - Proposed Dam Improvements As-Built, October, 1966
   Sheet 3 - Miscellaneous Details, June, 1966

2. Outlet Structure
   Crystal Lake
   October, 1954
   Vermont State Water Conservation Board
   Montpelier, Vermont
   Sheet 1 of 2 - Plan
   Sheet 2 of 2 - Elevation

3. Topography of Outlet
   Crystal Lake
   October, 1974 - Scale 1"=20'
   Water Conservation Board

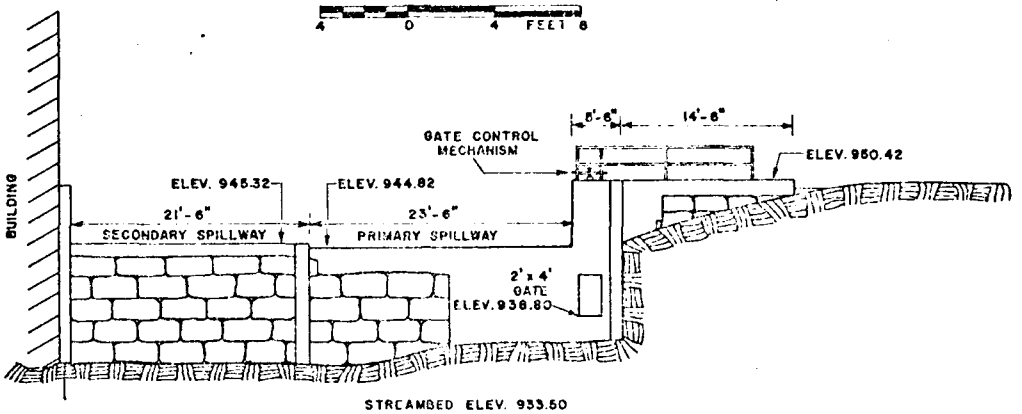
4. Crystal Lake Outlet
   Undated, initiated RWC
   Shows cross section of bridges at outlet

CRYSTAL LAKE OUTLET



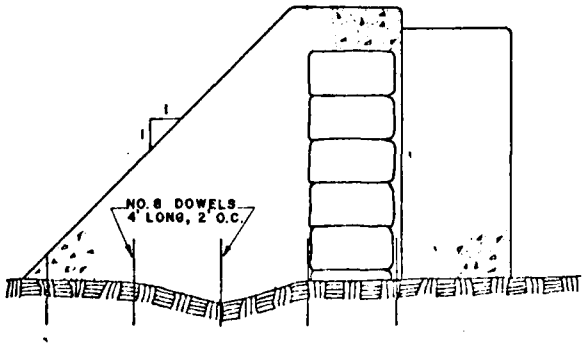
PLAN

4 0 4 FEET 8



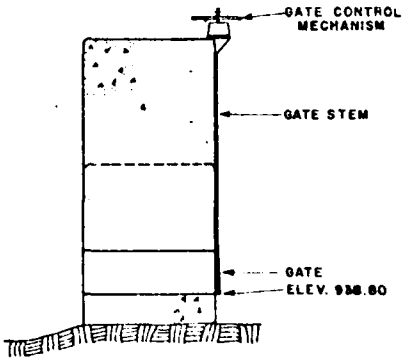
PROFILE

4 0 4 FEET 8



SECTION AA

2 0 2 FEET 4



SECTION BB

2 0 2 FEET 4

NOTE: THIS DRAWING COMPILED FROM PLANS FOR RECONSTRUCTION IN 1966 BY DUBOIS AND KING, ENGINEERS, MODIFIED AS OBSERVED IN THE FIELD.

JAMES W. SEWALL COMPANY
CONSULTING ENGINEERS
147 Centre Street
Old Town Me 04468
Tel 207 827 4456

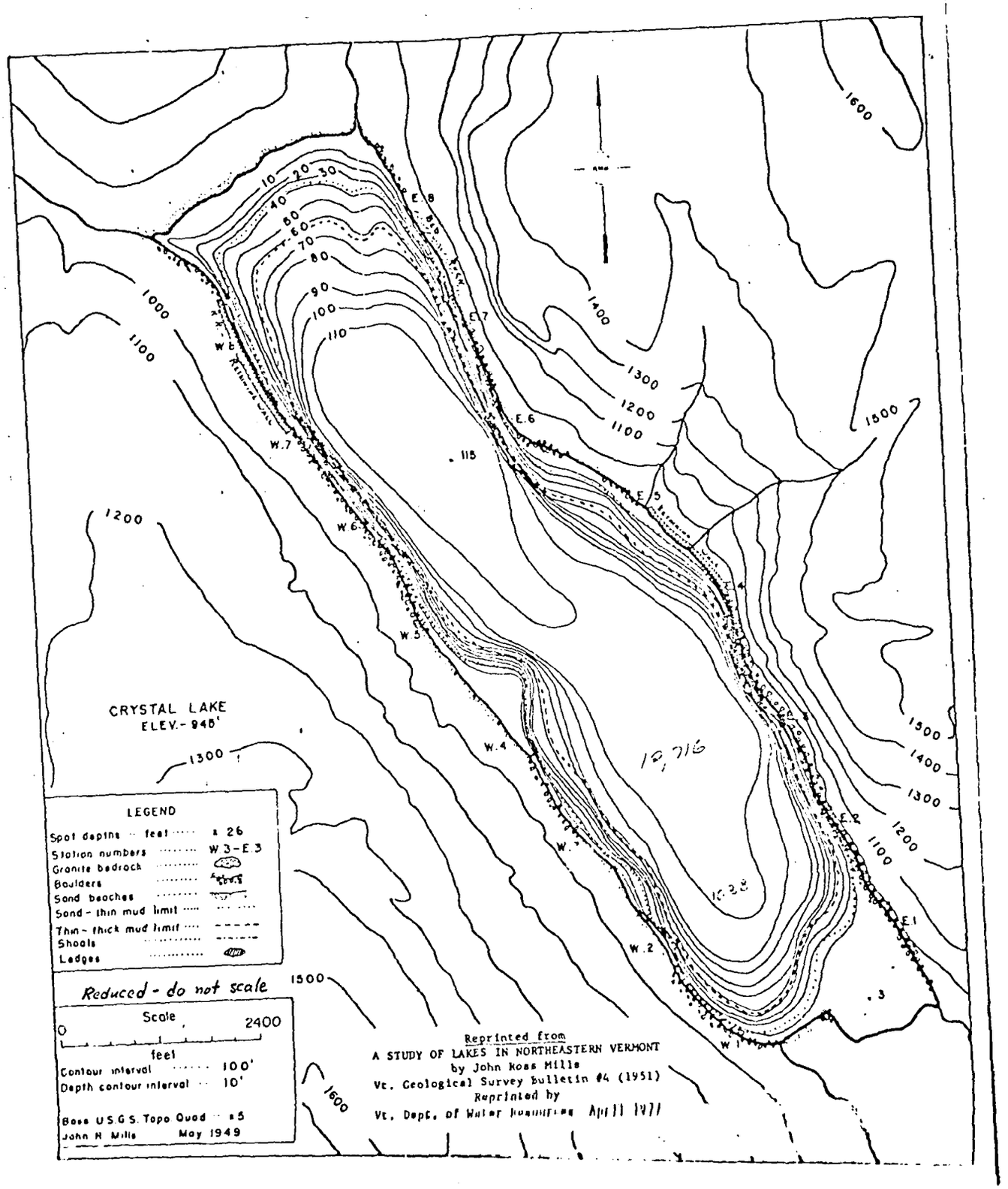
NATIONAL PROGRAM OF INSPECTION OF NON-FEDERAL DAMS

CRYSTAL LAKE DAM

BARTON VT.

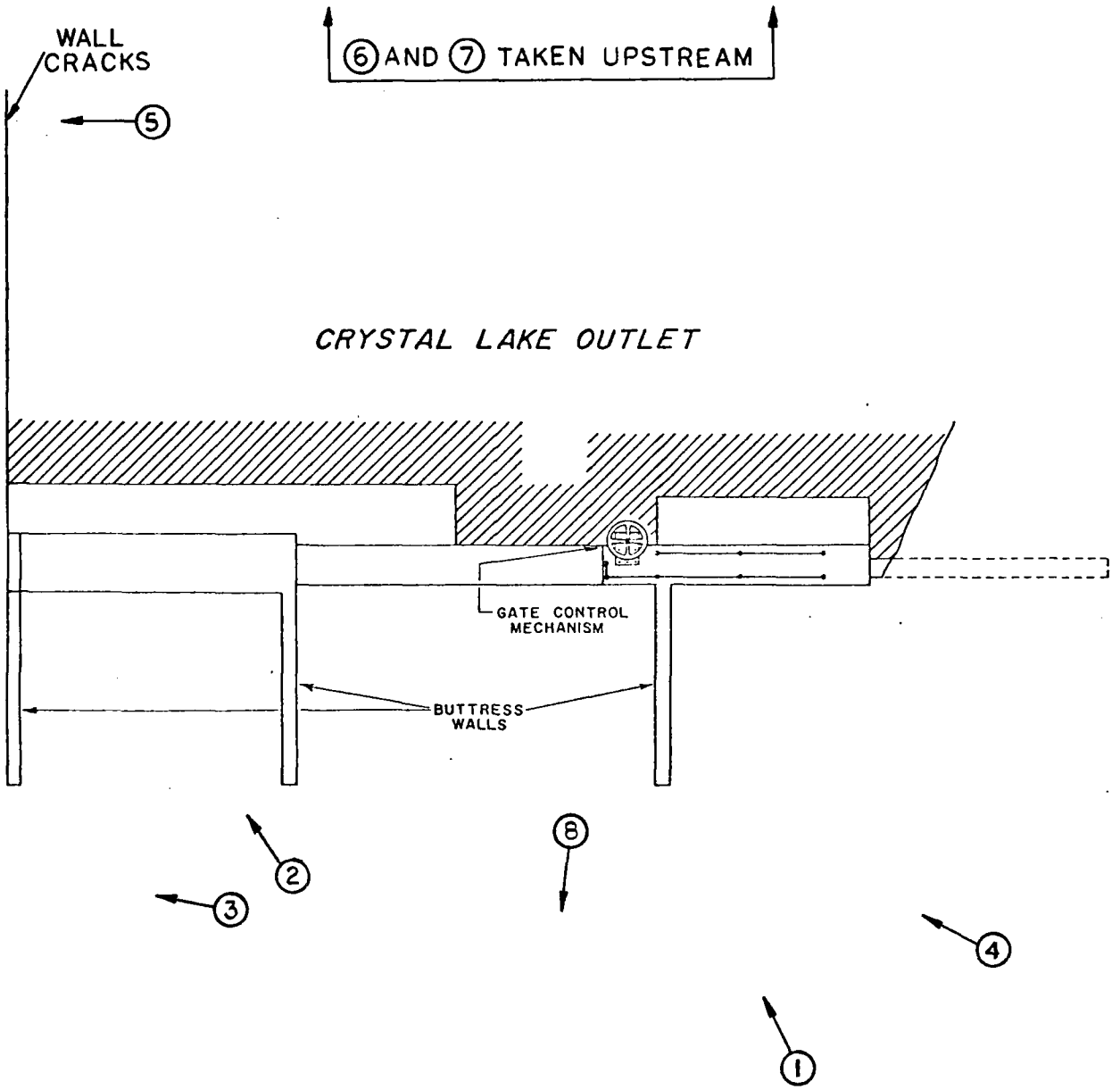
NO	REVISION	DATE	CK

Design | Check
Drawn | Approved | Date | SHEET B-1 OF


CRYSTAL LAKE
ELEV.- 945'
LEGEND
Spot depths - feet ..... ± 26
Station numbers ..... W 3-E 3
Granite bedrock .....
Boulders .....
Sand beaches .....
Sand - thin mud limit .....
Thin - thick mud limit .....
Shoals .....
Ledges .....
Reduced - do not scale
Scale
0
2400
feet
Contour interval ..... 100'
Depth contour interval ... 10'
Base U.S.G.S. Topo Quad ... ±5
John R. Mills May 1949
Reprinted from
A STUDY OF LAKES IN NORTHEASTERN VERMONT
by John Ross Mills
Vt. Geological Survey Bulletin #4 (1951)
Reprinted by
Vt. Dept. of Water Resources April 1971
10,716
10,328
.115
.3

APPENDIX C

DETAIL PHOTOGRAPHS



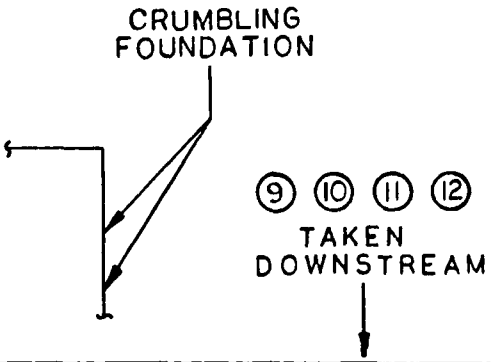


PHOTO LOCATION PLAN
CRYSTAL LAKE DAM

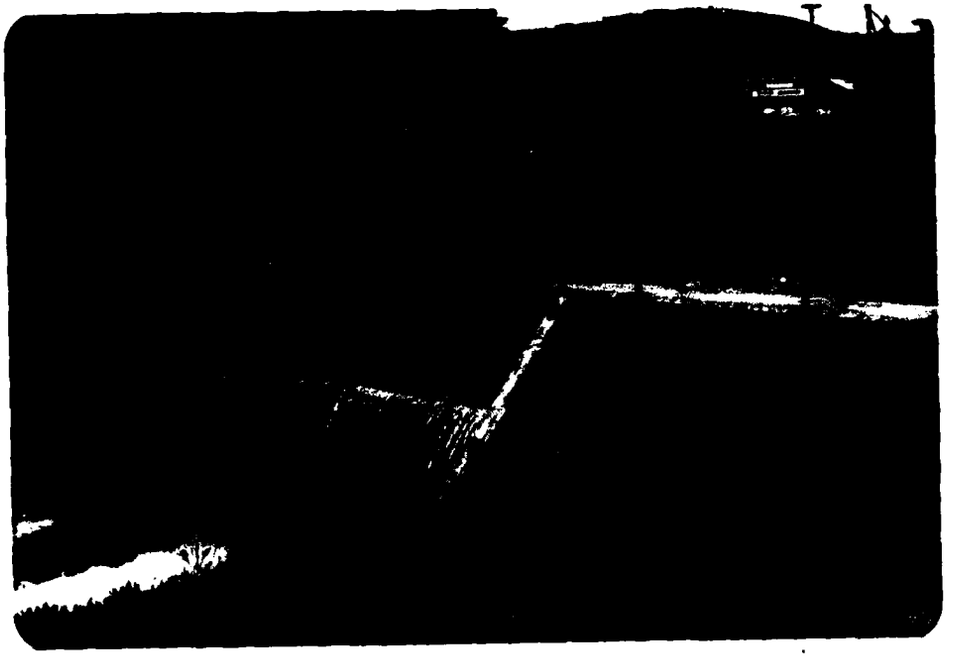
SCALE

4 0 4 FEET 8

(1) Downstream Face of Dam, Outlet and Gate Control Visible at Right

(2) Concrete Capping of Ashlar Masonry at Secondary Spillway

(3) Right Abutment Showing Building Foundation at Left, and Contact Between Concrete Buttress and Bedrock



(4) Dam and Immediate Upstream Area, Showing U.S. Route 5 Bridge in Background

(5) Portion of Concrete Retaining Wall Immediately Upstream of Right Abutment

(6) Upstream Side of U.S. Route 5 Bridge

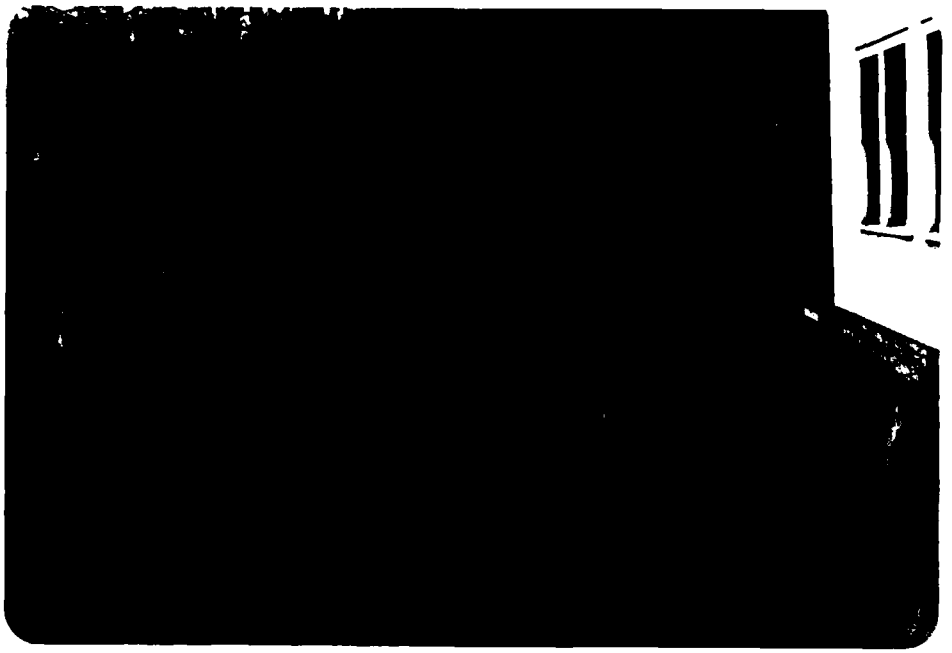
(7) Downstream Side of Canadian Pacific R.R. Bridge

(8) Downstream Channel Showing West Street Bridge

(9) Downstream Channel from West Street Bridge

(10) View of Channel Looking Upstream to Crystal Lake Dam in Distant Background

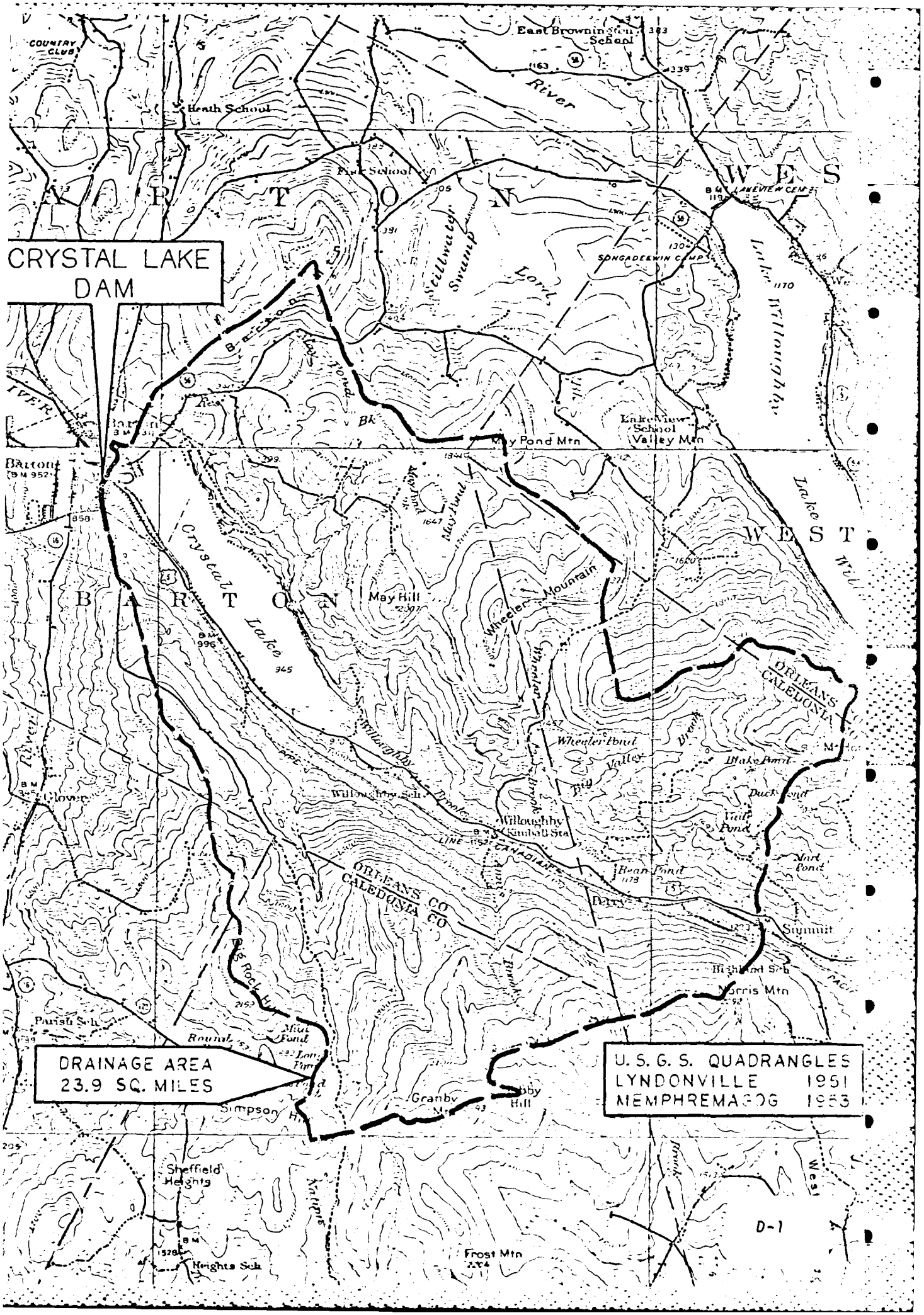
(11) Upstream Side of Vermont Route 16 Bridge Over Crystal Lake Outlet

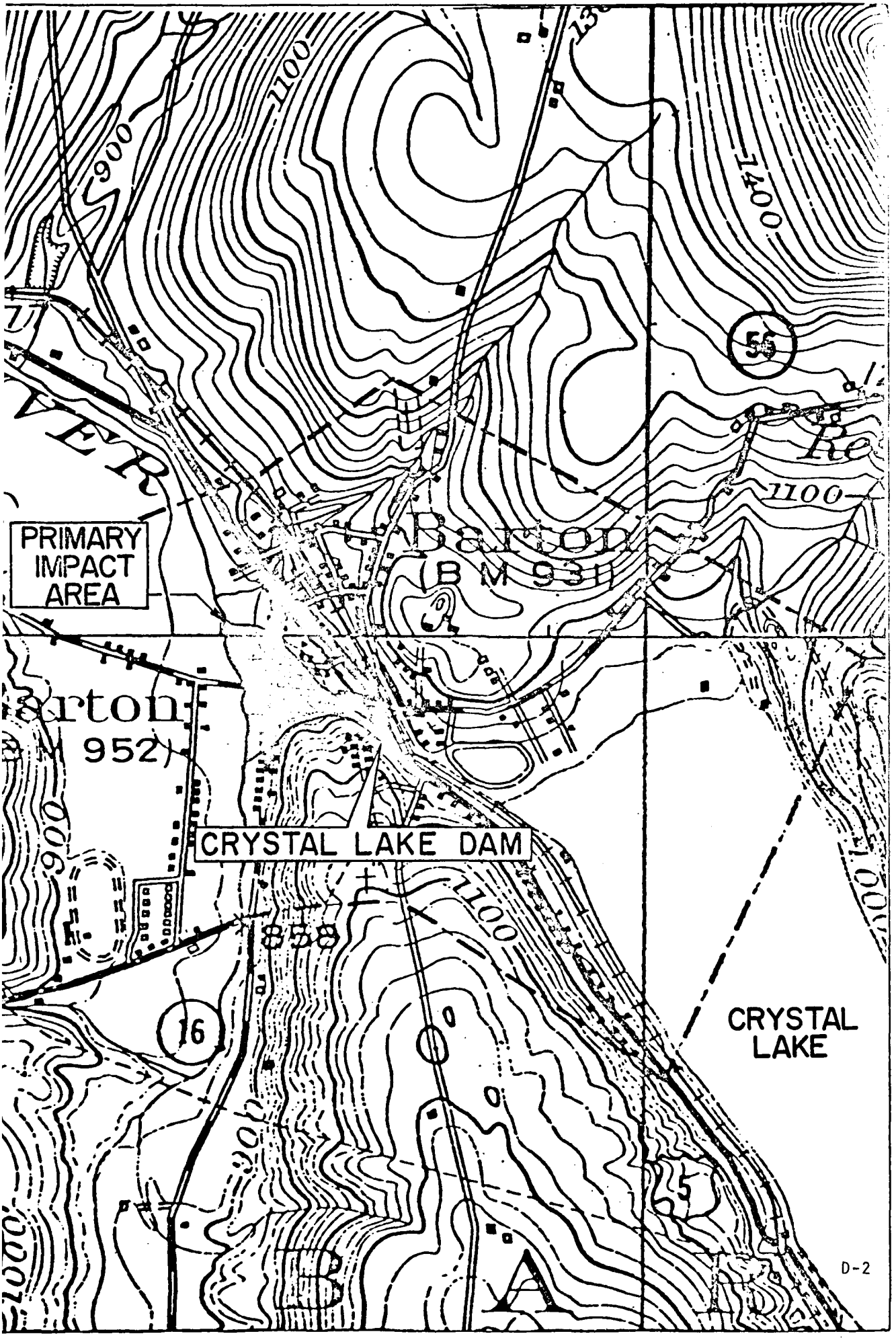


(12) Channel Upstream of Route 16 Bridge

APPENDIX D

HYDRAULICS/HYDROLOGIC COMPUTATIONS


CRYSTAL LAKE DAM
DRAINAGE AREA
23.9 SQ. MILES
U. S. G. S. QUADRANGLES
LYNDONVILLE 1951
MEMPHREMAGOG 1953
D-1
BARTON
WEST BURKE
ORLEANS CO
CALEDONIA CO
Crystal Lake
Willoughby River
Willoughby Brook
Wheeler Mountain
May Hill
May Pond Mtn
Lakeview School
Valley Mtn
Lake Willoughby
Stillwater Swamp
Long Pond
Big Rock Mtn
Granby Mtn
Gibby Hill
Sheffield Heights
Frost Mtn
Parish Sch
Heath School
East Brownington School
Songadeewin Camp
Lakeview Cem
Willoughby Kimball Sta
Summit
Morris Mtn
Highland Sch
Heights Sch
Barton
Lowell
Simpson Hill
Round Pond
Mud Pond
Long Pond
Wheeler Pond
Blake Pond
Duck Pond
Bean Pond
Perry
Valley
Brook
Canadian Line
Pipe
Lake
River
Brook
Pond
Mtn
Hill
West
Sch
Cem
Bk
Country Club


PRIMARY IMPACT AREA
CRYSTAL LAKE DAM
CRYSTAL LAKE
BM 931
952
1100
900
1400
858
55
16
5
A
B
D-2

Dam Inspection of non-federal dams

ion Crystal Lake Dam, Barton Vt Job No. 953-05 C

by MEB Checked by SDM Date 5-30-80

Hydrologic / Hydraulic Inspection Crystal Lake Dam

I) Performance at Test Flood Conditions

1) Maximum Probable Flood

a) Watershed Classified as "mountainous" ✓

b) Watershed area

25 sq miles (Dept of Water Resources Info Sheet)

23.92 sq miles (1977 H&D study)

23.9 sq miles planimeter from Lyndonville, Vt USGS sheet (use avg of 3 trials) ✓

c) From NED-ACE Preliminary Guidance for Estimating Max Probable Discharges - Guide Curve for PMF - Peak Flow Rate:

PMF = 1675 cfs / sq mile ✓

d) Peak Inflow

No substantial storage upstream of Crystal Lake ∴ PMF = 1675 (23.9) = 40,033 cfs ✓

2) Test Flood

a) Classification of Dams according to NED-ACE recommended Guidelines

i) Size

~~700~~ 710 acres (Dept of Water Resources Info Sheet)

702 acres Planimeter from Lyndonville Vt USGS sheet (use avg of 3 trials)

Assume 1' dam depth or less contributed to York Mountain Dam since lake that ~~700~~ 702 ac (1+5Q) = 6790 ac-ft ✓

height = 16.9 ft (Dept of Water Resources Info Sheet)

PRELIMINARY GUIDANCE

FOR ESTIMATING

MAXIMUM PROBABLE DISCHARGES

IN

PHASE I DAM SAFETY

INVESTIGATIONS

New England Division
Corps of Engineers

March 1978

:t Inspection of non-federal dams

:ation Crystal Lake Dam Job No. 953-05C

:ed by MEB Checked by SDK Date 8-4-80

d) Rise in stage D/s from Crystal Lake Dam at West St. Bridge cont.

Raise in stage = 13.2' - 7.6' = 5.6'

e) Flood Stage in Immediate Impact Area

Impact Area = ± 1800 ft downstream of the dam

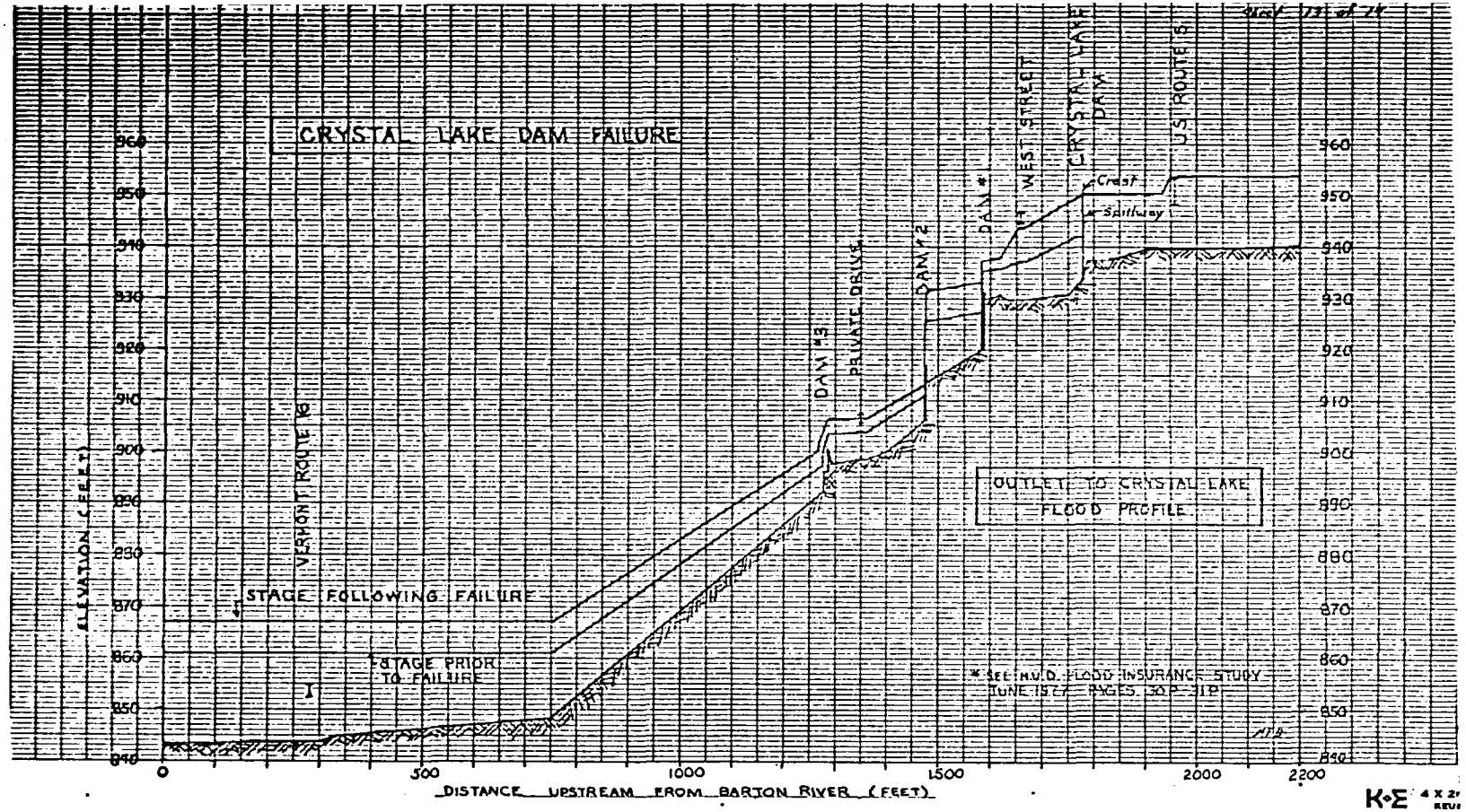
See Flood Profile p D-14 (derived from HUD study)

Maximum raise in stage ≅ 6' @ Route 16 Bridge
for Q = 3700 cfs (flow diverted at Route 5,
+100 cfs reenters stream
below West St. Bridge
∴ Q = 3600 + +100 = 3700 cfs
Σ Qf

Summary

a) Peak Failure Outflow
Q_p ≅ 3600 cfs btwn Crystal Lake Dam and West St.
Q_p ≅ 3700 cfs D/s West St. Bridge

b) Raise in Stage in Immediate Impact Area
Varies from approx 2' to 6' - see flood profile p 12


CRYSTAL LAKE DAM FAILURE
ELEVATION (FEET)
960
950
940
930
920
910
900
890
880
870
860
850
840
VERMONT ROUTE 10
STAGE FOLLOWING FAILURE
STAGE PRIOR TO FAILURE
DAM #3
PRIVATE DRIVE
DAM #2
DAM #1
WEST STREET
CRYSTAL LAKE DAM
U.S. ROUTE 6
Crest
Spillway
OUTLET TO CRYSTAL LAKE
FLOOD PROFILE
* SEE H.U.D. FLOOD INSURANCE STUDY
JUNE 1977 PAGES 30P-31P
0
500
1000
1500
2000
2200
DISTANCE UPSTREAM FROM BARTON RIVER (FEET)

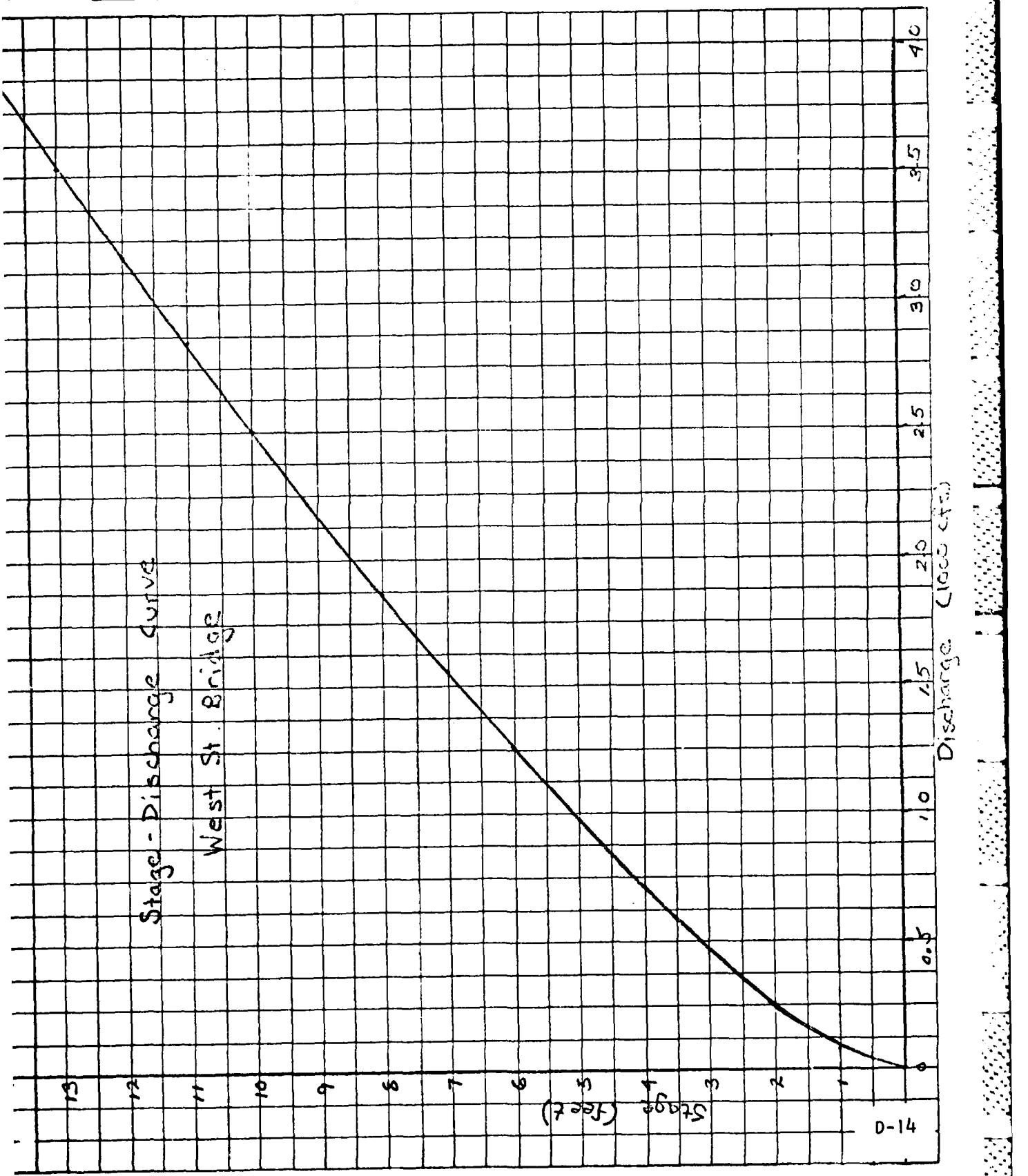
JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet 12 of 14

Project Inspection of non-fed dams

Computation Crystal Lake Dam Job No. 953-05C

Computed by MEB Checked by SDM Date 8-4-80



D-14

ect Inspection of non-fed dams

utation Crystal Lake Dam Job No. 953-05C

uted by MEB Checked by SDM Date 8-4-80

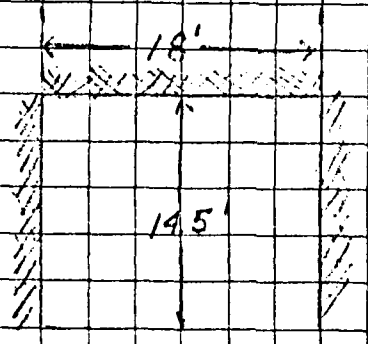
c) Peak Failure Flow

$Q_p = Q_b + Q_s$ = 2800 + 800 cfs

Q_p = 3700 cfs

d) Raise in stage DIs from Crystal Lake Dam at West St. Bridge

West St Bridge



$V = \frac{1.486}{n} R^{2/3} S^{1/2}$

H	A	R	V	Q
1	18	.90	4.62	83
2	36	1.64	6.89	248
4	72	2.77	9.77	703
6	108	3.40	11.63	1257
7	126	3.94	12.36	1557
8	144	4.24	12.98	1869
10	180	4.74	13.98	2515
11	198	4.95	14.39	2849
12	216	5.14	14.76	3188
13	234	5.32	15.09	3531
14	252	5.48	15.39	3879

See Curve p. 12

Stage prior to failure = 7.6' @ Q = 1700 cfs

Stage following failure = 13.2' @ Q = 3600 cfs

ject Inspection of non-fed dams

putation Crystal Lake Dam Job No. 953-05C

puted by MEB Checked by SDM Date 8-1-80

II Downstream Failure Hazard

1) Peak Failure Outflow

a) Breach Outflow

i) Breach width

Mid-Ht. elev = $\left(\frac{950.42 - 933.5^{*}}{2}\right) + 933.5 = 942.0$

* from N. Dept. of Water Resources

Approx. Mid-Height Length $L \cong 59'$ (from As-Built Plans)

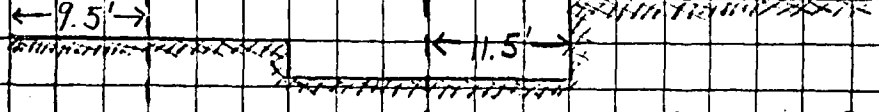
$W = 0.4\,(59) = 23.6'$ say $24'$

ii) Assume surcharge to top of dam ∴
height at time of failure ≅ 16.9'

iii) $Q_b = 8/27\ W_b \sqrt{g}\ h_o^{3/2}$ $W_b = 24'$, $h_o = 16.9'$

$Q_b \cong 2800$ cfs

b) Remaining Spillway Discharge



Primary Spillway El. 944.82

$Q = CLH^{3/2}$ $L = 11.5'$ $C = 3.3$

H	WS Elev	Q
5.6	950.42	1500

Secondary Spillway El. 945.32

$Q = CLH^{3/2}$ $L = 9.5$ $C = 2.8$

H	WS Elev	Q
5.1	950.42	1300

∴ $Q_s \cong 800$ cfs

Subject Inspection of non-fed dams

Computation Crystal Lake Dam Job No. 953-05C

Computed by MEB Checked by SDM Date 8-1-80

See rating curve p. 4, 5

∴ @ PMF

Routed Outflow Crystal Lake	16 750
Flow diverted at Route 5	−7 750
Crystal Lake Dam Outflow	9000

∴ @ ½ PMF

Routed Outflow	5000
Flow diverted at Route 5	− 1700
Crystal Lake Dam outflow	3300

Q_{p_3} = 9000 cfs H = 11.2' ✓ (See rating curve p 7)
Q_{p_3}' = 3300 cfs H = 7.2' ✓

b) Spillway capacity to top of dam
Q_s = 1700 cfs ✓ = 19% Q_{p_3}, 52% Q_{p_3}'

4) Summary

a) Peak Inflow to Crystal Lake
Q_{p_1} = 40,033 cfs Q_{p_1}' = 20,017 cfs

b) Peak Outflow from Crystal Lake Dam
Q_{p_3} = 9,000 cfs Q_{p_3}' = 3,300 cfs

c) Spillway Max Capacity
Q_s = 1700 cfs or 19% Q_{p_3} and 52% Q_{p_3}'

∴ At Test Flood (PMF), the dam is overtopped by 5.6' or to an average discharge above the spillway crest of 11.2'.
At ½ PMF the dam is overtopped by 1.6' or to an average discharge 7.2' above the spillway crest.

Subject Inspection of non-federal dams

Computation Crystal Lake Dam Job No. 953-05 C

Computed by DEB Checked by SDM Date 8-4-80

3) Effect of Surcharge on Max. Probable Discharge cont.

c) Lake area @ Flow line = 702 acres

d) Assume normal pool level at Crystal Lake Dam Spillway El. 999.8'.

e) Watershed Area = 23.9 mi² (pg 1)

f) Discharge (Q_{p_2}) at various surcharge elevations

H = 12 V = 702 x 12 = 8424 acre-ft ✓
S = 8424 / (53.3 x 23.9) = 6.61" ✓

H = 15 V = 702 x 15 = 10530 acre-ft ✓
S = 10530 / (53.3 x 23.9) = 8.27" ✓

From Approximate Storage Routing Guidelines (19" max probable R.O. in New England)

$Q_{p_2} = Q_{p_1}(1 - S/19)$ and $Q_{p_2}' = Q_{p_1}'(1 - S/9.5)$

$Q_{p_1} = 40,033$ $Q_{p_1}' = 20017$

H = 12 $Q_{p_2} = 26105$ ✓ $Q_{p_2}' = 6089$ ✓ cfs

H = 15 $Q_{p_2} = 22608$ ✓ $Q_{p_2}' = 2592$ ✓ cfs

g) Peak Outflow (Q_{p_3})

Using NED ACE Guidelines "Surcharge Storage Routing" Alternate method

The Peak Outflow from Crystal Lake Dam will be the routed peak outflow from Crystal Lake minus what is diverted over the dike at Section [illegible] there is no significant storage between the [illegible] dam

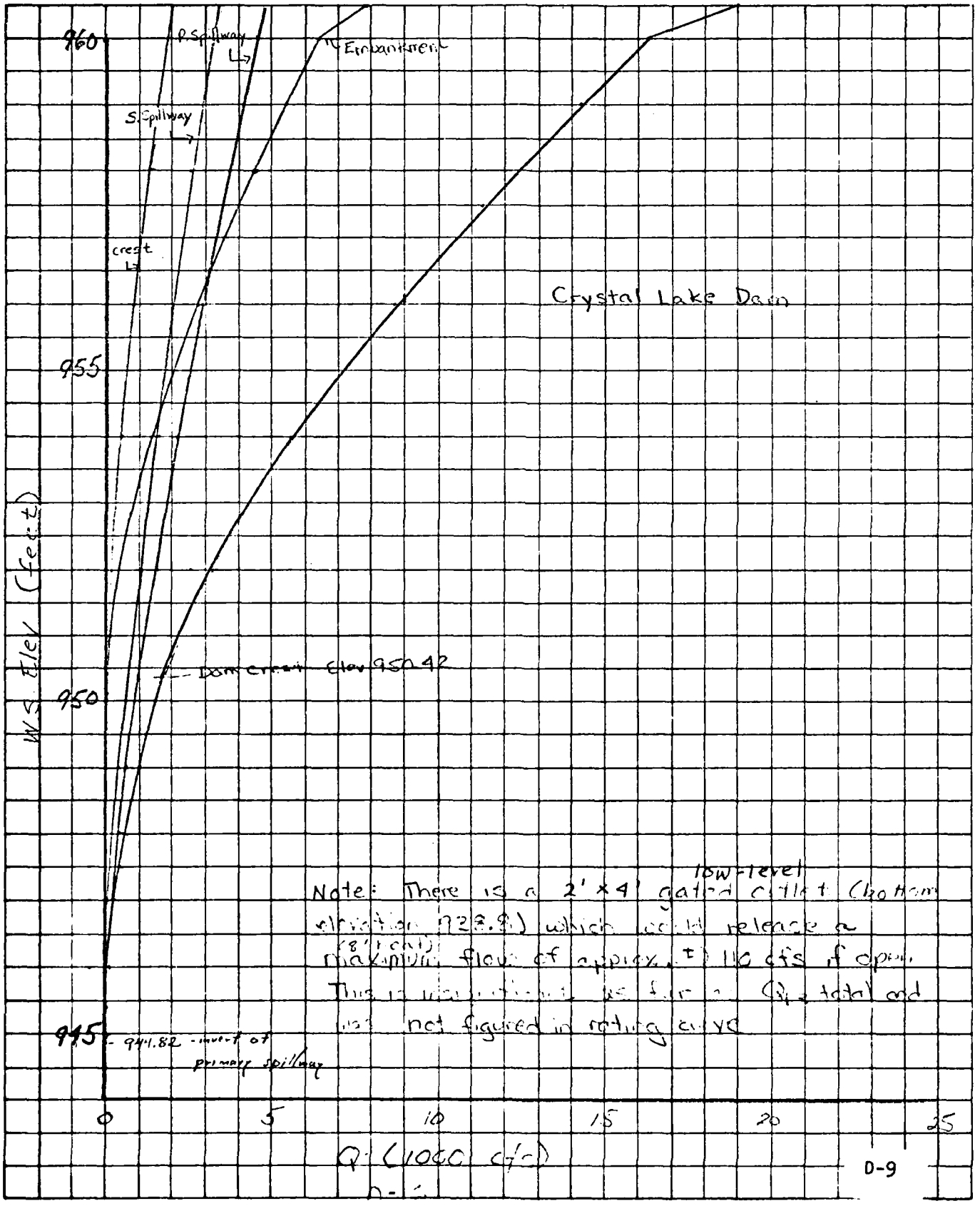
JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet 7 of 14

Subject Inspection of non-federal dams

Computation Crystal Lake Dam Barton Vt Job No. 953-05C

Computed by MEB Checked by SDM Date 6-4-80



Note: There is a 2' x 4' gated low-level outlet (bottom elevation 932.8') which could release a maximum flow (8' head) of approx. ± 110 cfs if open. This is not included in Q total and was not figured in rating curve

Subject Inspection of non-federal dams

Computation Crystal Lake Dam Barton Vt Job No. 953-05C

Computed by MEB Checked by SDM Date 6-9-80

3b) Outflow Rating Curve cont.

Crystal Lake Dam

Primary Spillway El. 944.92
$Q = CLH^{3/2}$ L=23.5 C=3.3

H	Q	WS El.
1.18	99	946.0
2.18	250	947.0
3.18	440	948.0
4.18	663	949.0
5.18	914	950.0
7.18	1493	952.0
9.18	2157	954.0
11.18	2899	956.0
13.18	3710	958.0
15.18	4587	960.0
16.18	5047	961.0

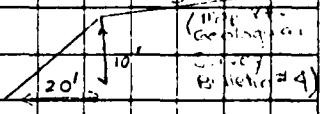
Secondary Spillway Elev 945.32
$Q = CLH^{3/2}$ L=21.5 C=2.8

H	Q	WS El.
.6	28	945.92
1.6	122	946.92
2.6	252	947.92
3.6	411	948.92
4.6	594	949.92
6.6	1021	951.92
8.6	1518	953.92
10.6	2078	955.92
12.6	2698	957.92
14.6	3358	959.92
15.6	3709	960.92

Crest elev 950.42
$Q = CLH^{3/2}$ L=20' C=3.3

H	Q	WS El
.58	29	951.0
1.58	131	952.0
3.58	447	954.0
5.58	870	956.0
7.58	1377	958.0
9.58	1957	960.0
10.58	2271	961.0

Lower Crest Wall + Embankment 950.17
Approximate:



$Q = CLH^{3/2}$ C=2.5

H max	Q	WS Elev
.83	145	951.0
1.83	481	952.0
3.83	1483	954.0
5.83	2840	956.0
7.83	4507	958.0
9.83	6450	960.0
10.33	6309	960.5
11.0	7870	961.17

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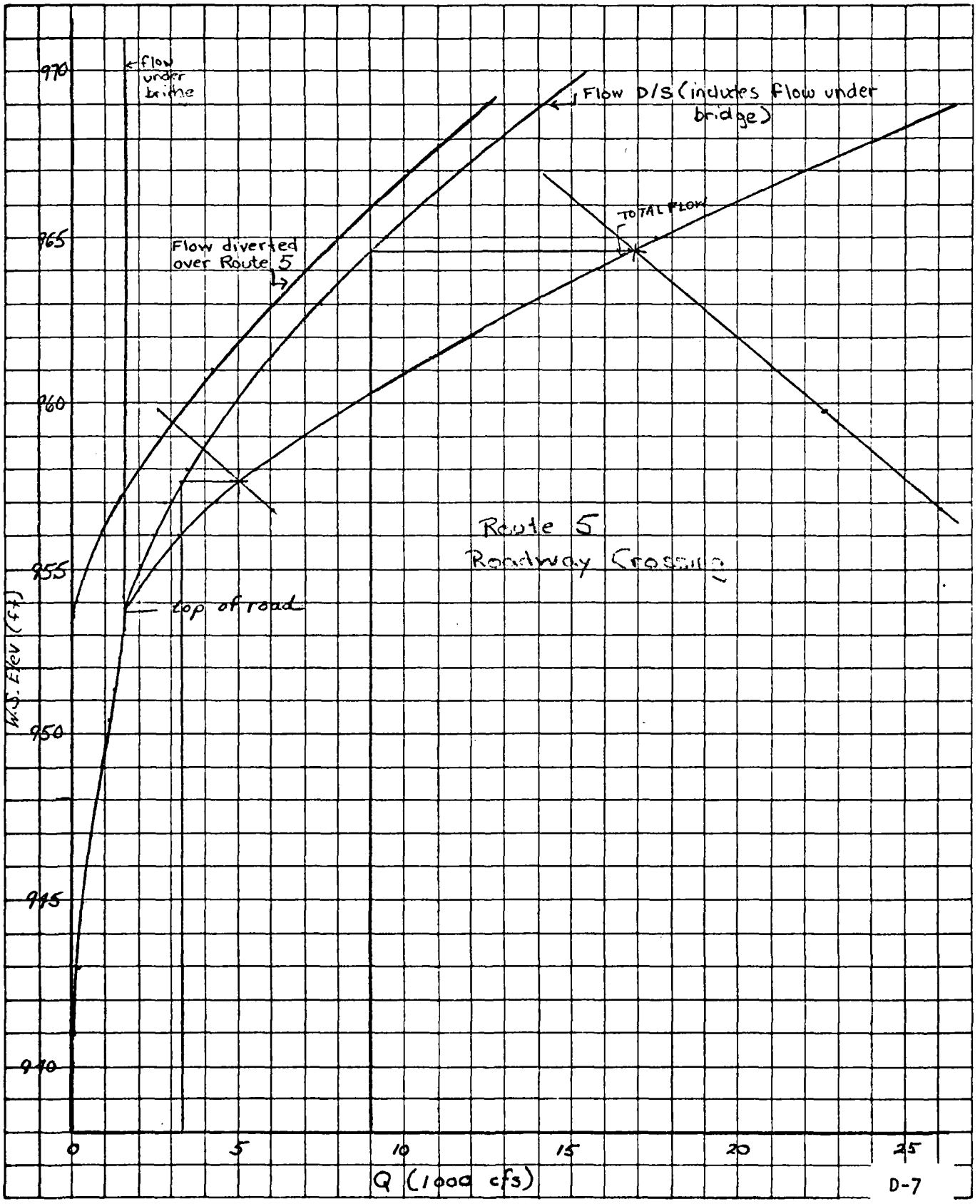
Civil and Sanitary Engineers

Sheet 5 of 14

Subject Inspection of non-federal dams

Computation Crystal Lake Dam Barton Vt Job No. 953-05C

Computed by MEB Checked by SDM Date 6-8-80



D-7

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Civil and Sanitary Engineers

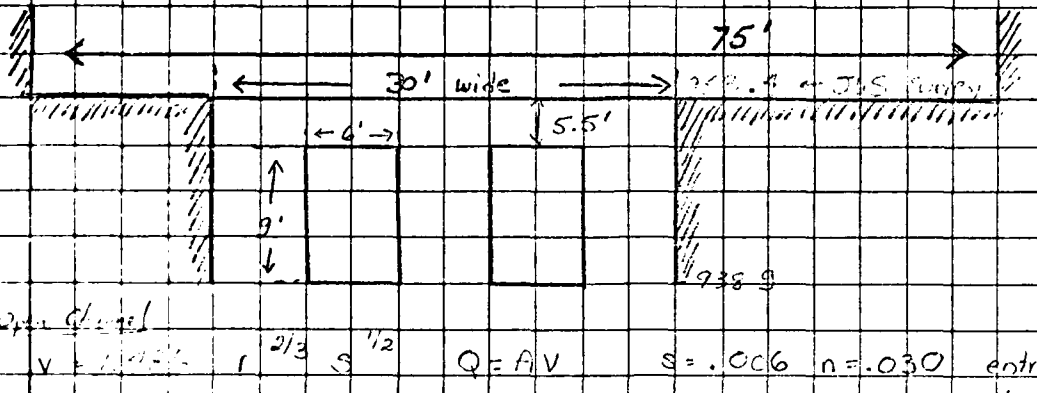
Sheet 4 of 14

Subject Inspection of non-federal dams

Computation Crystal Lake Dam Barton VT Job No. 953-05C

Computed by MEB Checked by SDM Date 6-2-80

Upstream Roadway Crossing



Open Channel

$V = \frac{1.49}{n} R^{2/3} S^{1/2}$ $Q = AV$ $S = .006$ $n = .030$ entrance exit losses negligible

H	A	R	V	Q	WS Elev
1	6	.75	3.17	38	939.9
2	12	1.2	4.33	104	940.9
4	24	1.71	5.49	263	942.9
6	36	2.0	6.09	439	944.9
8	48	2.18	6.45	619	946.9
9	54	2.25	6.57	712	947.9

Pressure Flow

$Q = CA\sqrt{2gH}$ $C = .75$ $A = 54$

H	2gH	WS Elev
0.24	31.8	939.24
0.53	47.3	939.53
0.86	60.3	939.86
1.31	74.4	940.31
1.73	85.5	940.73

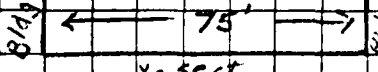
Weir

$Q = CLH^{3/2}$ $C = 2.7$

$L = 75'$ (less pier widths)

H	Q	WS Elev
.6	94	939.6
1.6	410	940.6
3.6	1383	942.6
5.6	2684	944.6
7.6	4202	946.6
9	5224	947.9
11.6	8002	950.6
13.6	10,156	952.6
15.6	12,477	954.6

* Flow also assumed northward along road crossing when road is overtopped



X-sect

Q approx same as that overflowing bridge

Subject Dam Inspection of non-federal dams

Computation Crystal Lake Dam Barton Vt Job No. 953-05C

Computed by MEB Checked by SCM Date 5-30-80

2) Hazard Potential

D/S channel has supercritical slope nearly to Vt Rt 16, 1500± ft away. Rise in stage there would be 6'± ft - enough to insure destruction of bridge, increased damage to the 10-20 affected residential structures, and probable loss of more than a few lives.

3) Classification

SIZE: Intermediate (Governed by storage, 1000 < S < 50,000 ac-ft)

HAZARD: High

b) PMF = 40,033 cfs = Test Flood

½ PMF = 20,017 cfs

3) Effect of Surcharge on Max Probable Discharge

a) Peak Inflow Q_p = 40,033 cfs $Q_{p'}$ = 20,017 cfs

b) Outflow Rating Curves

Approximately 300 feet upstream of the dam is a railroad crossing of the Canadian Pacific Railroad. About 200 feet upstream of the dam is a road crossing with three granite box culverts.

These two crossings would restrict the flow to Crystal Lake Dam. Rating curves were computed for both and the Route 5 crossing was found to be the controlling factor for the peak inflow to Crystal Lake Dam at PMF and ½ PMF

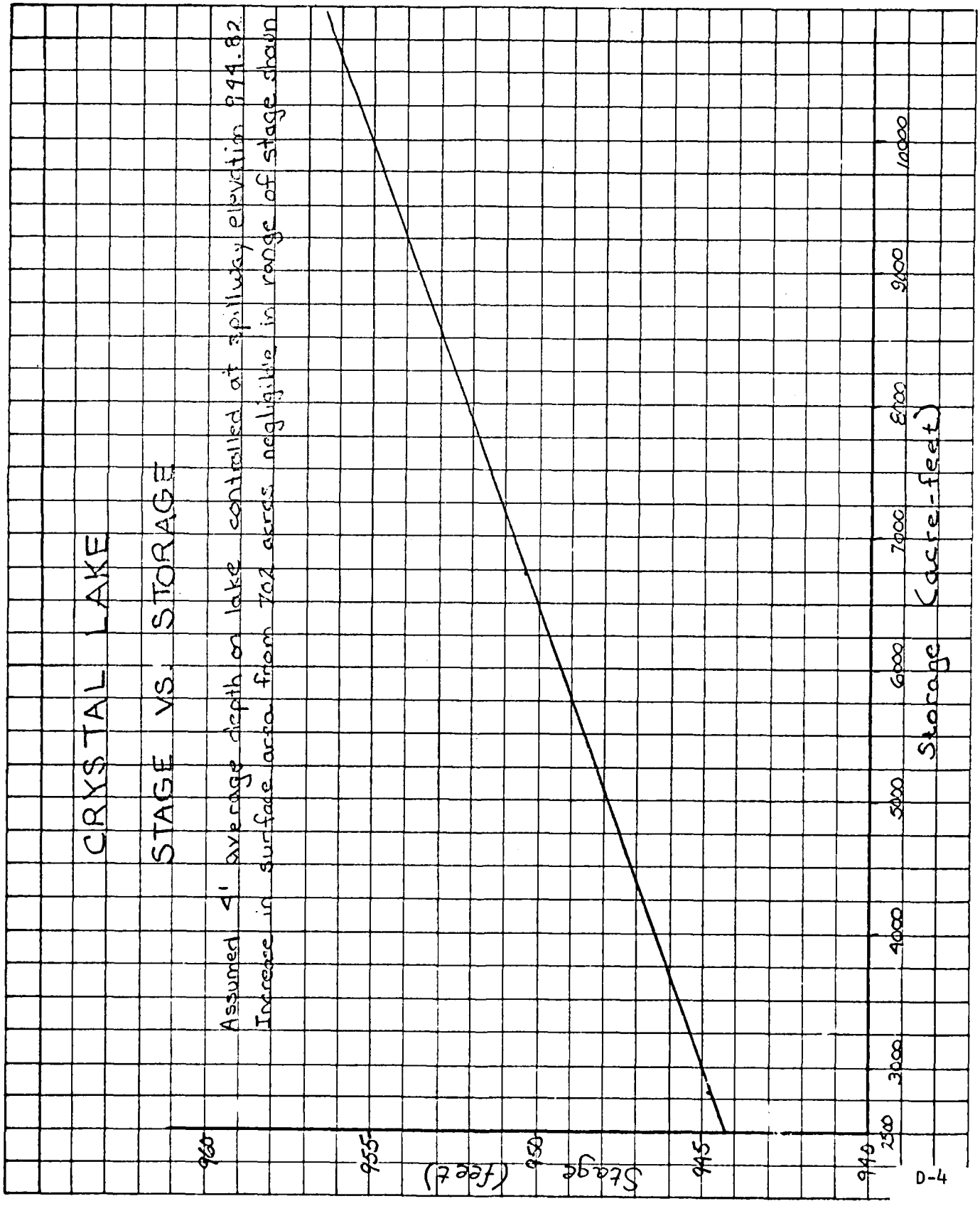
JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet 2 of 14

Subject Inspection of non-federal dams

Computation Crystal Lake Dam Job No. 953-05C

Computed by MEB Checked by Date 8-6-80

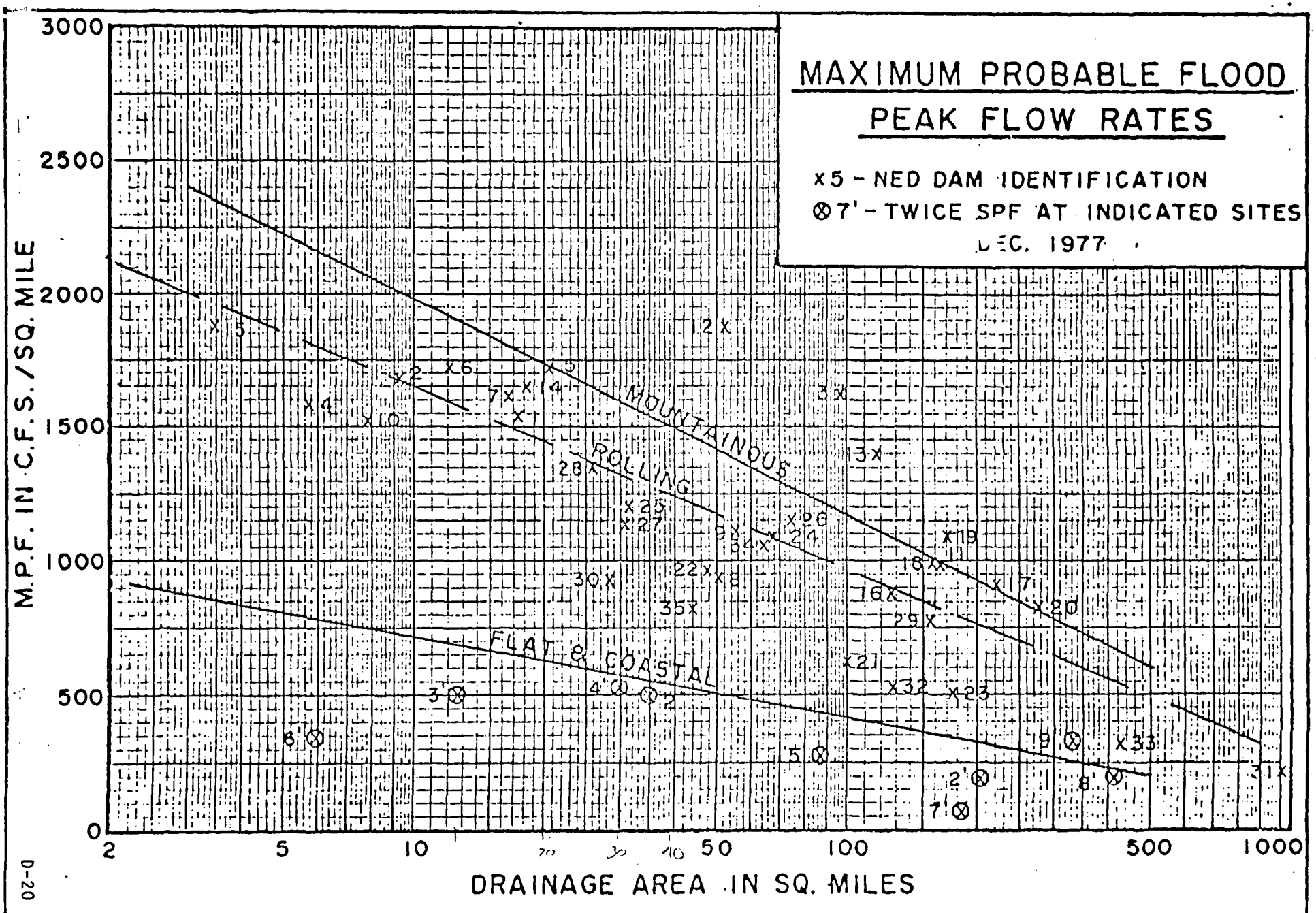


MAXIMUM PROBABLE FLOOD INFLOWS
NED RESERVOIRS

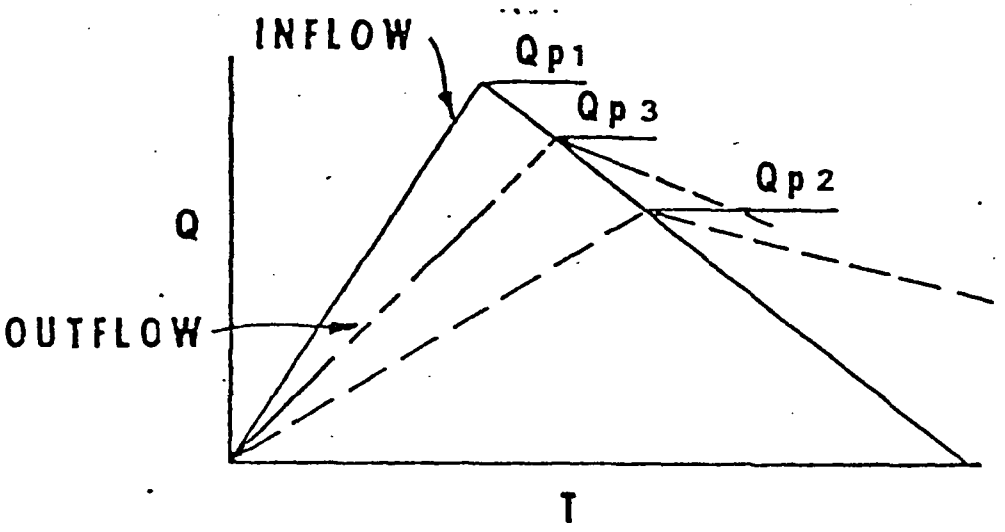
Project	Q (cfs)	D.A. (sq. mi.)	MPF cfs/sq. mi.
1. Hall Meadow Brook	26,600	17.2	1,546
2. East Branch	15,500	9.25	1,675
3. Thomaston	158,000	97.2	1,625
4. Northfield Brook	9,000	5.7	1,580
5. Black Rock	35,000	20.4	1,715
6. Hancock Brook	20,700	12.0	1,725
7. Hop Brook	26,400	16.4	1,610
8. Tully	47,000	50.0	940
9. Barre Falls	61,000	55.0	1,109
10. Conant Brook	11,900	7.8	1,525
11. Knightville	160,000	162.0	987
12. Littleville	98,000	52.3	1,870
13. Colebrook River	165,000	118.0	1,400
14. Mad River	30,000	18.2	1,650
15. Sucker Brook	6,500	3.43	1,895
16. Union Village	110,000	126.0	873
17. North Hartland	199,000	220.0	904
18. North Springfield	157,000	158.0	994
19. Ball Mountain	190,000	172.0	1,105
20. Townshend	228,000	106.0(278 total)	820
21. Surry Mountain	63,000	100.0	630
22. Otter Brook	45,000	47.0	957
23. Birch Hill	88,500	175.0	505
24. East Brimfield	73,900	67.5	1,095
25. Westville	38,400	99.5(32 net)	1,200
26. West Thompson	85,000	173.5(74 net)	1,150
27. Hodges Village	35,600	31.1	1,145
28. Buffumville	36,500	26.5	1,377
29. Mansfield Hollow	125,000	159.0	786
30. West Hill	26,000	28.0	928
31. Franklin Falls	210,000	1000.0	210
32. Blackwater	66,500	128.0	520
33. Hopkinton	135,000	426.0	316
34. Everett	68,000	64.0	1,062
35. MacDowell	36,300	44.0	825

MAXIMUM PROBABLE FLOWS BASED ON TWICE THE STANDARD PROJECT FLOOD (Flat and Coastal Areas)

	River	SPF (cfs)	D.A. (sq. mi.)	MPF (cfs/sq. mi.)
1.	Pawtuxet River	19,000	200	190
2.	Mill River (R.I.)	8,500	34	500
3.	Peters River (R.I.)	3,200	13	490
4.	Kettle Brook	8,000	30	530
5.	Sudbury River.	11,700	86	270
6.	Indian Brook (Hopk.)	1,000	5.9	340
7.	Charles River.	6,000	184	65
8.	Blackstone River.	43,000	416	200
9.	Quinebaug River	55,000	331	330


MAXIMUM PROBABLE FLOOD
PEAK FLOW RATES
x5 - NED DAM IDENTIFICATION
⊗7' - TWICE SPF AT INDICATED SITES
DEC. 1977
M.P.F. IN C.F.S./SQ. MILE
DRAINAGE AREA IN SQ. MILES
MOUNTAINOUS
ROLLING
FLAT & COASTAL
3000
2500
2000
1500
1000
500
0
2
5
10
20
30
40
50
100
500
1000

ESTIMATING EFFECT OF SURCHARGE STORAGE ON MAXIMUM PROBABLE DISCHARGES



STEP 1: Determine Peak Inflow (Q_{p1}) from Guide Curves.

STEP 2: a. Determine Surcharge Height To Pass "Q_{p1}".

b. Determine Volume of Surcharge ($STOR_1$) In Inches of Runoff.

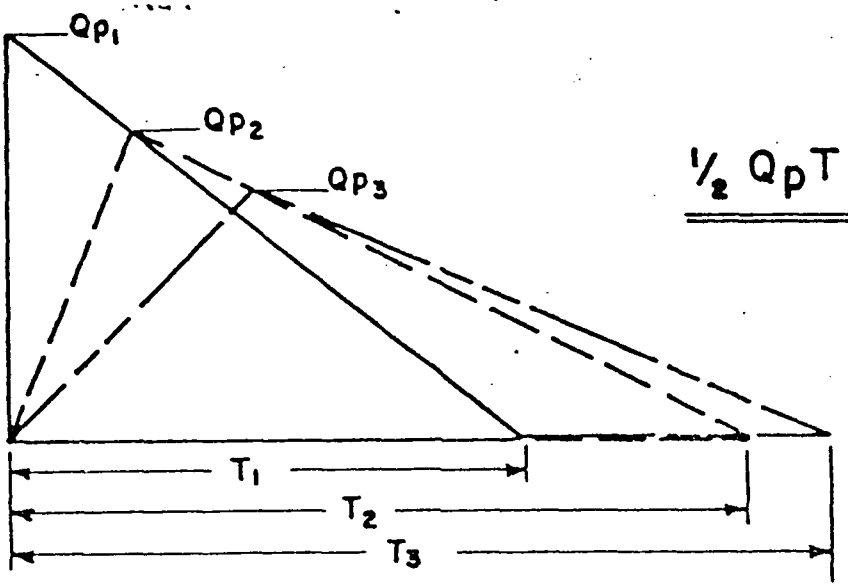
c. Maximum Probable Flood Runoff In New England equals Approx. 19", Therefore:

$$Q_{p2} = Q_{p1} \times \left(1 - \frac{STOR_1}{19}\right)$$

STEP 3: a. Determine Surcharge Height and "$STOR_2$" To Pass "Q_{p2}"

b. Average "$STOR_1$" and "$STOR_2$" and Determine Average Surcharge and Resulting Peak Outflow "Q_{p3}".

"RULE OF THUMB" GUIDANCE FOR ESTIMATING DOWNSTREAM DAM FAILURE HYDROGRAPHS



$\frac{1}{2} Q_p T = 12 S$

STEP 1: DETERMINE OR ESTIMATE RESERVOIR STORAGE (S) IN AC-FT AT TIME OF FAILURE.

STEP 2: DETERMINE PEAK FAILURE OUTFLOW (Q_{p1}).

$$Q_{p1} = \frac{8}{27} W_b \sqrt{g} Y_o^{3/2}$$

W_b = BREACH WIDTH - SUGGEST VALUE NOT GREATER THAN 40% OF DAM LENGTH ACROSS RIVER AT MID HEIGHT.

Y_o = TOTAL HEIGHT FROM RIVER BED TO POOL LEVEL AT FAILURE.

STEP 3: USING USGS TOPO OR OTHER DATA, DEVELOP REPRESENTATIVE STAGE-DISCHARGE RATING FOR SELECTED DOWNSTREAM RIVER REACH.

STEP 4: ESTIMATE REACH OUTFLOW (Q_{p2}) USING FOLLOWING ITERATION.

A. APPLY Q_{p1} TO STAGE RATING, DETERMINE STAGE AND ACCOPMANYING VOLUME (V_1) IN REACH IN AC-FT. (NOTE: IF V_1 EXCEEDS 1/2 OF S, SELECT SHORTER REACH.)

B. DETERMINE TRIAL Q_{p2}.

$$Q_{p_2}(\text{TRIAL}) = Q_{p_1}\left(1 - \frac{V_1}{S}\right)$$

C. COMPUTE V_2 USING Q_{p2} (TRIAL).

D. AVERAGE V_1 AND V_2 AND COMPUTE Q_{p2}.

$$Q_{p_2} = Q_{p_1}\left(1 - \frac{V_{avg}}{S}\right)$$

STEP 5: FOR SUCCEEDING REACHES REPEAT STEPS 3 AND 4.

APRIL 1978

APPENDIX E

INFORMATION AS CONTAINED IN

THE NATIONAL INVENTORY OF DAMS

END

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