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NATIONAL DAM SAFETY PROGRAM CROTON FALLS DAM, (NY39) LOWER HUDS--ETC(U)
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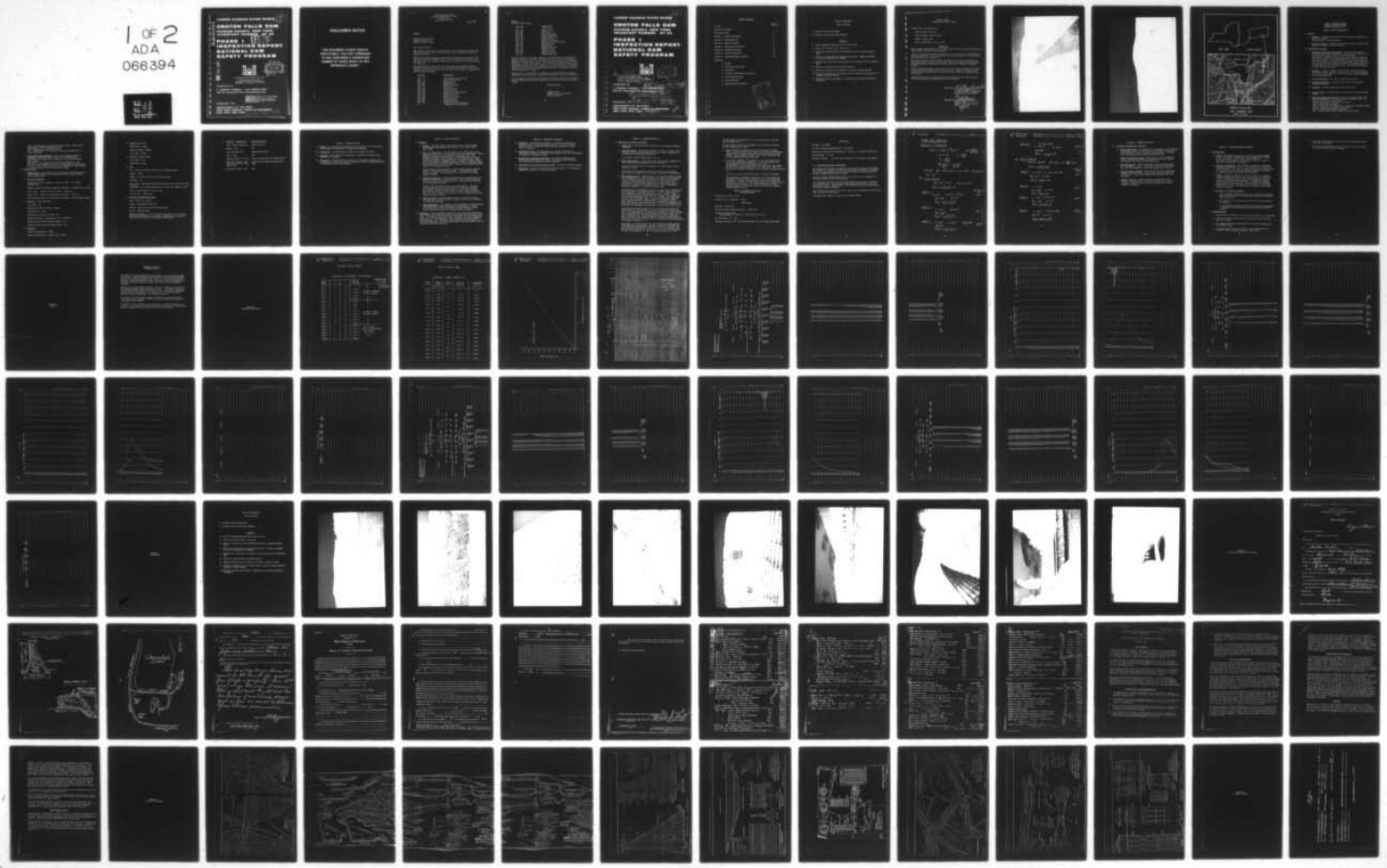

AD A066394

LOWER HUDSON RIVER BASIN

CROTON FALLS DAM

PUTNAM COUNTY, NEW YORK
INVENTORY NUMBER NY 39

PHASE 1 INSPECTION REPORT NATIONAL DAM SAFETY PROGRAM

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CONTRACT NO. DACW-51-78-C-0025

Prepared by

L. ROBERT KIMBALL and ASSOCIATES
615 W. Highland Ave. Ebensburg, Pa.

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Prepared For

DEPARTMENT OF THE ARMY
NEW YORK DISTRICT, CORPS OF ENGINEERS
NEW YORK, NEW YORK

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DEPARTMENT OF THE ARMY
U. S. ARMY ENGINEER DISTRICT, NEW YORK
26 FEDERAL PLAZA
NEW YORK, NEW YORK 10007

2 OCT 1978

NANEN-F

Honorable Hugh L. Carey
Governor of New York
Albany, New York 12224

Dear Governor Carey:

The purpose of this letter is to inform you of a clarification of the guidelines used by this office in assessing dams under the National Program of Inspection of Dams.

Office of the Chief of Engineers has recently provided a clarification that dams with seriously inadequate spillways are to be assessed as unsafe, non-emergency, until more detailed studies prove otherwise or corrective measures are completed.

The following dams in your state have previously been assessed as having seriously inadequate spillways, with capability to pass safely only the percentage of the probable maximum flood as noted in each report. They are now to be assessed as unsafe:

I.D. NO.	NAME OF DAM
N.Y. 59	Lower Warwick Reservoir Dam
N.Y. 4	Salisbury Mills Dam
N.Y. 45	Amawalk Dam
N.Y. 418	Jamesville Dam
N.Y. 685	Colliersville Dam
N.Y. 6	Delta Dam
N.Y. 421	Oneida City Dam
N.Y. 39	Croton Falls Dam
N.Y. 509	Chadwick Dam (Plattenkill)
N.Y. 66	Boyds Corner Dam
N.Y. 397	Cranberry Lake Dam
N.Y. 708	Seneca Falls Dam
N.Y. 332	Lake Sebago Dam
N.Y. 338	Indian Brook Dam
N.Y. 33	Lower(S) Wiccopee Dam (Lower Hudson W.S. for Peekskill)

NANEN-F
Honorable Hugh L. Carey

I.D. NO.	NAME OF DAM
N.Y. 49	Pocantico Dam
N.Y. 445	Attica Dam
N.Y. 658	Cork Center Dam
N.Y. 153	Jackson Creek Dam
N.Y. 172	Lake Algonquin Dam
N.Y. 318	Sixth Lake Dam
N.Y. 13	Butlet Storage Dam
N.Y. 90	Putnam Lake (Bog Brook Dam)
N.Y. 166	Pecks Lake Dam
N.Y. 674	Bradford Dam
N.Y. 75	Sturgeon Pool Dam
N.Y. 414	Skaneateles Dam
N.Y. 155	Indian Lake Dam
N.Y. 472	Newton Falls Dam
N.Y. 362	Buckhorn Lake Dam

The classification of "unsafe" applied to a dam because of a seriously inadequate spillway is not meant to connote the same degree of emergency as would be associated with an "unsafe" classification applied for a structural deficiency. It does mean, however, that based on an initial screening, and preliminary computations, there appears to be a serious deficiency in spillway capacity so that if a severe storm were to occur, overtopping and failure of the dam would take place, significantly increasing the hazard to loss of life downstream from the dam.

Consequently, it is advisable to implement the recommendations previously furnished in the reports for the above-mentioned dams as soon as practicable.

It is requested that owners of these dams be furnished a copy of this letter and that copies be permanently appended to all reports previously furnished to you.

Sincerely yours,

CLARK H. BENN
Colonel, Corps of Engineers
District Engineer

LOWER HUDSON RIVER BASIN

CROTON FALLS DAM

PUTNAM COUNTY, NEW YORK
INVENTORY NUMBER NY 39

PHASE 1 INSPECTION REPORT NATIONAL DAM SAFETY PROGRAM

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(NY39)

(6) National Dam Safety Program. Croton Falls Dam, Lower Hudson River Basin, Putnam County, New York (NY 39). Phase I Inspection Report.

Prepared by

(10) R. Jeffrey Kimball, Jr.

L. ROBERT KIMBALL and ASSOCIATES
615 W. Highland Ave. Ebensburg, Pa.

(15) DACW51-78-C-0025

Prepared For (11) 30 Jun 78 (12) 112p.

DEPARTMENT OF THE ARMY
NEW YORK DISTRICT, CORPS OF ENGINEERS
NEW YORK, NEW YORK

79 03 26 185

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2. Overall view from above left abutment.

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4. Front view of major crack in structure.
5. Close up of downstream slope showing deterioration, seepage and major crack.
6. Close up of downstream face showing deterioration, seepage and buildup of calcium carbonate due to seepage.
7. Upstream face, gate house and portions of the spillway from left abutment area.
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11. Emergency spillway exit channel, stilling basin and energy dissipators in channel.

Phase I Report
National Dam Safety Program

Name of Dam: Croton Falls Dam

State Located: New York

County Located: Putnam County

Stream: Croton River

Date of Inspection: May 1-2, 1978

ASSESSMENT

The inspection and evaluation of the Croton Falls Dam did not reveal any problems which require immediate emergency action.

The test boring program currently proposed by the owner should be completed this summer as scheduled. Follow up stability and seepage analysis of the dam should be completed as soon as practical.

Results of conservative flood routing conducted for this report indicated that the spillway will not pass the PMF or SPF. Based on this analysis the spillway is termed seriously inadequate as defined by ETL 1110-2 "Reviews of Spillway Adequacy."

A more detailed hydrologic analysis should be conducted to determine the extent of necessary modifications to hydrologic controls. Should the detailed study conclude remedial modifications are necessary they should be completed in the near future.

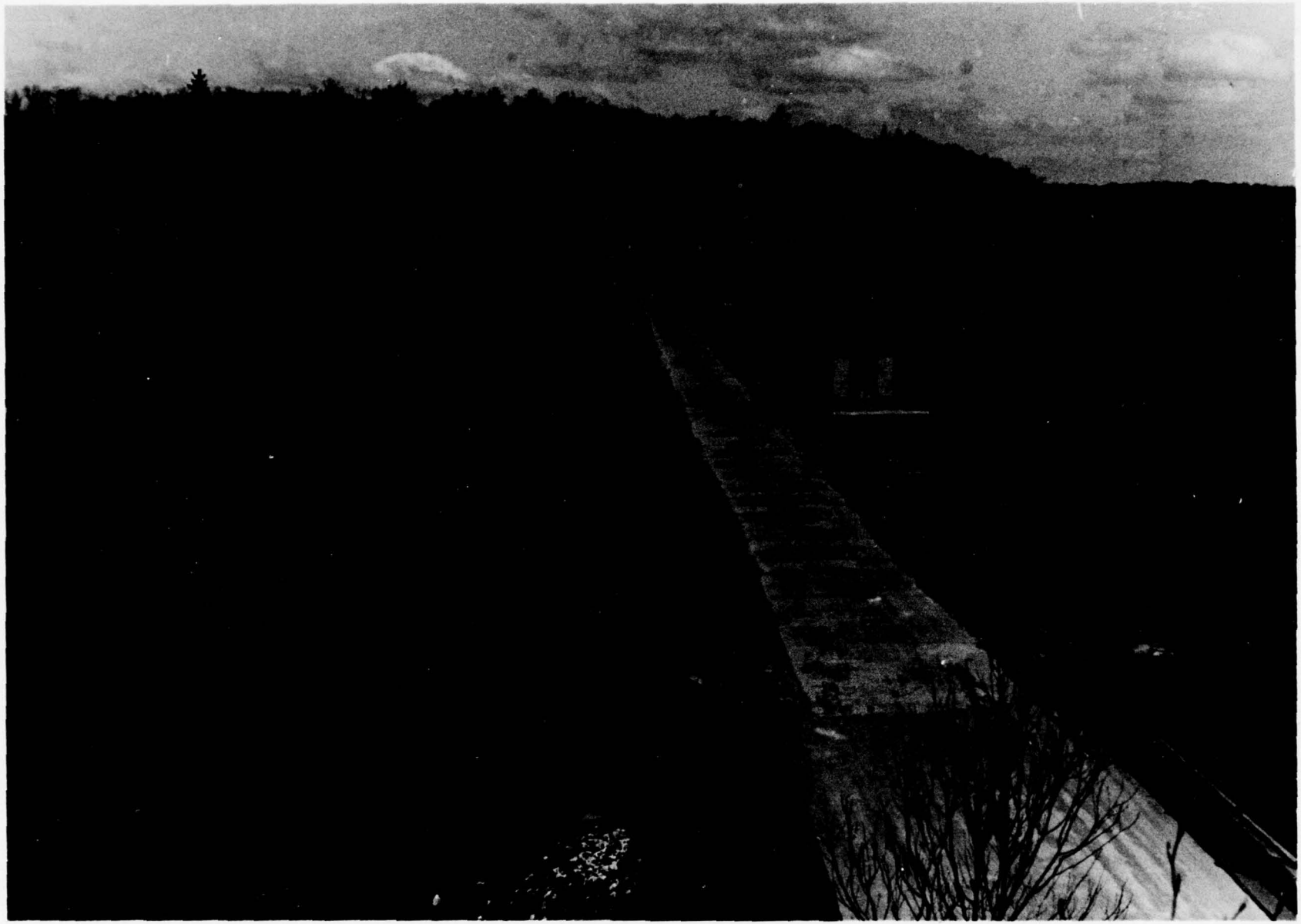
A monitoring program to evaluate movement and seepage from the major crack in the structure should be implemented as soon as possible.

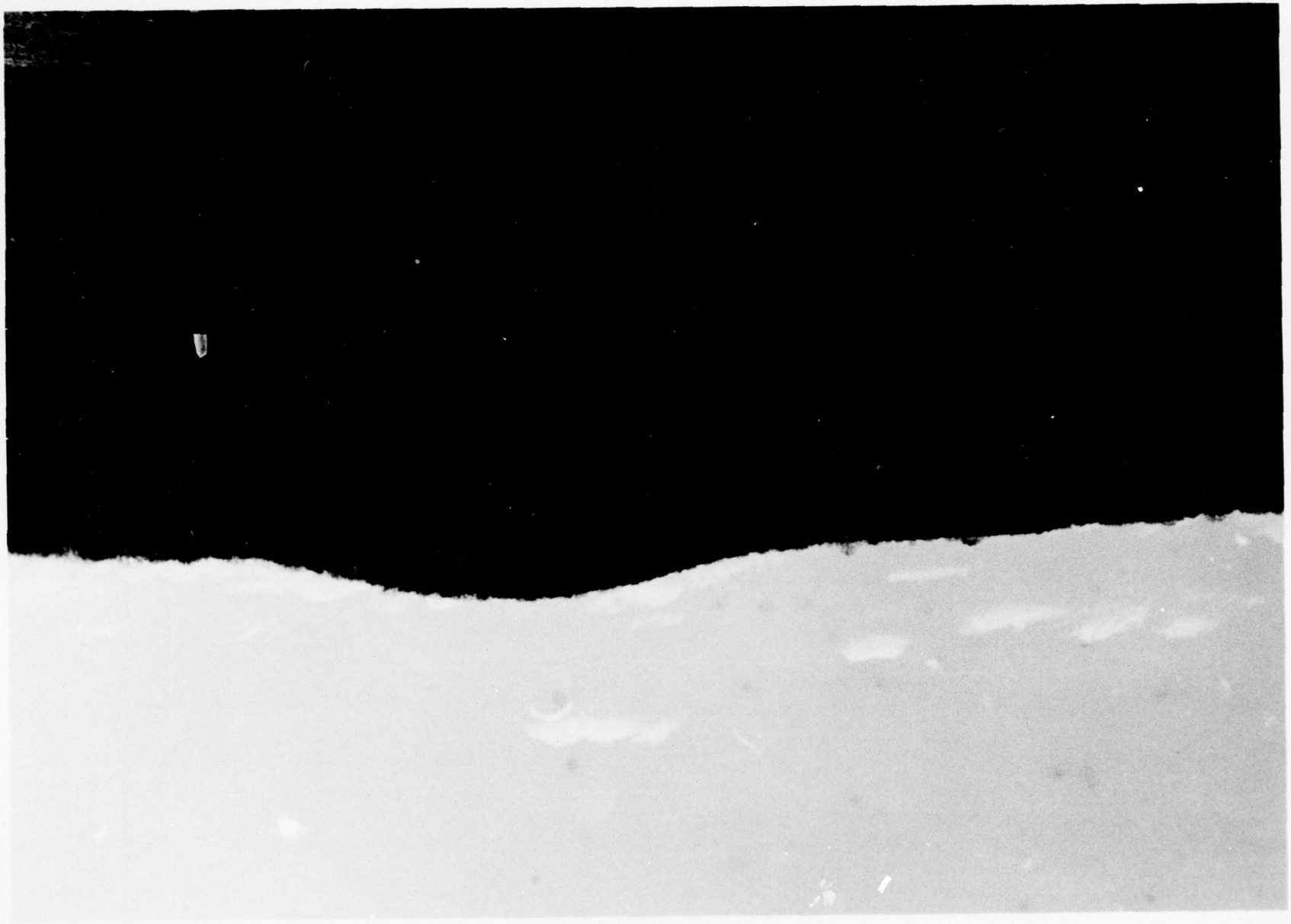
Approved by: R Jeffrey Kimball

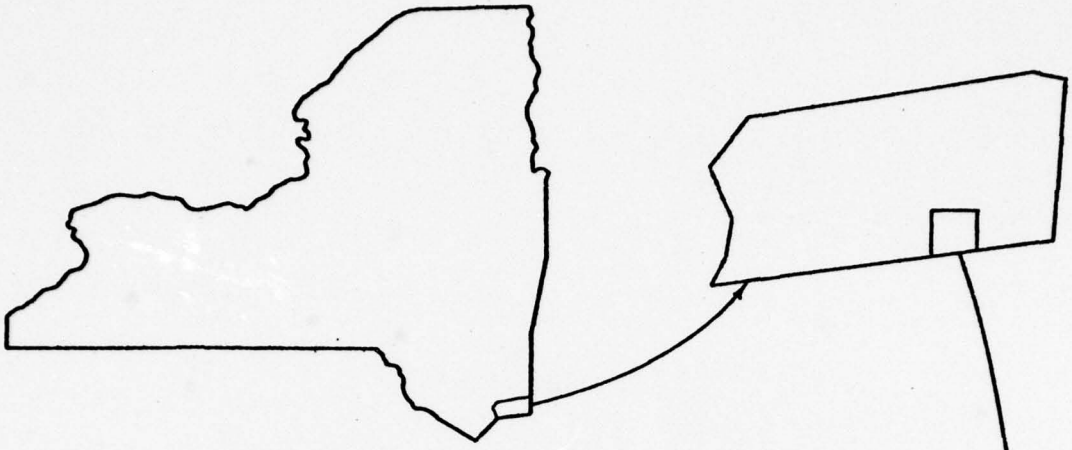
R. Jeffrey Kimball, P.E.
L. ROBERT KIMBALL & ASSOCIATES
Registration No. PA 26275E

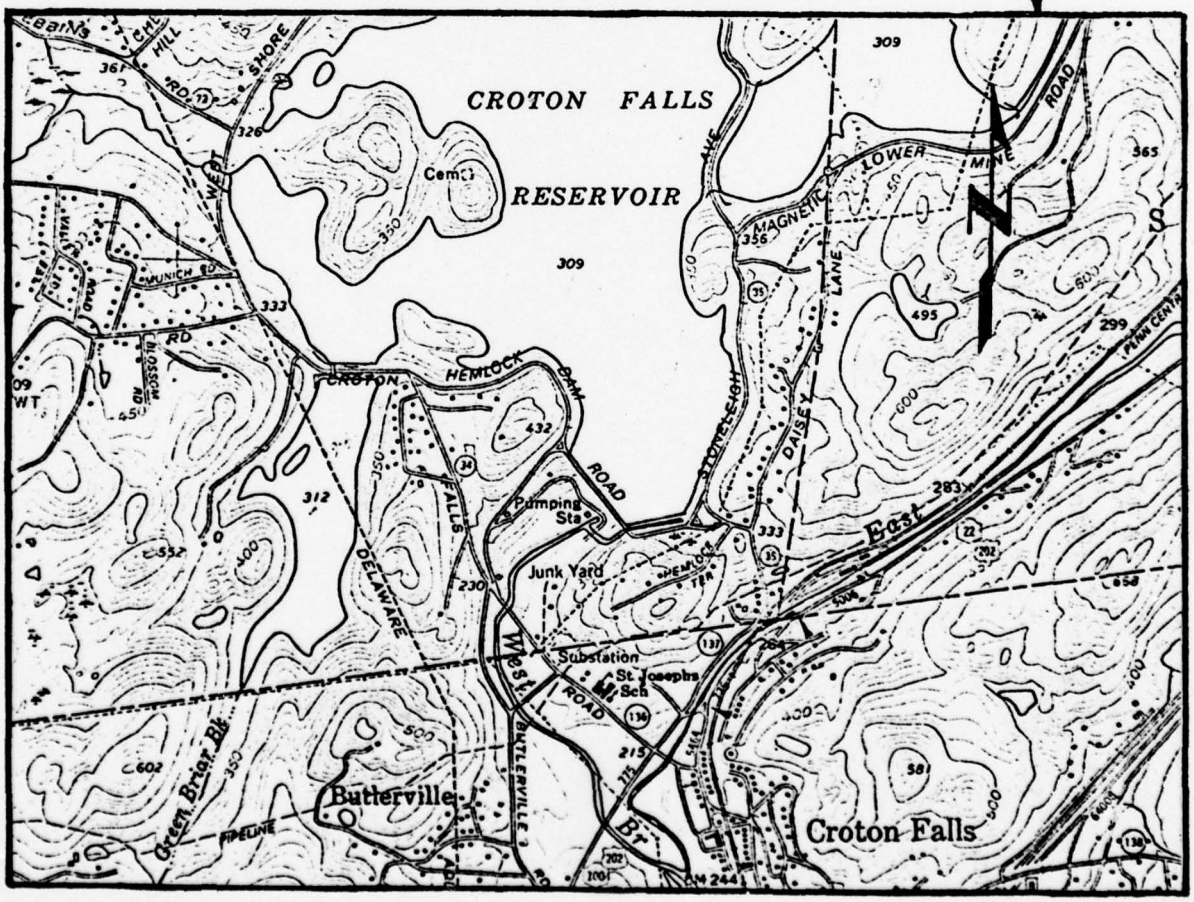
Approved by:

CLARK H. BENN
Colonel, Corps of Engineers
District Engineer
30 June 78









CROTON FALLS DAM

SITE LOCATION MAP

SCALE : 1"=2000'

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
CROTON FALLS DAM ID # 39

SECTION I PROJECT INFORMATION

1.1 General

a. Authority: Authority is provided by the National Dam Inspection Act Public Law 92-367
Contract Number: DACW51-78-C-0025

b. Purpose of Project: Evaluation of non-Federal dams to identify dams which are a threat to life and property.

1.2 Description of Project:

a. Description of Dam and Appurtenances: The Croton Falls Dam is a cyclopean masonry gravity dam with a total structural height of 175 feet above the cutoff and 98 feet above final grade.
The emergency spillway is a 700 foot long broad crested weir which flows into a sloping and diverging (width) side channel. Below the side channel control (at the approximate dam axis) the channel is a concrete cascading exit channel with large baffle energy dissipators.
The principal spillway and water supply lines are controlled by a concrete intake structure and gate house. The outlet works consist of three 48" cast iron pipes.

b. Location: The dam is located in Putnam County near Croton Falls, Westchester County, New York. The location of the dam can be found on the Croton Falls, New York U.S.G.S. 7.5 minute series quadrangle (see site location map).

c. Size Classification: The dam is a large size structure.

d. Hazard Classification: The Croton Falls Dam is a high hazard potential structure.

e. Ownership: The dam is owned by the City of New York.

f. Purpose of Dam : The dam is part of the New York City water supply system.

g. Design and Construction History: The dam was designed by New York City staff engineers. Construction began in September 1906. The dam was put in service in June 1910.
The post construction chronology is as follows:
1912 - Repairs made to spillway.
1921-22- Downstream face shows signs of deposits from seepage through the dam. Portions of face begin to deteriorate.
1923 - Spillway modifications recommended.
1924 - Valves in gate chamber cracked, repaired in 1929.

1942 - Erosion noted on upstream of over flow weir. Repairs were recommended in 1959 and completed in 1960.
1975 - Seepage tests conducted by owner.
1977 - Merlin Copen, P.E. retained to evaluate the condition of Croton Falls Dam.

h. Normal Operational Procedures: Under normal conditions water is discharged to the water supply system on an as-needed basis. Maintenance and inspection are conducted by city staff stationed near the dam.
Upper gate in the intake tower is operated periodically. The lower gate and drawdown drain are not operated because trash screens are not in place, therefore, it may not be possible to close the gates or trash may pass into and block the outlet pipes.

1.3 Pertinent Data

a. Drainage Areas: The drainage area is recorded as 168.64 square miles. Parts of the drainage area are developed and parts remain in their natural wooded state.

b. Discharge at Damsite:

Maximum known flood at damsite: October 15, 1955 - 3.24' above spillway crest.

Spillway capacity at maximum design pool elevation: 16,500 cfs top of dam

Outlet works capacity at pool elevation: 1,800 cfs

Outlet works capacity at maximum pool elevation: 1,875 cfs

Total spillway capacity at maximum pool elevation: 18,375 cfs (Top of dam)

c. Elevation: (feet above MSL)

Top of Dam: 322

Maximum Pool Design Surcharge: Unknown

Spillway Crest: 310.0

Stream bed at Centerline of Dam: 212

Maximum Tail water: Approximately 213.5 at fountain

Upstream portal invert diversion tunnel: 215

Downstream portal invert diversion tunnel: 212

d. Reservoir:

Length of normal pool: 17,500'

Length of maximum pool: 18,500' (Top of Dam)

e. Storage (acre feet)

Normal Pool: 43,500

Design Surcharge: Unknown

Top of Dam: 49,760

f. Reservoir Surface (acres)

Top of Dam: 1,324

Normal Pool: 1,166

g. Dam:

Type: Gravity structure constructed of cyclopean masonry

Length: 1,070'

Height: 175' above cutoff, 98' above final grade

Top Width: 23'

Side slopes: Upstream-vertical above elevation 210', below 210' slope is 0.25:1
Downstream - 0.56:1 above elevation 210', below 210' slope is 0.75:1

Cutoff: Approximately 10' deep in rock

Grout Curtain : None known

h. Diversion and Regulating Tunnel:

Type: Three 48" C I pipes

Length: Approximately 100' long

Closure: Gates at gate house on upstream face.

Access: From gate house

Regulating Facilities: Flow can also be regulated at toe to by-pass flow into turbine station. The turbine station is used to drive a pump which forces water into the water supply tunnel.

i.	Spillway:	Spillway Weir	Side Channel Weir
	Type:	Broad crested weir	Control section
	Length:	700'	60'
	Crest Elevation	310'	Approximately 297.5'
	Gates:	None	None
	Upstream Channel:	5' long	Same as spillway weir downstream channel
	Downstream Channel:	Open and cut in rock 700' long, 23-60' wide	Concrete paved cascading spillway 450' wide
j.	Regulating outlets:	None	None

Section 2: Engineering Data

2.1 Design: The construction drawings were made available at the city office. No information on hydrologic or stability calculations.

2.2 Construction: No construction records were available for review.

2.3 Operation: Minor amounts of information on rainfall and repairs of the spillway were available.

2.4 Evaluation: Good information is available on the physical dimensions of the structure. However, hydrologic and stability data is lacking to perform a detailed analysis of the structure.

Section 3: Visual Inspection

3.1 Findings:

a. General: The Croton Falls Dam was inspected by L. Robert Kimball and Associates and personnel from the City of New York on May 1 and 2, 1978.

b. Dam: The dam appears to conform closely to the design construction drawings in most areas. The dam appears to be well maintained. Several cracks are visible on the upstream and downstream faces. One significantly large crack is present on the downstream face and can be traced through the drainage gallery to the upstream face. These cracks show evidence of seepage and have deposits of calcium carbonate around them making an unsightly appearance. Slabs of ornamental blocks have fallen from the top of the dam. Spalling of both faces is present probably from freeze-thaw action.

From inside the drainage gallery vertical and horizontal cracks are visible. Some of the concrete is porous. In both bastions open cracks are visible. The dam appears to be well seated into dense schist or gneiss.

c. Appurtenant Structure: Water was flowing over the spillway weir, but the weir appeared to be in good condition. Exit channels have water flowing but the concrete appeared to be in relatively good condition as it was repaired in 1960.

The gate house and power house were in good condition. The three 48 inch pipes are used for water supply to the Deleware Aqueduct. The emergency drawdown sluice gate has not been opened for quite some time due to the fact that it does not have a trash screen and fear that it has silted up and the potential for damaging outlet works should the pipe be opened.

d. Reservoir Area: The lake impounds the water of the Croton River. The overburden is relatively thin throughout the area and the slopes are steep and vegetated.

e. Downstream Channel: The immediate downstream channel is wide, grassed, and undeveloped. Further downstream some development is present. The valley bottom is wide and contains glacial sediment with the valley slopes consisting of hard inplace schist or gneiss.

3.2 Evaluation: Visual inspection reveals that some cracks have developed in the structure and through these cracks some seepage and leaching is taking place. The structure is well founded on competent rock and no seepage is present at the toe or downstream. Some development is present beyond 1/2 mile downstream. The spillway and water drawdown facilities appear to be in good condition. The dam and appurtenant structures appear to closely follow the construction drawings.

SECTION 4: OPERATIONAL PROCEDURES

4.1 Procedures: The operational procedure to control the lake level or outflow is based on the water supply needs of the City of New York. When more water is needed for the City of New York water is drawn from the reservoir.

4.2 Maintenance of Dam: The maintenance and operation of the dam is controlled by the East of Hudson Division, Katonah, New York. Maintenance of the dam is performed as needed.

4.3 Maintenance of Operating Facilities: The operating facilities are operated and maintained by the staff of the East of Hudson Division. The facilities are operated at regular intervals.

4.4 Description of any warning system in effect: No warning system is present.

4.5 Evaluation: The dam and appurtenant structures appear to be operated at regular intervals and to be well maintained.

SECTION 5: HYDRAULIC/HYDROLOGIC

5.1 Hydrologic Evaluation of Features

a. Design Data: No design data was available on the emergency spillway structure.

b. Experience Record: The maximum discharge of record occurred in 1955. The water rose to 3.24 feet above the spillway crest, equivalent to a discharge of approximately 11,000 cfs.

A rain gage is located downstream of the dam.

c. Visual Observations: At the time of the inspection approximately 0.2 feet of water was discharging over the spillway weir.

No serious deterioration of the spillway weir, side channel or exit channel was noted.

The bridge over the spillway at the side channel control section appeared to be influential in the discharge capacity of the spillway.

d. Overtopping Potential: Overtopping potential was investigated through the development of the probable maximum flood (PMF) for the watershed and the subsequent routing of the PMF through the reservoir system. The PMF is that hypothetical flow induced by the most critical combination of precipitation, minimum infiltration losses, and concentration of run-off at a specific location, that is considered reasonably possible for a particular drainage area.

The drainage area contributing to the Croton Falls Dam is approximately 168 square miles. To develop the basic hydrologic working tool, the unit hydrograph, Snyder Coefficients were used. A report titled "Lower Hudson River Basin Hydrologic Flood Routing Model" prepared by Water Resources Engineers, Inc., 1977 was reviewed. This report did not model the Croton Falls River. An adjacent watershed, Peekskill Hollow Creek was modeled. This information was used to develop Snyder Coefficients. The average Cp for Peekskill Hollow area was 0.57. This value was selected for Croton Falls. A review and comparision of watershed size and shape led to the selection of a value of Tp = 9.07.

Using hydrometeorological Report No. 33, the PMP index rainfall was determined to be 21.0 inches for a 24 hour duration, 200 square mile basin. The percentages of the index rainfall applied to other durations were interpolated from the plot of drainage area versus percent of 24 hour, 200 square mile. The computed PMF peak flow was 98,700 CFS. After routing the PMF through the impounded storage, the peak flow was reduced to 92,890 CFS. A plot of the PMF inflow and outflow hydrographs is included in Appendix B.

The ability of the Croton Falls Dam to discharge the standard project flood (SPF) was also evaluated. The SPF peak flow of 48,210 CFS was routed through the impounded storage and reduced to 36,320 CFS. The SPF outflow is indicative of a pool elevation of 325.4 feet above MSL. The dam is overtopped by 3.4 feet, the spillway crest by 15.4 feet.

The PMF outflow is equivalent to 8.5 feet over the dam (20.5 feet above spillway crest).

To allow inflow and outflow hydrographs to be developed and routed several assumptions were made.

1. Numerous lakes and reservoirs are located upstream of Croton Falls. For the purpose of this analysis the storage and discharge characteristics of these water bodies were ignored, as they were unknown. This assumption yields a conservative analysis if none of the upstream structures should fail.

2. To develop a discharge rating both flow over the spillway and in the side channel were considered. A weir coefficient of 2.8 was assumed for both the spillway and top of dam.
Critical depth at the opening under the bridge at the side channel control was assumed and the critical flow calculated. This flow was used as a limiting discharge once the spillway discharge exceeded it.

   Flow over the top of the dam was added to evaluate overtopping.

   The hydrologic and hydraulic evaluation of the Croton Falls Dam conducted during this study is considered to be conservative and approximate. Because of numerous unknowns the flood routing was performed to provide a tool for determining whether further detailed studies would be required. The results indicate that a more detailed analysis is necessary to quantify the need for remedial modifications at the site.

SUMMARY OF HYDROLOLOGIC ANALYSES
CROTON FALLS DAM

Elevation Top of Dam = 322.0

Elevation Crest of Spillway = 310.0

PMF Routing

PMF Peak - 98,700 CFS

PMF After Routing through Reservoir - 92,890 CFS

Elevation of Routed PMF
Corresponding to 92,890 cfs - 330.5 Feet above M.S.L.

Dam Overtopped - 8.5 Feet

Spillway Surcharge - 20.5 Feet above spillway, 33.0 Feet above side channel

SPF Routing

SPF Peak - 48,210 CFS

SPF After Routing Through Reservoir - 36,320 CFS

Elevation of Routed SPF Corresponding to 36,320 cfs - 325.4 Feet above M.S.L.

Dam Overtopped - 3.4 Feet

Spillway Surcharge - 15.4 Feet above spillway, 27.9 Feet above side channel

5.2 Hydraulic Evaluation of Flood Wave

For the dam break analysis the flood wave for both total and partial failures was computed to a distance of 6,500 feet downstream of the dam. Croton Falls Dam is a cyclopean masonry gravity structure founded on rock making partial failure the most likely of the two cases.

The reach studied extended downstream of Croton Falls to the backwaters of the Muscoot Reservoir and the Croton River.

The calculations indicate that only minimal damage would occur in the event of a partial breach. The calculated water depth would be below the town of Croton Falls and St. Josephs School. The chlorination house and structures at the junk yard would be damaged.

Total failure would result in 20 feet of water over the school and 15 to 20 feet over the town of Croton Falls.

Calculated water depths are shown on the following pages.

Croton Falls Reservoir

Hydraulics – Flood Wave

$$Q_{max} = .29\sqrt{g}\, K^{.28} W_b D_b^{1.5}, \quad K = \frac{W_d Y_o}{W_b D_b}$$

$$T_s = L \cdot t_s, \quad t_s = \frac{\Delta S}{\Delta Q}$$

$$S_i = \frac{12 V_o}{Q_{max}}$$

$$\frac{\text{Att. } Q_{max}}{Q_{max}} = \frac{0.9 S_i}{S_i + T_s}$$

Storage $V_o = 59{,}000$ AF @ El. 323' – Top of Dam

$Y_o = 100'$

A) Full Breach

$W_b = W_d = 1100'$ $\quad D_b = Y_o = 100'$

$Q_{max} = 1.85 \times 10^6$ cfs

			Distance fr Dam
Reach 1	$L = 1800'$	@ Croton Falls Rd.	1,800'
	$D_{DS} = 88'$	$W = 1200'$	
	$Q_{max} = 1.67 \times 10^6$ cfs		
Reach 2	$L = 2000'$	$W = 3300'$	3,800'
	$D_{DS} = 45'$		
	$Q_{max} = 1.52 \times 10^6$ cfs		
Reach 3	$L = 700'$	$W = 3000'$ @ Hwy #100	4,500'
	$D_{DS} = 43'$		
	$Q_{max} = 1.37 \times 10^6$ cfs		

Reach 4 @ Croton Falls

$L = 2{,}000'$ $W = 2200'$ 6,500'

$D_{DS} = 48'$

$Q_{max} = 1.23 \times 10^6$ cfs

B) Partial Breach

Assume $W_b = 50'$ $D_b = Y_o = 100$ $K = \frac{1100}{50} = 22$

$Q_{max} = 199{,}700$ cfs

Distance to Dam

Reach 1 $L = 1{,}800'$ @ Croton Falls Rd 1,800'

$D_{DS} = 30.5'$ $W = 650'$

$Q_{max} = 181{,}600$ cfs

Reach 2 $L = 2000'$ 3,800'

$D_{DS} = 14.5'$ $W = 1{,}800'$

$Q_{max} = 167{,}000$ cfs

Reach 3 $L = 700'$ @ Hwy #100 4,500'

$D_{DS} = 13.7'$ $W = 1800'$

$Q_{max} = 153{,}000$ cfs

Reach 4 $L = 2{,}000'$ @ Croton Falls. 6,500'

$D_{DS} = 16'$ $W = 1300'$

$Q_{max} = 140{,}000$ cfs

SECTION 6: STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability:

a. Visual Observations: No misalignment or settlement of the structure was observed. Water was flowing over the spillway and prevented a close examination of the crest slab and exit channel. One large crack is present possibly extending through the dam.

b. Design and Construction Data: Design data is not available for review. Dam typical sections are available but do not indicate the stability of the dam or the spillway weir.

c. Operating Records: Little information on the operating records was available for review. One photograph was found which shows the large crack present one year after completion of the dam.

d. Post Construction Changes: There have been no post construction changes other than repair of the spillway and exit channel and replacement of valves, which should affect the stability of the structure.

e. Seismic Stability: Seismic stability computations are not available. The reservoir is located in seismic zone 1 and is assumed to present no hazard unless static conditions are unfavorable or marginal.

SECTION 7: ASSESSMENT/REMEDIAL MEASURES

7.1 Dam Assessment:

a. Safety: This dam does not appear to present an immediate danger to life or property. However, the cracks, seepage, and leaching of the concrete may increase with time and reduce the stability of the structure. The dam does not appear to present any serious operational deficiencies.

b. Adequacy of Information: The information available is inadequate for complete analysis of the dam. The validity of the information available appears to be good. Information on upstream structures was not available to conduct adequate hydrology analysis of the river. No stability analysis calculations were available.

c. Urgency: Although the dam does not have any structural stability information and the presence of one large crack, it is considered to be a non-emergency situation not requiring immediate action to protect current downstream development. It cannot be overemphasized that the need for the test borings and laboratory testing, initiated by the City of New York, should proceed at the earliest possible date to obtain information on the condition of the seeps, cracks and concrete.

d. Necessity for Additional Analyses:

1. After the proposed drilling and testing is completed, a detailed report should be prepared to include the condition of the cracks, seeps and concrete.

2. An analysis of the structural stability of the structure should be conducted.

3. A more detailed hydrologic analysis of the reservoir is necessary to determine spillway adequacy considering upstream reservoir storage.

7.2 Recommendations:

1. Access should be provided for easy close up viewing of the large crack.

2. Permanent reference points should be installed to monitor any movement in the crack.

3. The seepage water should periodically be tested and compared with the reservoir water.

4. An attempt should be made to install a flow measuring device to provide a record of seepage through the major crack.

5. The structural stability of the dam should be evaluated with the high water level (PMF).

6. An adequate warning system should be developed to be used in the event of potential failure or flooding.

Appendix A
Geology

GEOLOGICAL REVIEW OF
CROTON FALLS DAM

The bedrock in the Lower Hudson River Basin Region has been severely folded and deformed. Based on radiometric measurements the rocks near Croton Falls Dam are of the middle Proterozoic Age. These rocks were intially deformed during the Grenville geotectonic cycle and were additionally deformed by the Aoalonian, Quebician, Taconian, Acadian, and possibly by the Alleghanian Orogenies.

Because of all this movement and stress, the rocks located near the dam have been metamorphosed into biotite granitic gneiss A specimen collected near the dam had a mineral content of microline, plagioclase, quartz, hornblende, biotite, magnetite and apatite. In a large sense a crude foliation is produced by the interlayering of the different minerals.

To the east of the dam, pyritic gneiss is found and is characterized by a rusty, gossan-type weathering. Locally the weathering has been extreme and the gneiss is very crumbly.

In addition to the tectonics, this area has been glaciated during the late Cenozoic. The glaciers have eroded and deposited sediments of various thicknesses throughout the area, particularly in the valley bottoms.

Appendix B
Hydrologic Computations

CROTON FALLS DAM

ELEVATION - DISCHARGE RELATIONSHIP

ELEV. (FT)	H	C	TOTAL Q (C.F.S.)
310.0	0	2.8	0
311.0	1	2.8	1960
312.0	2	2.8	5544
313.0	3	2.8	10184
314.0	4	2.8	15680
315.0	5	2.8	16500
316.0	6	2.8	16500
317.0	7	2.8	16500
318.0	8	2.8	16500
319.0	9	2.8	16500
320.0	10	2.8	16500
321.0	11	2.8	16500
322.0	12	2.8	16500
323.0	1	2.8	19608
324.0	2	2.8	25290
326.0	4	2.8	41360
328.0	6	2.8	62180
330.0	8	2.8	86830

OVERFLOW WEIR
$Q = CLH^{3/2}$
$L = 700'$
Assume $C = 2.8$
$Q = 1960 H^{3/2}$

ASSUMING OVERFLOW WEIR CONTROL

ASSUMING SIDE CHANNEL CONTROL

TOP OF DAM; BEGIN OVERFLOW OVER DAM CREST
$L = 1110'$
$C = 2.8$

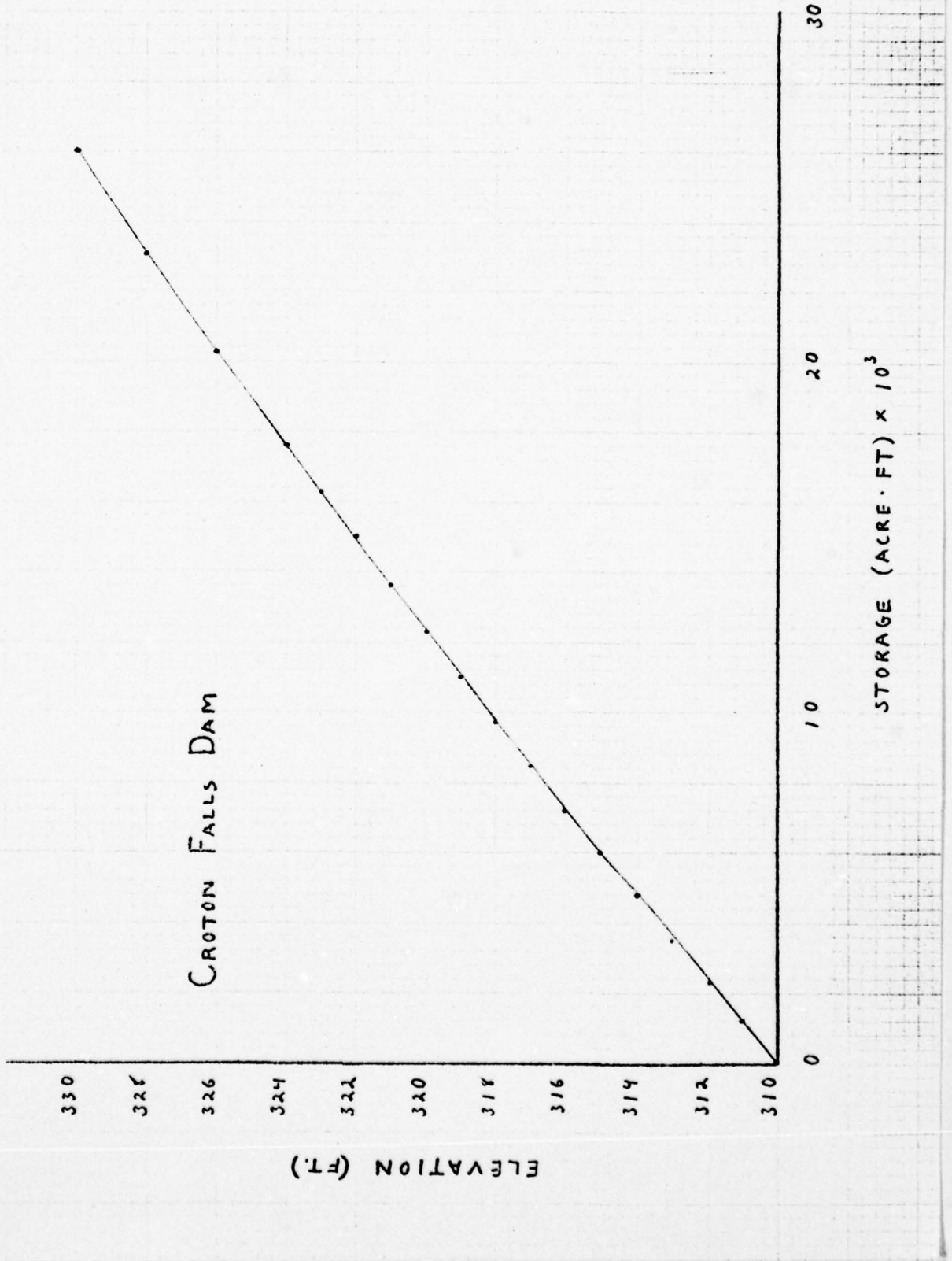
CROTON FALLS DAM

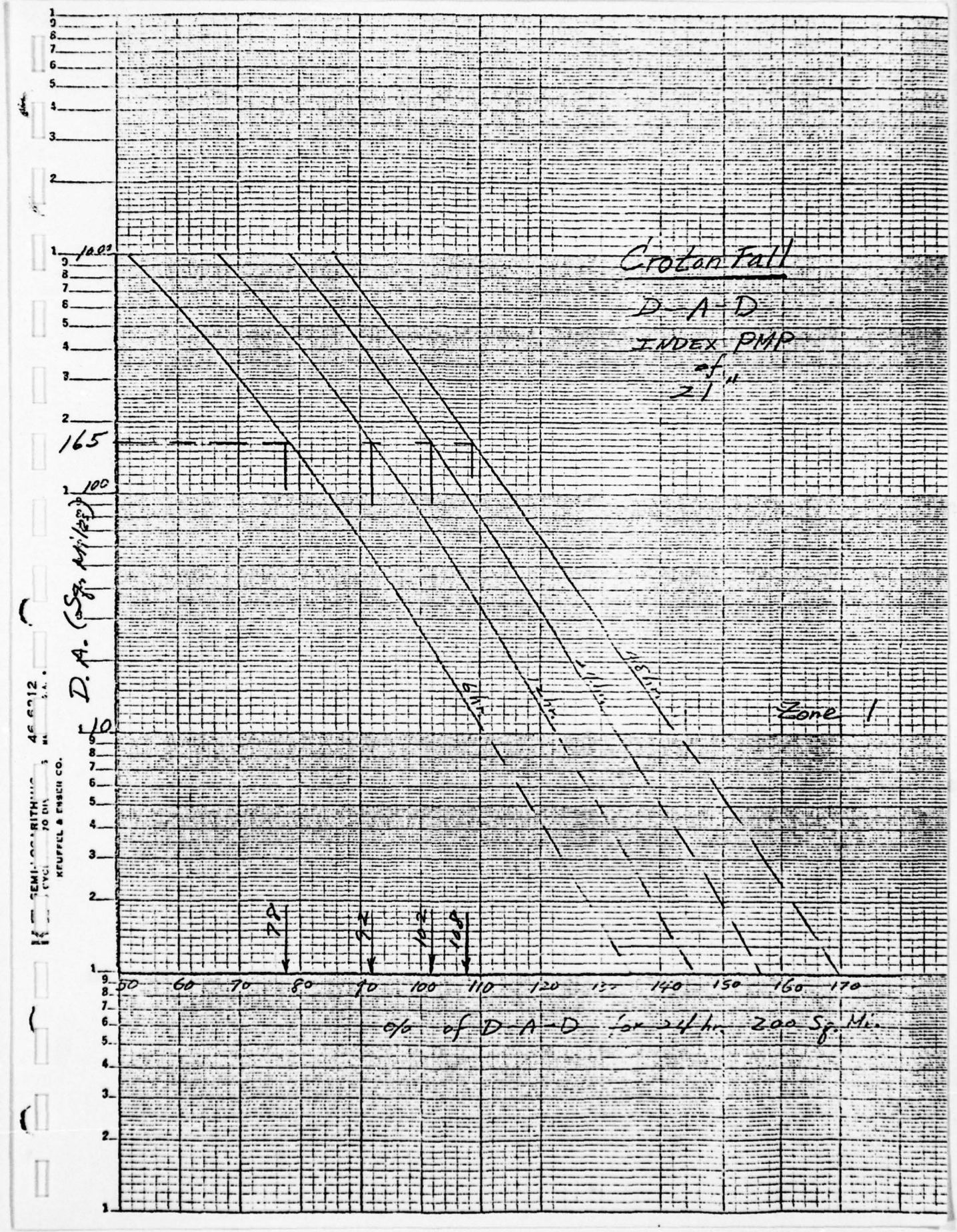
ELEVATION - STORAGE RELATIONSHIP

ELEV. (FT.)	SURFACE AREA (ACRES)	Δ ELEV. (FT.)	TOTAL STORAGE (AC. FT.)	DISCHARGE TOTAL Q (C. F. S.)
310.0	1166		0	0
		1.0		
311.0	1179		1172.5	1960
		1.0		
312.0	1192		2351.0	5544
		1.0		
313.0	1205		3556 5	10184
		1.0		
314.0	1218		4766.0	15680
		1.0		
315.0	1231		5992.5	16500
		1.0		
316.0	1243		7229 5	16500
		1.0		
317.0	1256		8479.0	16500
		1.0		
318.0	1269		9741 5	16500
		1.0		
319.0	1282		11017.0	16500
		1.0		
320.0	1295		12305.5	16500
		1.0		
321.0	1310		13608.0	16500
		1.0		
322.0	1324		14925.0	16500
		1.0		
323.0	1339		16256.5	19608
		1.0		
324.0	1354		17603.0	25290
		2.0		
326.0	1383		20340.0	41360
		2.0		
328.0	1413		23136.0	62180
		2.0		
330.0	1442		25991.0	86830

L. ROBERT KIMBALL
Consulting Engineers

JOB NAME N.Y. State Dam Inspection BY D.G DATE 5/3
JOB NUMBER SHEET NO. 3 OF




Croton Fall
D-A-D
INDEX PMP
of
21 "
Zone 1
D.A. (Sq. Mi.)
165
100
10
1
6 hr.
12 hr.
18 hr.
24 hr.
77
94
102
108
50 60 70 80 90 100 110 120 130 140 150 160 170
% of D-A-D for 24 hr. 200 Sq. Mi.
KEUFFEL & ESSER CO.

****
HEC-1 VERSION DATED JAN 1973
UPDATED AUG 74
CHANGE NO. 01
****

CHOTON FALLS DAM
RESERVOIR AT TOP OF FLOOD POOL
TEST SPF

JOB SPECIFICATION

NQ	NMR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
100	1	0	0	0	0	0	2	0	0

JOPER	NWT
3	0

********** ********** ********** ********** **********

SUB-AREA RUNOFF COMPUTATION

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME
1	0	0	0	0	0	0

HYDROGRAPH DATA

IHYDG	IUNG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
1	1	165.00	0.0	165.00	0.0	0.0	0	0	0

PRECIP DATA

SPFE	PMS	R6	R12	R24	R48	R72	R96
11.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRSPC COMPUTED BY THE PROGRAM IS 0.878

LOSS DATA

STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOK	STRTL	CNSTL	ALSMX	RTIMP
0.0	0.0	1.00	0.0	0.0	1.00	1.50	0.10	0.0	0.0

UNIT HYDROGRAPH DATA
TP# 9.07 CP#0.57 NTA# 0

RECESSION DATA
STRTQ# 165.00 QRCSN# -0.25 RTIOR# 3.00
APPROXIMATE CLARK COEFFICIENTS FROM GIVEN SNYDER CP AND TP ARE TC# 9.91 AND R# 9.95 INTERVALS

UNIT HYDROGRAPH 58 END-OF-PERIOD ORDINATES. LAG# 9.10 HOURS, CP# 0.57 VOL# 1.00

231.	862.	1748.	2775.	3891.	4979.	5869.	6483.	6808.	6766.
6319.	5714.	5167.	4672.	4225.	3821.	3455.	3124.	2825.	2555.
2310.	2089.	1889.	1708.	1545.	1397.	1263.	1142.	1033.	934.
845.	764.	691.	625.	565.	511.	462.	418.	378.	342.
309.	279.	253.	228.	207.	187.	169.	153.	138.	125.
113.	102.	92.	83.	76.	68.	62.	56.		

END-OF-PERIOD FLOW

TIME	RAIN	EXCS	COMP Q
1	0.00	0.00	148.
2	0.00	0.00	132.
3	0.00	0.00	119.
4	0.00	0.00	106.
5	0.00	0.00	95.
6	0.00	0.00	85.
7	0.01	0.00	76.
8	0.01	0.00	69.
9	0.01	0.00	61.
10	0.01	0.00	55.

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11		0.	
12	0.01	0.00	44.
13	0.03	0.00	40.
14	0.03	0.00	35.
15	0.04	0.00	32.
16	0.10	0.00	29.
17	0.04	0.00	26.
18	0.03	0.00	23.
19	0.00	0.00	21.
20	0.00	0.00	18.
21	0.00	0.00	16.
22	0.00	0.00	15.
23	0.00	0.00	13.
24	0.00	0.00	12.
25	0.01	0.00	11.
26	0.01	0.00	10.
27	0.01	0.00	9.
28	0.01	0.00	8.
29	0.01	0.00	7.
30	0.01	0.00	6.
31	0.03	0.00	5.
32	0.03	0.00	5.
33	0.03	0.00	4.
34	0.03	0.00	4.
35	0.03	0.00	4.
36	0.03	0.00	3.
37	0.11	0.00	3.
38	0.14	0.00	3.
39	0.17	0.00	2.
40	0.43	0.00	2.
41	0.16	0.04	10.
42	0.12	0.02	39.
43	0.02	0.00	86.
44	0.02	0.00	145.
45	0.02	0.00	211.
46	0.02	0.00	278.
47	0.02	0.00	337.
48	0.02	0.00	381.
49	0.07	0.00	408.
50	0.07	0.00	415.
51	0.07	0.00	397.
52	0.07	0.00	364.
53	0.07	0.00	329.
54	0.07	0.00	298.
55	0.21	0.11	294.
56	0.21	0.11	361.
57	0.21	0.11	526.
58	0.21	0.11	804.
59	0.21	0.11	1204.
60	0.21	0.11	1722.
61	0.75	0.65	2465.
62	0.91	0.81	3655.
63	1.13	1.03	5515.
64	2.87	2.77	8610.
65	1.06	0.96	13303.
66	0.83	0.73	19272.
67	0.13	0.03	25958.
68	0.13	0.03	32740.
69	0.13	0.03	38957.
70	0.13	0.03	43892.
71	0.13	0.03	47031.
72	0.13	0.03	48210.
73	0.00	0.00	47431.
74	0.00	0.00	44911.
75	0.00	0.00	41438.
76	0.00	0.00	37793.

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77	0.00	0.00	34329.
78	0.00	0.00	31143.
79	0.01	0.00	28236.
80	0.01	0.00	25577.
81	0.01	0.00	23150.
82	0.01	0.00	20939.
83	0.01	0.00	18934.
84	0.01	0.00	17122.
85	0.04	0.00	15483.
86	0.05	0.00	14001.
87	0.07	0.00	12661.
88	0.17	0.07	11464.
89	0.06	0.00	10411.
90	0.05	0.00	9479.
91	0.01	0.00	8651.
92	0.01	0.00	7916.
93	0.01	0.00	7255.
94	0.01	0.00	6652.
95	0.01	0.00	6094.
96	0.01	0.00	5574.
97	0.0	0.0	5081.
98	0.0	0.0	4608.
99	0.0	0.0	4165.
100	0.0	0.0	3765.
SUM	12.39	7.92	803876.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	48210.	45486.	28915.	11146.	803880.
INCHES		2.56	6.52	7.54	7.55
AC-FT		22566.	57382.	66358.	66471.

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OVF

STATION 1

INFLOW%I<, OUTFLOW%O< AND OBSERVED FLOW%*<

0.	10000.	20000.	30000.	40000.	50000.	0.	0.	0.	0.	0.	0.	0.

PRECIP%L< AND EXCESS%X<

0.	0.	0.	0.	0.	0.	0.	0.	0.	3.	2.	1.	0.

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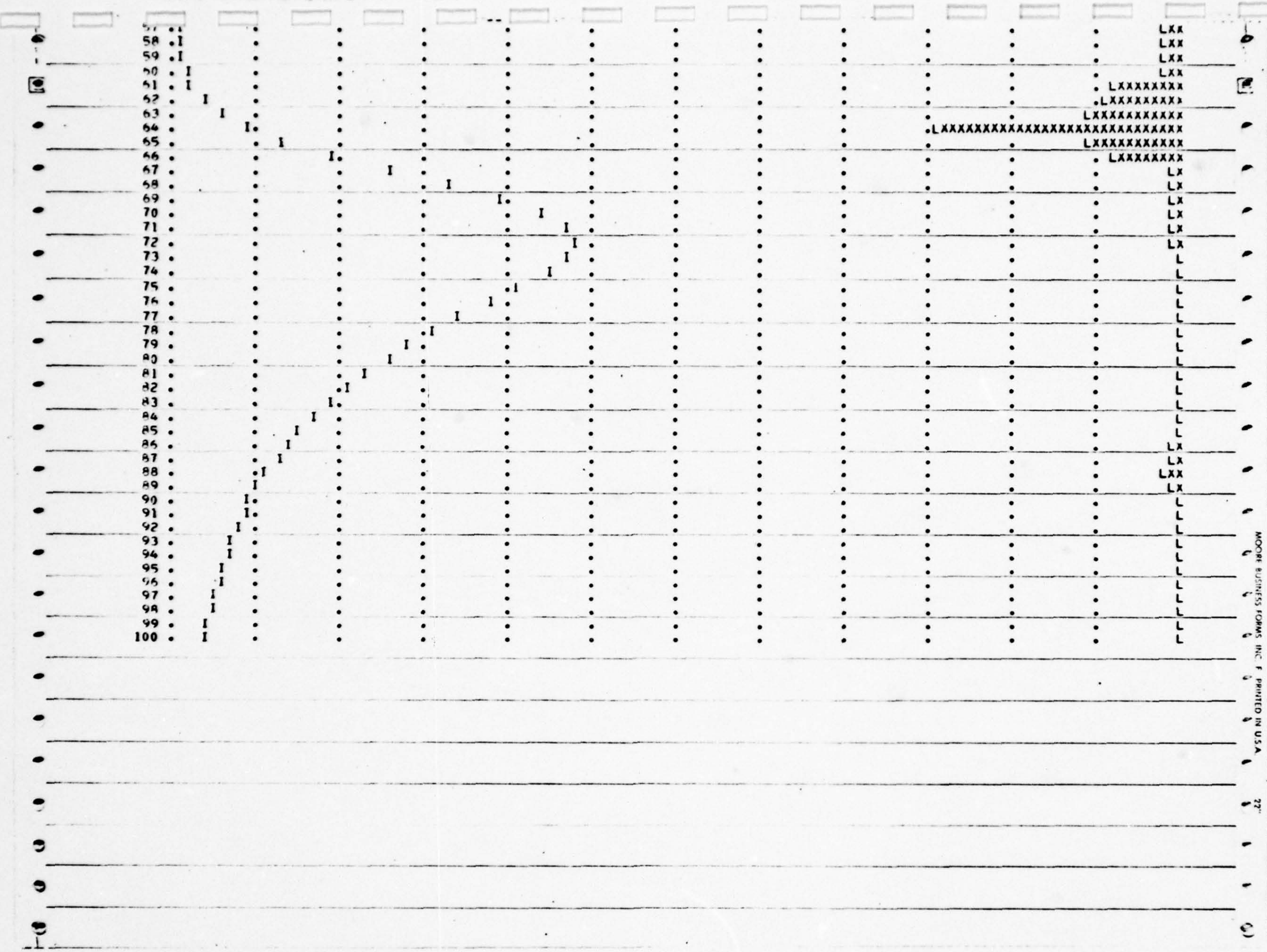
4	I	L
5	I	L
6	I	L
7	I	L
8	I	L
9	I	L
10	I	L
11	I	L
12	I	L
13	I	L
14	I	L
15	I	L
16	I	LX
17	I	L
18	I	L
19	I	L
20	I	L
21	I	L
22	I	L
23	I	L
24	I	L
25	I	L
26	I	L
27	I	L
28	I	L
29	I	L
30	I	L
31	I	L
32	I	L
33	I	L
34	I	L
35	I	L
36	I	L
37	I	LX
38	I	LX
39	I	LLX
40	I	LLLLX
41	I	LLX
42	I	LX
43	I	L
44	I	L
45	I	L
46	I	L
47	I	L
48	I	L
49	I	LX
50	I	LX
51	I	LX
52	I	LX
53	I	LX
54	I	LX
55	I	LXX
56	I	LXX

MOORE BUSINESS FORMS, INC. PRINTED IN U.S.A.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MOORE BUSINESS FORMS INC. F PRINTED IN U.S.A.
22"

OVN

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HYDROGRAPH ROUTING

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME
2	1	0	0	0	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME
0.0	0.0	0.0	1	0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA
1	0	0	0.0	0.0	0.0	-1.

STORAGE#	0.	1173.	3557.	5993.	8479.	11017.	13608.	16257.	20340.	25991.
OUTFLOW#	0.	1960.	10184.	16500.	16500.	16500.	16500.	19608.	41360.	86803.

TIME	EOP STOR	AVG IN	EOP OUT
1	88.	148.	148.
2	88.	140.	147.
3	86.	126.	144.
4	84.	112.	140.
5	81.	101.	135.
6	77.	90.	129.
7	74.	81.	123.
8	70.	72.	116.
9	66.	65.	110.
10	62.	58.	103.
11	58.	52.	97.
12	54.	47.	90.
13	50.	42.	84.
14	47.	37.	78.
15	43.	34.	72.
16	40.	30.	67.
17	37.	27.	62.
18	34.	24.	57.
19	31.	22.	52.
20	29.	19.	48.
21	26.	17.	44.
22	24.	16.	40.
23	22.	14.	37.
24	20.	13.	34.
25	18.	11.	31.
26	17.	10.	28.
27	15.	9.	26.
28	14.	8.	23.
29	13.	7.	21.
30	12.	6.	19.
31	11.	6.	18.
32	10.	5.	16.
33	9.	5.	15.
34	8.	4.	13.
35	7.	4.	12.
36	7.	3.	11.
37	6.	3.	10.
38	5.	3.	9.
39	5.	2.	8.
40	4.	2.	7.
41	4.	6.	7.
42	6.	24.	9.
43	10.	62.	16.
44	17.	116.	29.

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45	29.	178.	48.
46	44.	245.	74.
47	62.	308.	104.
48	82.	359.	137.
49	102.	395.	170.
50	121.	411.	201.
51	136.	406.	228.
52	148.	381.	248.
53	156.	347.	260.
54	160.	314.	267.
55	162.	296.	271.
56	167.	328.	278.
57	179.	444.	300.
58	208.	665.	347.
59	258.	1004.	432.
60	338.	1463.	565.
61	456.	2094.	763.
62	634.	3060.	1059.
63	906.	4585.	1515.
64	1325.	7063.	2485.
65	1937.	10957.	4599.
66	2763.	16288.	7516.
67	3885.	22615.	11037.
68	5252.	29349.	14581.
69	6931.	35849.	16500.
70	8991.	41425.	16500.
71	11384.	45462.	16500.
72	13940.	47621.	16890.
73	16361.	47821.	20164.
74	18122.	46171.	29548.
75	19045.	43175.	34464.
76	19394.	39616.	36323.
77	19376.	36057.	36227.
78	19140.	32732.	34966.
79	18782.	29690.	33062.
80	18365.	26907.	30841.
81	17927.	24363.	28504.
82	17489.	22044.	26173.
83	17067.	19937.	23923.
84	16667.	18028.	21796.
85	16295.	16303.	19814.
86	15902.	14742.	19192.
87	15440.	13331.	18650.
88	14921.	12063.	18040.
89	14361.	10938.	17383.
90	13774.	9945.	16695.
91	13152.	9065.	16500.
92	12473.	8283.	16500.
93	11736.	7586.	16500.
94	10947.	6954.	16500.
95	10110.	6373.	16500.
96	9229.	5834.	16500.
97	8305.	5328.	16500.
98	7342.	4845.	16500.
99	6341.	4387.	16500.
100	5372.	3965.	14890.
SUM			745515.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	36323.	34314.	23548.	10323.	745515.
INCHES		1.93	5.31	6.98	7.01
AC-FT		17024.	46731.	61457.	61645.

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OVF

STATION 2

INFLOW*I<, OUTFLOW%O< AND OBSERVED FLOW%*<

	0.	10000.	20000.	30000.	40000.	50000.	0.	0.	0.	0.	0.	0.	0.
1	I												
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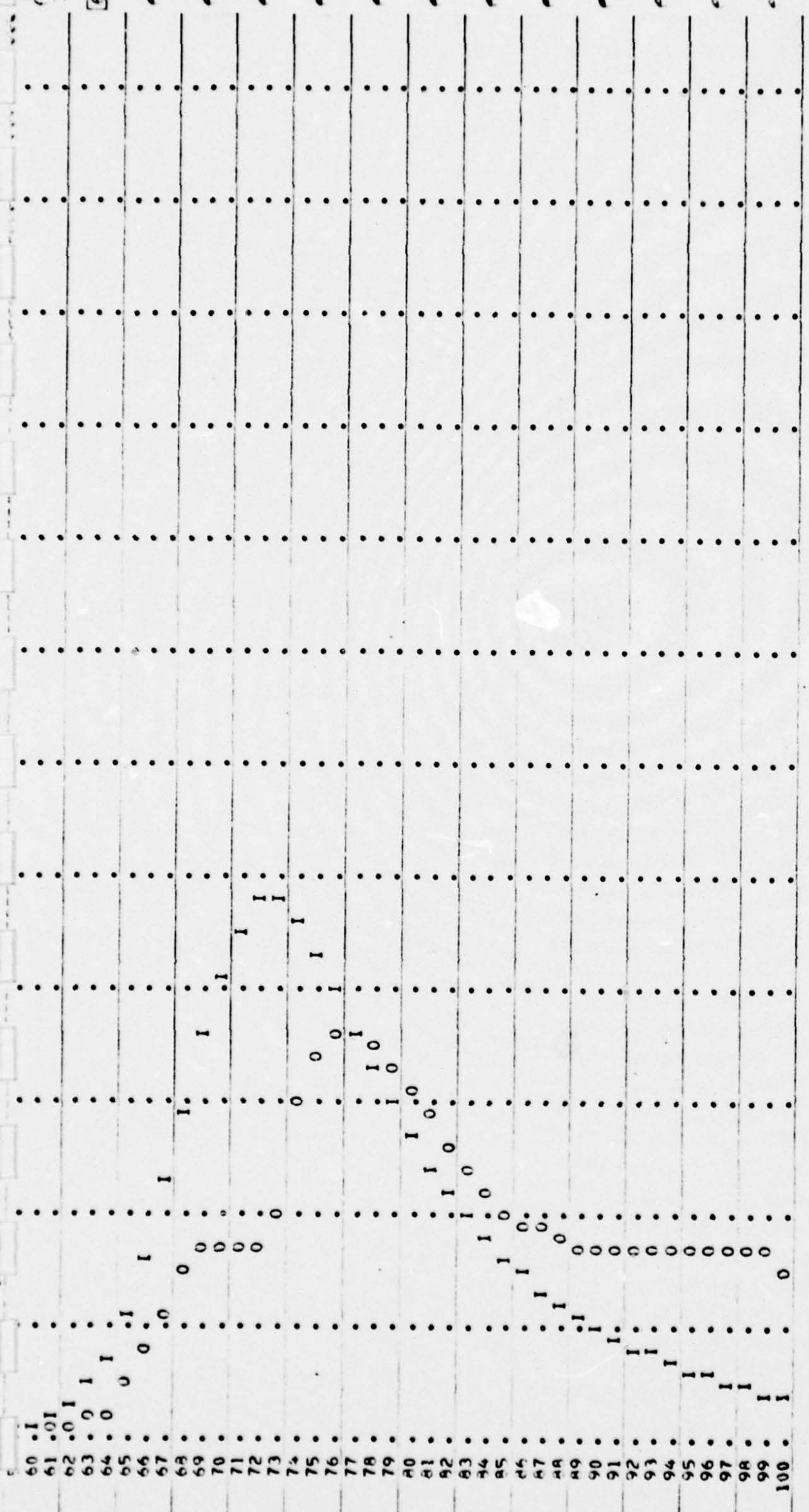
MCF BY BUSINESS FORMS, INC. PRINTED IN U.S.A.

MOORE BUSINESS FORMS INC. F PRINTED IN U.S.A. 27"



MOORE BUSINESS FORMS, INC. F PRINTED IN U.S.A. 22"

RUNOFF SUMMARY. AVERAGE FLOW

		PEAK	6-HOUR	24-HOUR	72-HOUR	AREA
HYDROGRAPH AT	1	48210.	45486.	28915.	11146.	165.00
ROUTED TO	2	36323.	34314.	23548.	10323.	165.00

MOORE BUSINESS FORMS, INC. PRINTED IN U.S.A.

HEC-1 VERSION DATED JAN 1973
UPDATED AUG 74
CHANGE NO. 01

CROTON FALLS DAM
RESERVOIR AT TOP OF FLOOD POOL
TEST PMF

JOB SPECIFICATION

NO	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
100	1	0	0	0	0	0	2	0	0

JOPER	NWT
3	0

SUB-AREA RUNOFF COMPUTATION

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME
1	0	0	0	0	0	0

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
1	1	165.00	0.0	165.00	0.0	0.0	0	0	0

PRECIP DATA

SPFE	PMS	R6	R12	R24	R48	R72	R96
0.0	21.00	77.50	92.00	102.00	107.50	0.0	0.0

TRSPC COMPUTED BY THE PROGRAM IS 0.878

LOSS DATA

STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOK	STRTL	CNSTL	ALSMX	RTIMP
0.0	0.0	1.00	0.0	0.0	1.00	1.50	0.10	0.0	0.0

UNIT HYDROGRAPH DATA
TP# 9.07 CP#0.57 NTA# 0

RECESSION DATA
STRTQ# 165.00 QRCSN# -0.25 RTIOR# 3.00

APPROXIMATE CLARK COEFFICIENTS FROM GIVEN SNYDER CP AND TP ARE TC# 9.91 AND R# 9.95 INTERVALS

UNIT HYDROGRAPH 58 END-OF-PERIOD ORDINATES. LAG# 9.10 HOURS. CP# 0.57 VOL# 1.00

231.	862.	1748.	2775.	3891.	4979.	5869.	6483.	6808.	6766.
6319.	5714.	5167.	4672.	4225.	3821.	3455.	3124.	2825.	2555.
2310.	2089.	1889.	1708.	1545.	1397.	1263.	1142.	1033.	934.
845.	764.	691.	625.	565.	511.	462.	418.	378.	342.
309.	279.	253.	228.	207.	187.	169.	153.	138.	125.
113.	102.	92.	83.	76.	68.	62.	56.		

END-OF-PERIOD FLOW

TIME	RAIN	EXCS	COMP Q
1	0.01	0.00	148.
2	0.01	0.00	132.
3	0.01	0.00	119.
4	0.01	0.00	106.
5	0.01	0.00	95.
6	0.01	0.00	85.
7	0.02	0.00	76.
8	0.02	0.00	69.
9	0.02	0.00	61.
10	0.02	0.00	55.

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1	0.02	00	44.
12	0.02	0.00	44.
13	0.08	0.00	40.
14	0.09	0.00	35.
15	0.12	0.00	32.
16	0.29	0.00	29.
17	0.11	0.00	26.
18	0.08	0.00	23.
19	0.01	0.00	21.
20	0.01	0.00	18.
21	0.01	0.00	16.
22	0.01	0.00	15.
23	0.01	0.00	13.
24	0.01	0.00	12.
25	0.12	0.00	11.
26	0.12	0.00	10.
27	0.12	0.00	9.
28	0.12	0.00	8.
29	0.12	0.02	13.
30	0.12	0.02	33.
31	0.45	0.35	148.
32	0.45	0.35	491.
33	0.45	0.35	1145.
34	0.45	0.35	2156.
35	0.45	0.35	3547.
36	0.45	0.35	5303.
37	1.43	1.33	7580.
38	1.72	1.62	10741.
39	2.14	2.04	15147.
40	5.43	5.33	21819.
41	2.00	1.90	31388.
42	1.57	1.47	43231.
43	0.18	0.08	56296.
44	0.18	0.08	69407.
45	0.18	0.08	81323.
46	0.18	0.08	90701.
47	0.18	0.08	96594.
48	0.18	0.08	98704.
49	0.0	0.0	97038.
50	0.0	0.0	92008.
51	0.0	0.0	85115.
52	0.0	0.0	77849.
53	0.0	0.0	70883.
54	0.0	0.0	64461.
55	0.0	0.0	58538.
56	0.0	0.0	53083.
57	0.0	0.0	48071.
58	0.0	0.0	43486.
59	0.0	0.0	39324.
60	0.0	0.0	35560.
61	0.0	0.0	32156.
62	0.0	0.0	29078.
63	0.0	0.0	26294.
64	0.0	0.0	23778.
65	0.0	0.0	21502.
66	0.0	0.0	19443.
67	0.0	0.0	17582.
68	0.0	0.0	15899.
69	0.0	0.0	14377.
70	0.0	0.0	13001.
71	0.0	0.0	11757.
72	0.0	0.0	10631.
73	0.0	0.0	9614.
74	0.0	0.0	8693.
75	0.0	0.0	7861.
76	0.0	0.0	7109.

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77	0.0	0.0	6428.
78	0.0	0.0	5813.
79	0.0	0.0	5257.
80	0.0	0.0	4753.
81	0.0	0.0	4298.
82	0.0	0.0	3887.
83	0.0	0.0	3515.
84	0.0	0.0	3178.
85	0.0	0.0	2874.
86	0.0	0.0	2599.
87	0.0	0.0	2349.
88	0.0	0.0	2123.
89	0.0	0.0	1902.
90	0.0	0.0	1704.
91	0.0	0.0	1527.
92	0.0	0.0	1368.
93	0.0	0.0	1226.
94	0.0	0.0	1098.
95	0.0	0.0	984.
96	0.0	0.0	882.
97	0.0	0.0	790.
98	0.0	0.0	708.
99	0.0	0.0	634.
100	0.0	0.0	568.
SUM	19.80	16.31	1731780.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	98704.	93360.	60181.	24033.	1731762.
INCHES		5.26	13.57	16.26	16.27
AC-FT		46318.	119429.	143081.	143195.

MOORE BUSINESS FORMS INC. F PRINTED IN U.S.A. 22

OVF

STATION 1

INFLOW*I<, OUTFLOW*O< AND OBSERVED FLOW*O<

0. 20000. 40000. 60000. 80000. 100000. 0. 0. 0. 0. 0. 0. 0.

PRECIP*L< AND EXCESS*X<

0. 0. 0. 0. 0. 0. 0. 0. 0. 6. 4. 2. 0.

1 I L
2 I L
3 I L
4 I L
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6 I L
7 I L
8 I L
9 I L
10 I L
11 I L
12 I L
13 I L
14 I L
15 I LX
16 I LX
17 I LX
18 I L
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21 I L
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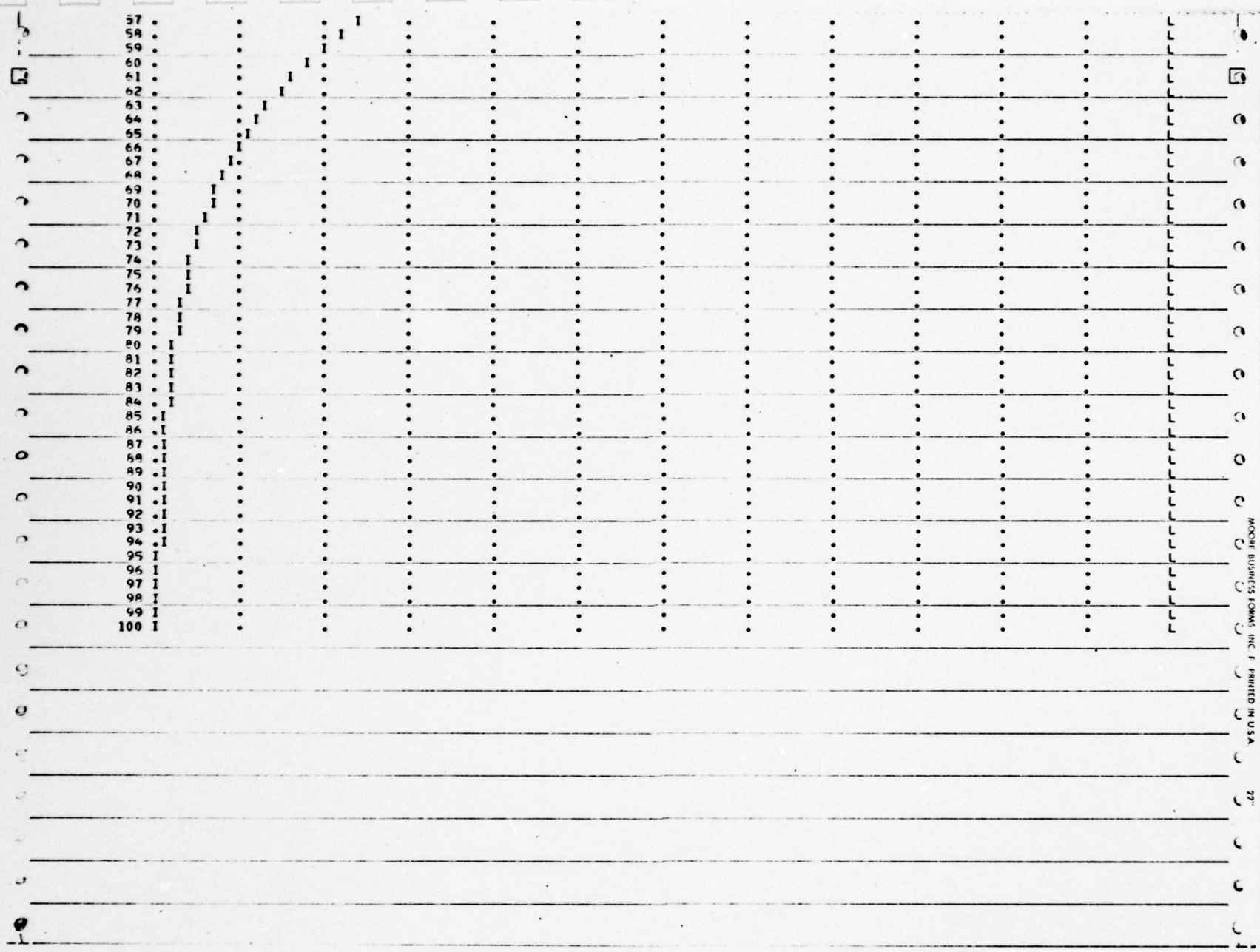
MOORE BUSINESS FORMS, INC. PRINTED IN U.S.A.



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OVN

********** ********** ********** ********** **********

HYDROGRAPH ROUTING

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME
2	1	0	0	0	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME
0.0	0.0	0.0	1	0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA
1	0	0	0.0	0.0	0.0	-1.

STORAGE#	0.	1173.	3557.	5993.	8479.	11017.	13608.	16257.	20340.	25991.
OUTFLOW#	0.	1960.	10184.	16500.	16500.	16500.	16500.	19608.	41360.	86803.

TIME	EOP STOR	AVG IN	EOP OUT
1	88.	148.	148.
2	88.	140.	147.
3	86.	126.	144.
4	84.	112.	140.
5	81.	101.	135.
6	77.	90.	129.
7	74.	81.	123.
8	70.	72.	116.
9	66.	65.	110.
10	62.	58.	103.
11	58.	52.	97.
12	54.	47.	90.
13	50.	42.	84.
14	47.	37.	78.
15	43.	34.	72.
16	40.	30.	67.
17	37.	27.	62.
18	34.	24.	57.
19	31.	22.	52.
20	29.	19.	48.
21	26.	17.	44.
22	24.	16.	40.
23	22.	14.	37.
24	20.	13.	34.
25	18.	11.	31.
26	17.	10.	28.
27	15.	9.	26.
28	14.	8.	23.
29	13.	11.	22.
30	13.	23.	22.
31	18.	91.	31.
32	41.	320.	68.
33	99.	818.	165.
34	214.	1651.	357.
35	406.	2851.	679.
36	696.	4425.	1163.
37	1104.	6441.	1845.
38	1638.	9160.	3564.
39	2316.	12944.	5905.
40	3226.	18483.	9043.
41	4526.	26604.	12698.
42	6403.	37310.	16500.
43	9152.	49763.	16500.
44	12983.	62851.	16500.

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45	17455.	75365.	25994.
46	21421.	86012.	50055.
47	24125.	93647.	71800.
48	25729.	97649.	84694.
49	26546.	97871.	91267.
50	26748.	94523.	92891.
51	26479.	88561.	90731.
52	25906.	81482.	86117.
53	25177.	74366.	80255.
54	24396.	67672.	73978.
55	23622.	61500.	67754.
56	22881.	55811.	61796.
57	22185.	50577.	56200.
58	21539.	45778.	51001.
59	20944.	41405.	46214.
60	20399.	37442.	41838.
61	19864.	33854.	38826.
62	19308.	30617.	35864.
63	18754.	27686.	32913.
64	18221.	25036.	30071.
65	17717.	22640.	27390.
66	17249.	20472.	24894.
67	16817.	18513.	22592.
68	16420.	16741.	20480.
69	16026.	15134.	19338.
70	15581.	13689.	18815.
71	15073.	12379.	18220.
72	14520.	11194.	17570.
73	13933.	10123.	16881.
74	13310.	9154.	16500.
75	12630.	8277.	16500.
76	11885.	7485.	16500.
77	11081.	6769.	16500.
78	10223.	6121.	16500.
79	9317.	5535.	16500.
80	8367.	5005.	16500.
81	7377.	4526.	16500.
82	6352.	4093.	16500.
83	5362.	3701.	14865.
84	4502.	3347.	12635.
85	3785.	3026.	10776.
86	3196.	2737.	8941.
87	2728.	2474.	7327.
88	2360.	2236.	6057.
89	2068.	2013.	5048.
90	1833.	1803.	4238.
91	1643.	1616.	3584.
92	1489.	1448.	3051.
93	1362.	1297.	2613.
94	1257.	1162.	2251.
95	1169.	1041.	1954.
96	1090.	933.	1822.
97	1014.	836.	1695.
98	941.	749.	1573.
99	871.	671.	1456.
100	805.	601.	1346.
SUM			1723475.

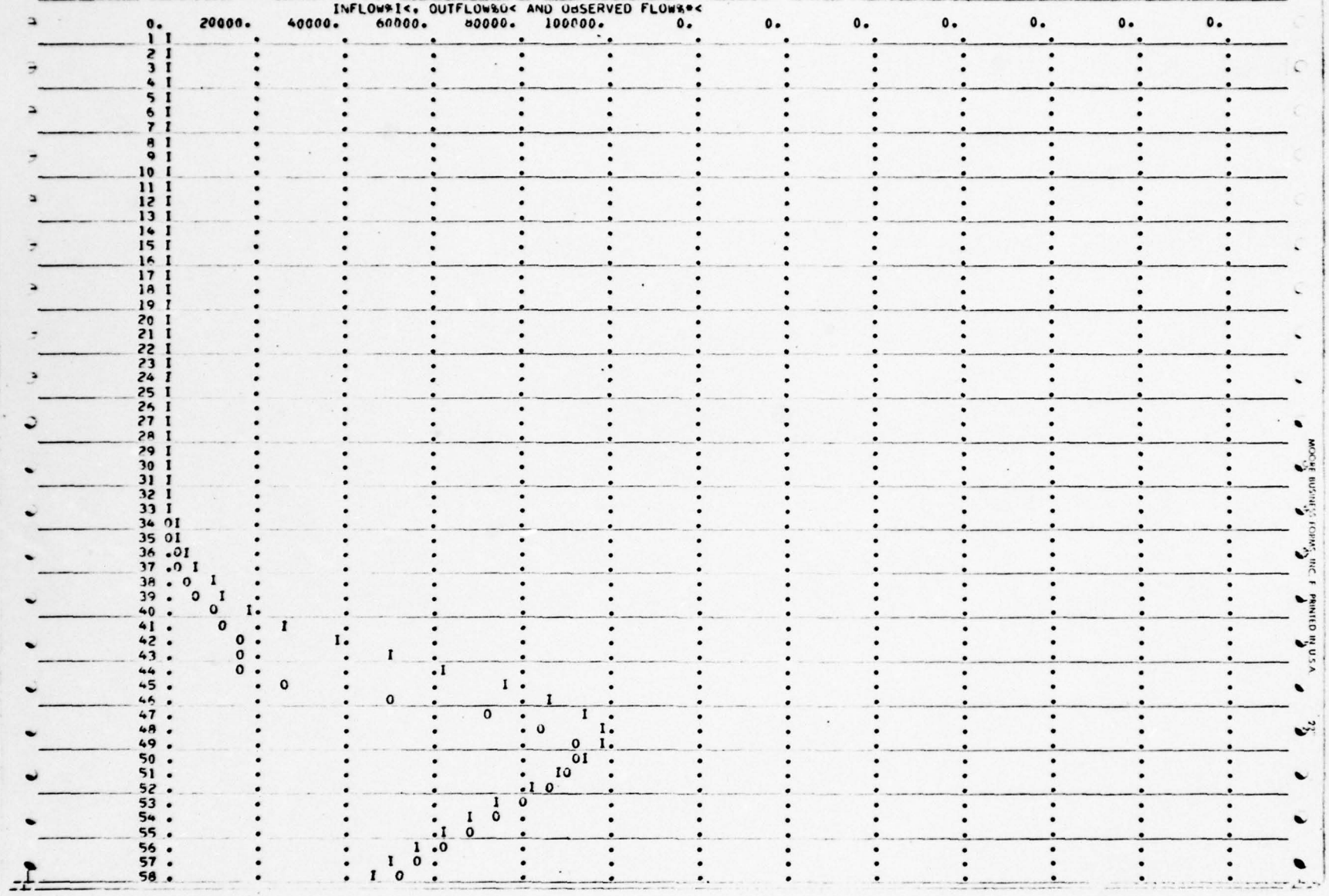
	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	92891.	87659.	54400.	23906.	1723475.
INCHES		4.94	12.27	16.17	16.19
AC-FT		43490.	107957.	142321.	142509.

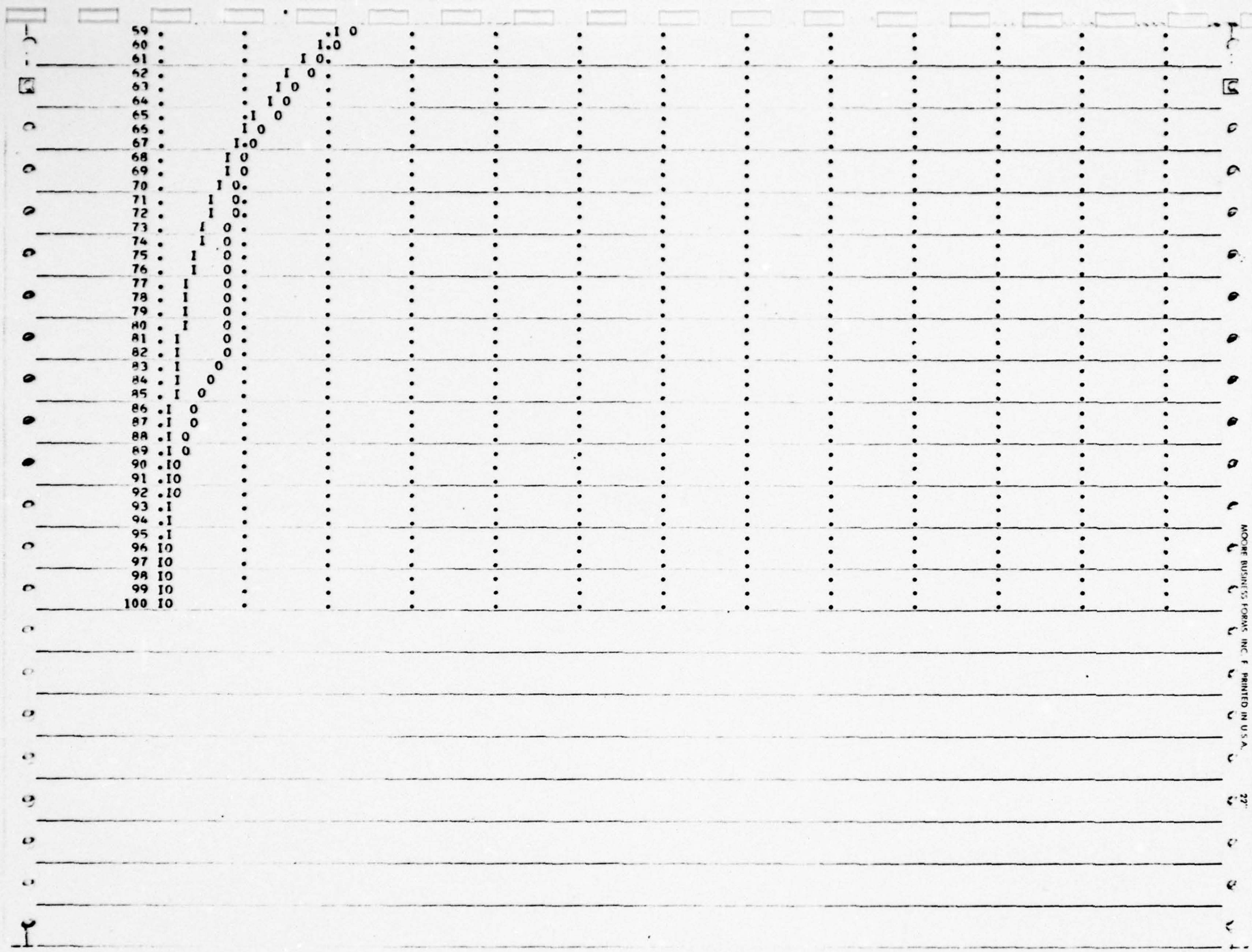
MOORE BUSINESS FORMS INC. F PRINTED IN U.S.A.

OVF

STATION 2

INFLOW*I<, OUTFLOW&O< AND OBSERVED FLOW$*<

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MOORE BUSINESS FORMS INC. F PRINTED IN U.S.A.

MOORE BUSINESS FORMS, INC. F PRINTED IN U.S.A. 22"

RUNOFF SUMMARY, AVERAGE FLOW

		PEAK	6-HOUR	24-HOUR	72-HOUR	AREA
HYDROGRAPH AT	1	98704.	93360.	60181.	24033.	165.00
ROUTED TO	2	92891.	87659.	54400.	23906.	165.00

MOORE BUSINESS FORMS INC. PRINTED IN U.S.A.

Appendix C
Photographs

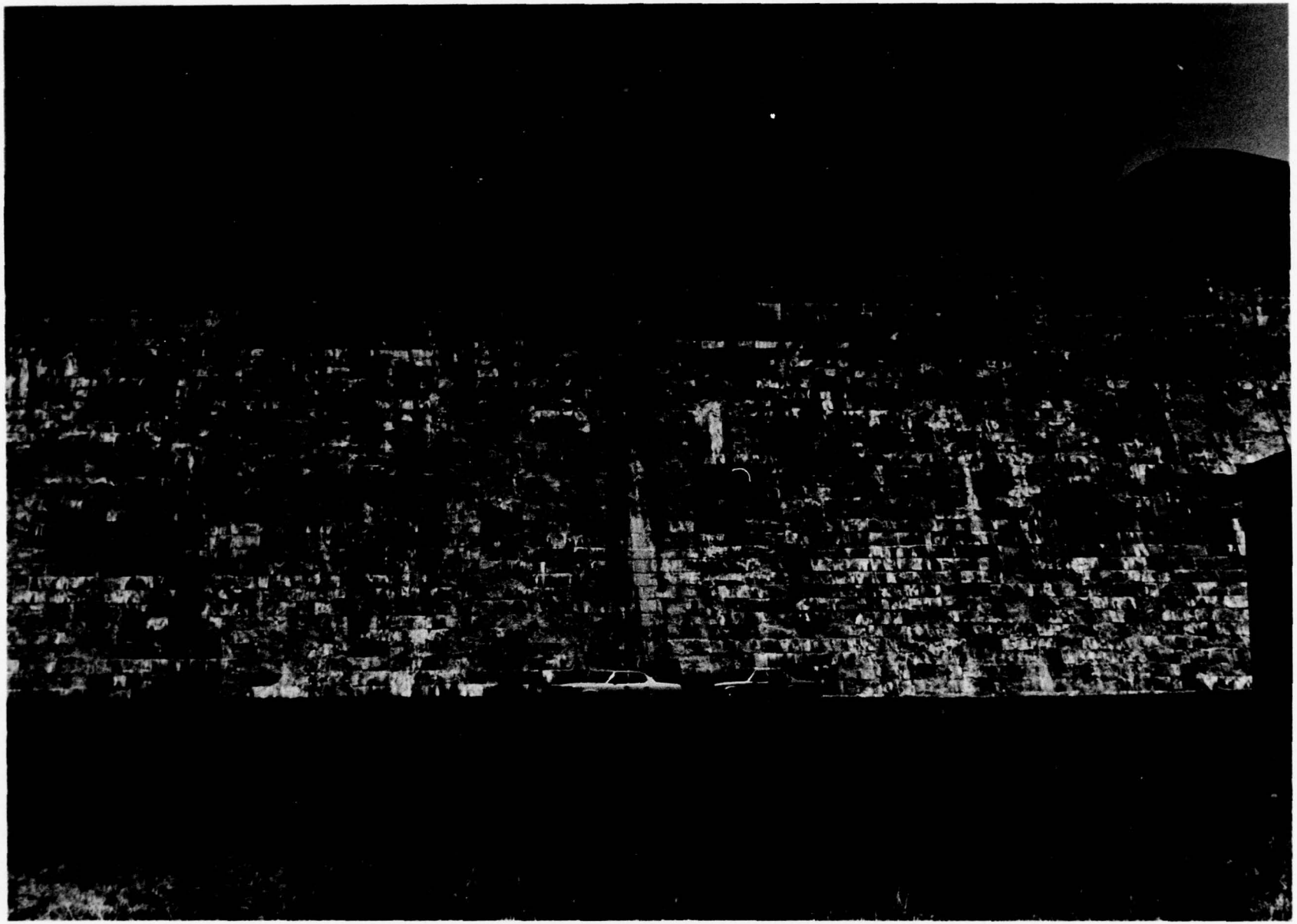
Index of Photographs

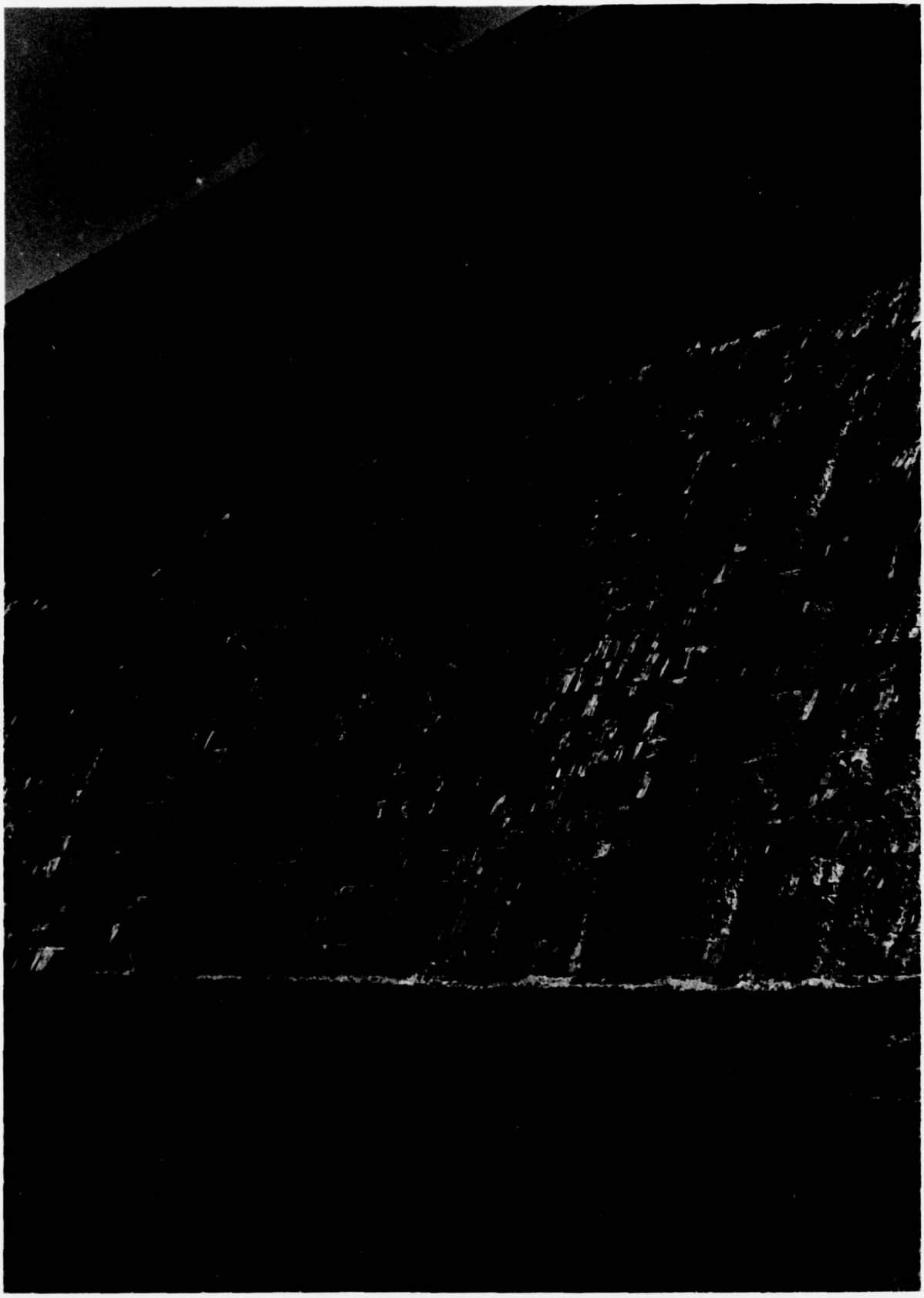
Croton Falls Dam

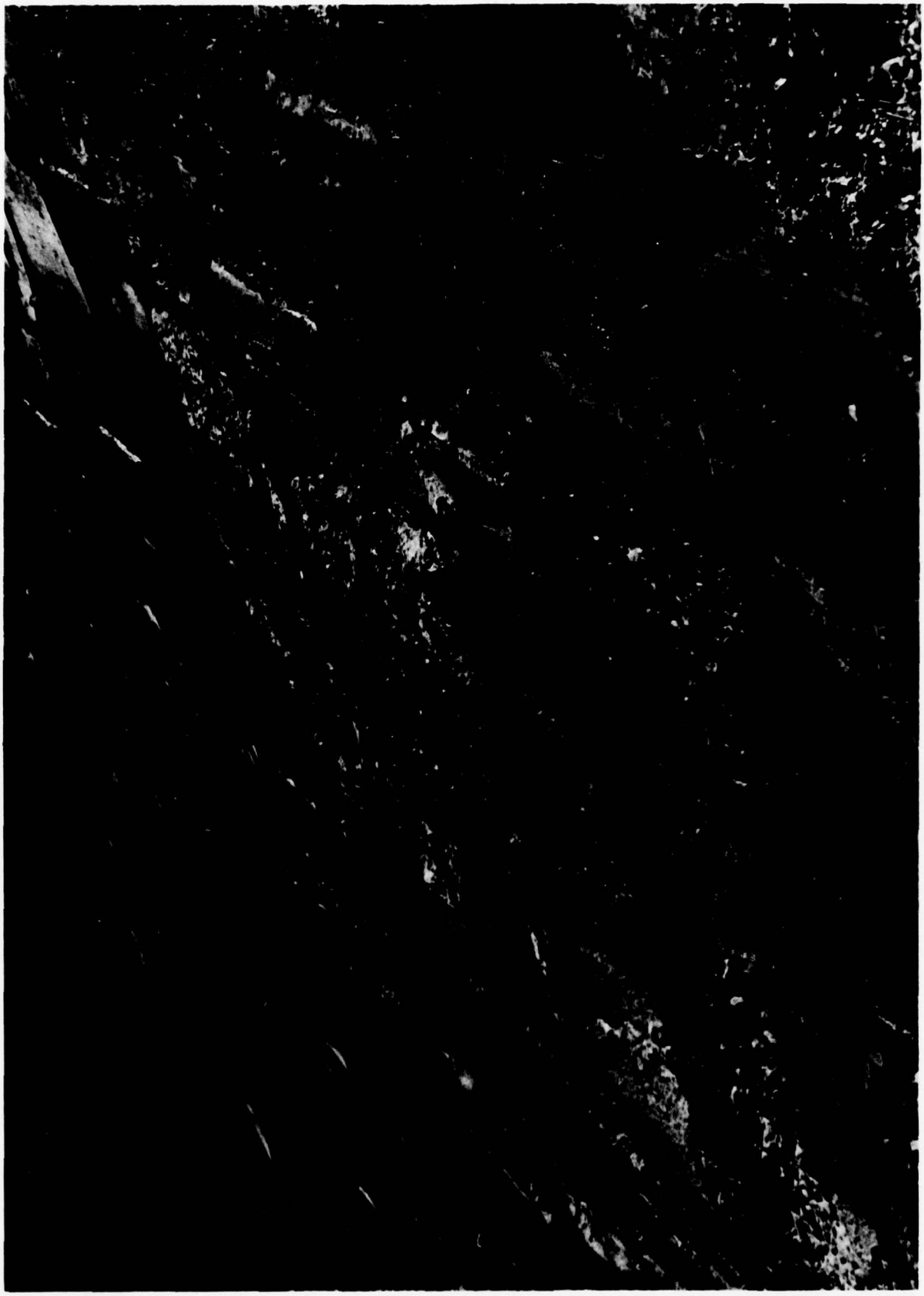
1. Overall view from downstream.
2. Overall view from above left abutment.

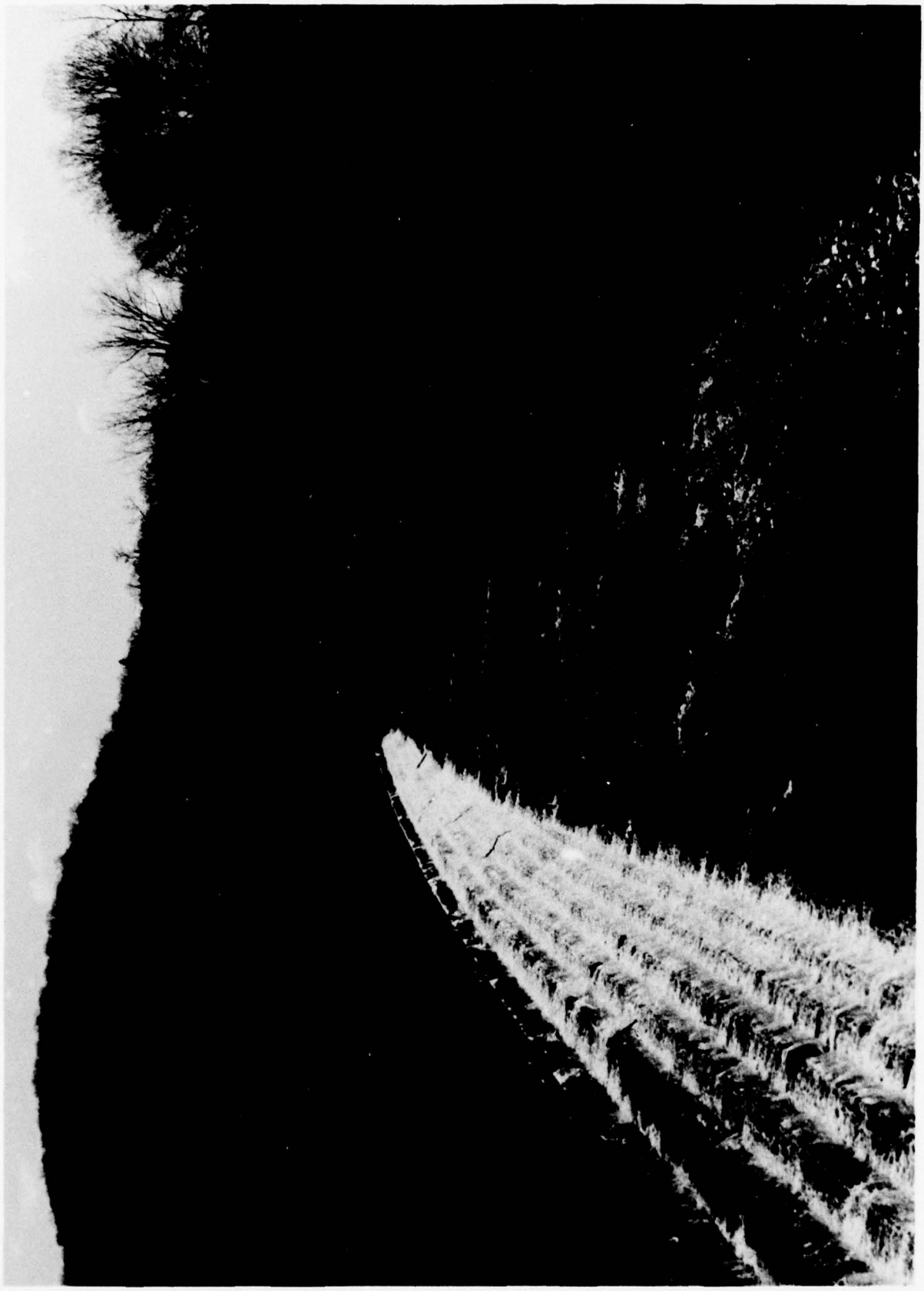
APPENDIX C

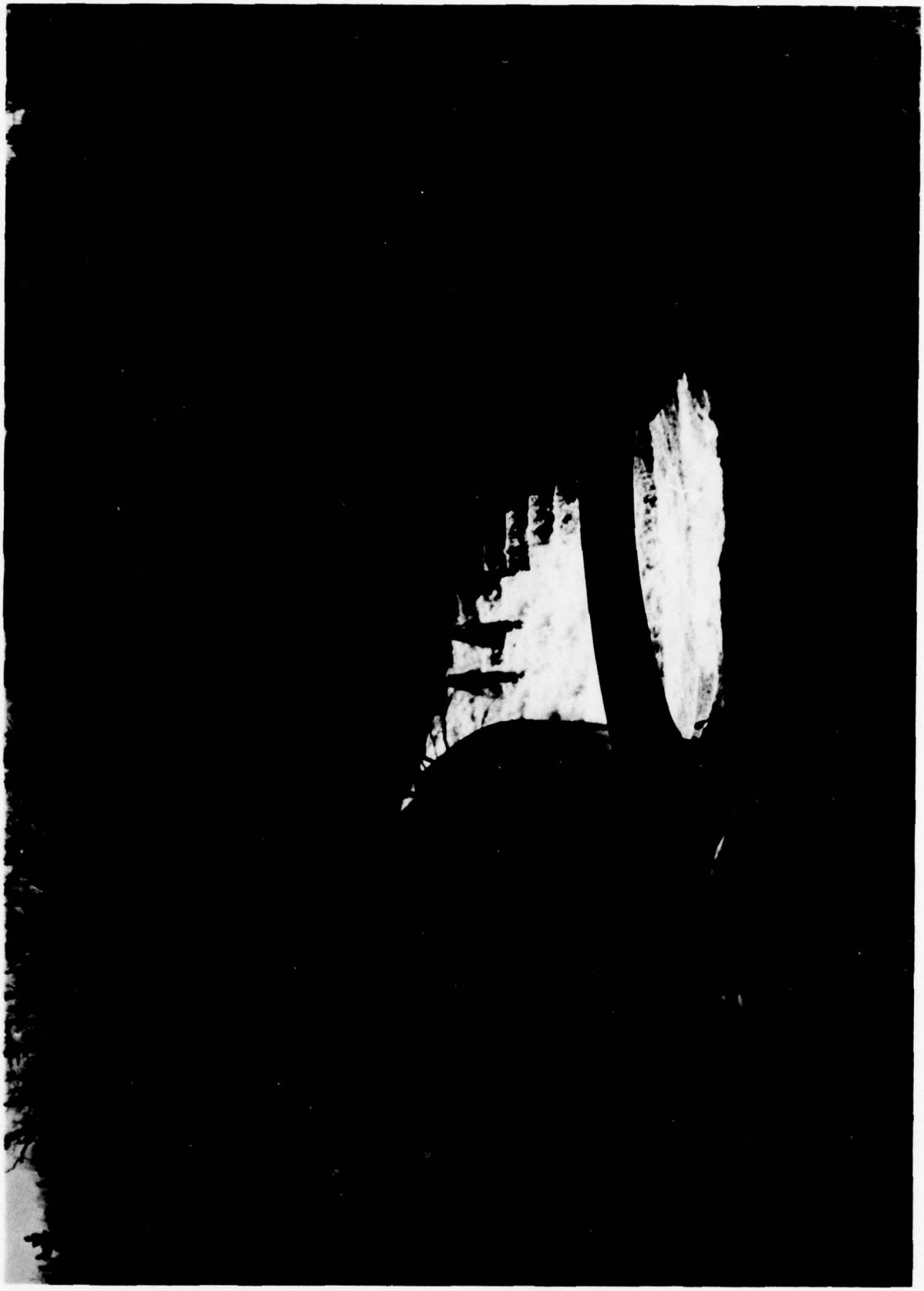
3. View of immediate downstream area from top of dam.
4. Front view of major crack in structure.
5. Close up of downstream slope showing deterioration, seepage and major crack.
6. Close up of downstream face showing deterioration, seepage and buildup of calcium carbonate due to seepage.
7. Upstream face, gate house and portions of the spillway from left abutment area.
8. Close up of upstream face from right abutment.
9. Emergency spillway and side channel from bridge, looking upstream.
10. Bridge over spillway at side channel control section and upper portion of emergency spillway channel.
11. Emergency spillway exit channel, stilling basin and energy dissipators in channel.











Appendix D
Pertinent Correspondence and Reports

(NOTICE: After filling out one of these forms as completely as possible for each dam in your district, return it at once to the Conservation Commission, Albany.)

STATE OF NEW YORK

CONSERVATION COMMISSION

ALBANY

DAM REPORT

August 6th 1915
(Date)

CONSERVATION COMMISSION,

DIVISION OF INLAND WATERS.

GENTLEMEN:

I have the honor to make the following report in relation to the structure known as the Croton Falls Dam.

This dam is situated upon the West Branch of Croton River (Give name of stream)

in the Town of Carmel, Putnam County,

about 1 mile (State distance) from the Village ~~limit~~ of Croton Falls

The distance down (Up or down) stream from the dam, to the E. B. Croton River (Give name of nearest important stream or of a lake)

is about 3/4 mile (State distance)

The dam is now owned by N.Y. City (Give name and address in full)

and was built in or about the year 1910, and was extensively repaired or reconstructed during the year.....

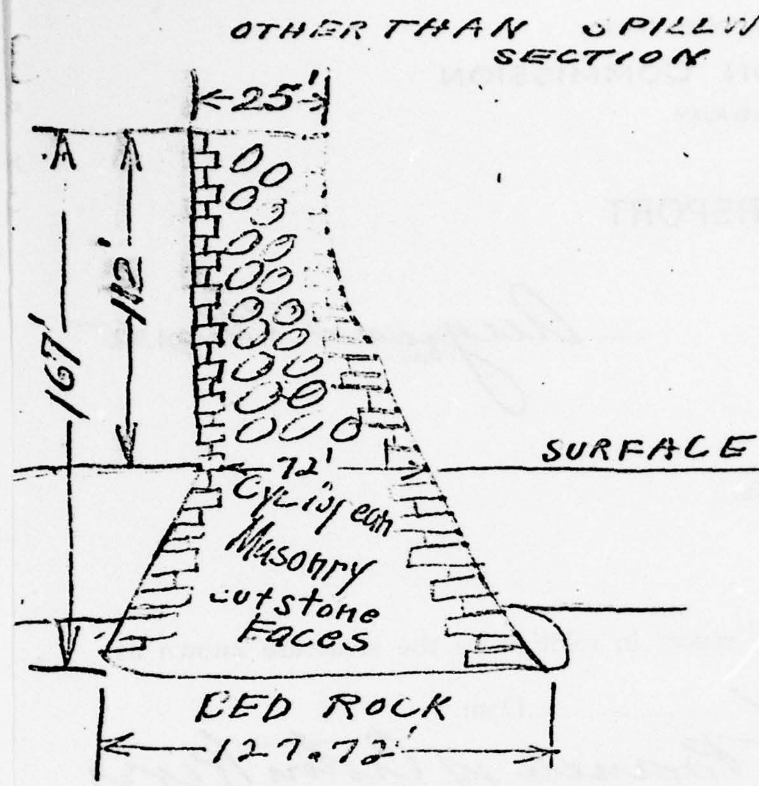
As it now stands, the spillway portion of this dam is built of Cut stone & Concrete (State whether of masonry, concrete or timber)

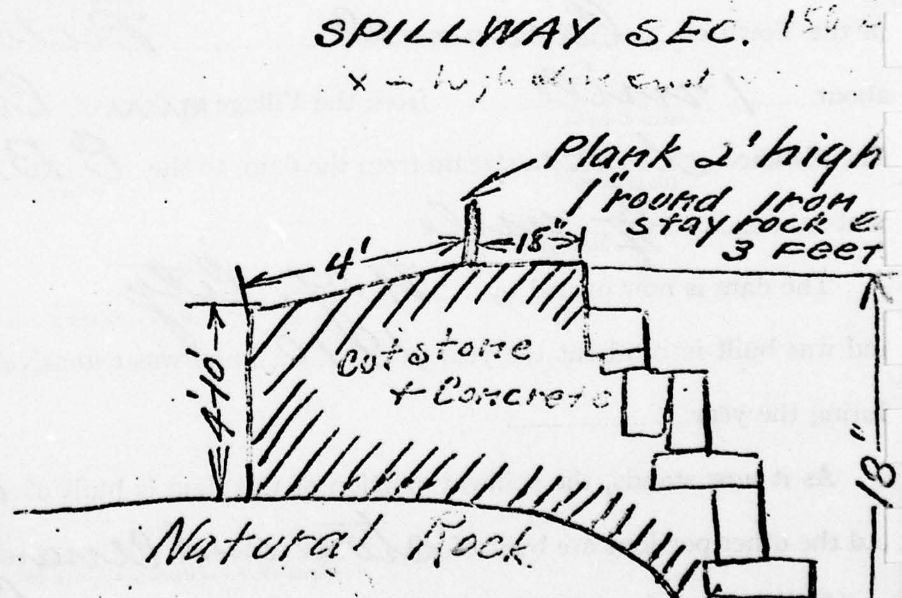
and the other portions are built of stone and cement (Cyclopean) concrete (State whether of masonry, concrete, earth, timber with ~~stone~~ facing, etc.) Blocks front & back

As nearly as I can learn, the character of the foundation bed under the spillway portion of the dam is Rock and under the remaining portions such foundation bed is Rock

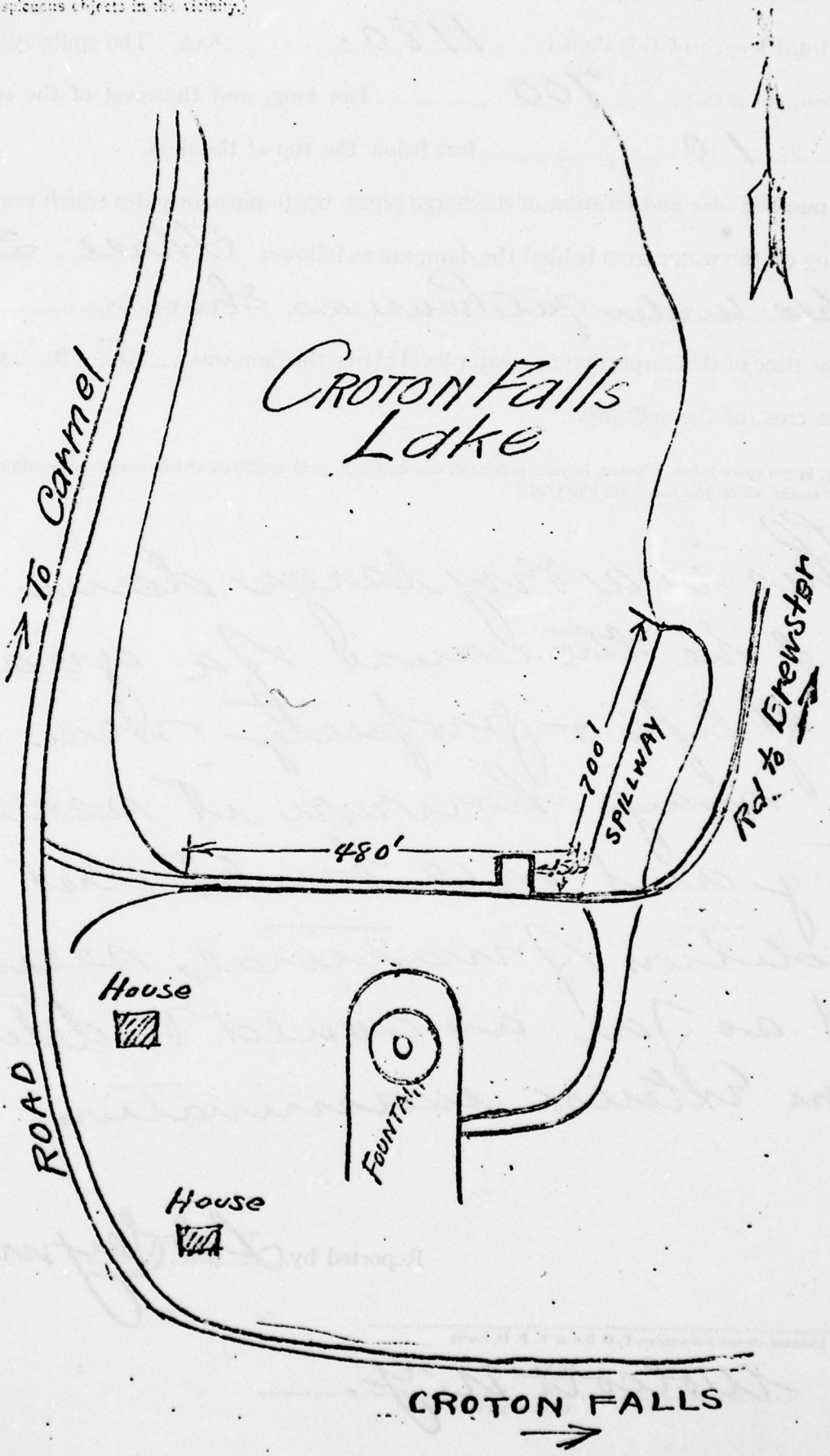
Map 231-A

(In the space below, make one sketch showing the form and dimensions of a cross section through the spillway or waste-weir of this dam, and a second sketch showing the same information for a cross section through the other portion of the dam. Show particularly the greatest height of the dam above the stream bed, its thickness at the top, and thickness at the bottom, as nearly as you can learn.)





(In the space below, make a sketch showing the general plan of the dam, and its approximate position in relation to buildings or other conspicuous objects in the vicinity.)



The total length of this dam is 1180. feet. The spillway or waste-weir portion, is about 700 feet long, and the crest of the spillway is about 10 feet below the top of the dam.

The number, size and location of discharge pipes, waste pipes or gates which may be used for drawing off the water from behind the dam, are as follows: Three 30" pipes under gatehouse as shown

At the time of this inspection the water level above the dam was 5 ft. 2 in. below ~~above~~ the crest of the spillway.

(State briefly, in the space below, whether, in your judgment, this dam is in good condition, or bad condition, describing particularly any leaks or cracks which you may have observed.)

This is a very large dam and would be the cause of a great loss of life & property were it to give way however it seems strong and well built and the condition of materials seems good so far as could be determined from Exterior examination.

Reported by L D Seymour
(Signature)

(Address—Street and number, P. O. Box or R. F. D. route)

Wolcott N.Y.
(Name of place)

8-22-21-3000 (6-1206)

STATE OF NEW YORK

DEPARTMENT OF

State Engineer and Surveyor

ALBANY

Report of a Structure Impounding Water

To assist in carrying out the provisions of Section 22 of the Conservation Law, being Chapter LXV of the Consolidated Laws of New York State, relating to safeguarding life and property and the erection, reconstruction, or maintenance of structures for impounding water, owners of such structures are requested to fill out as completely as possible this report form for each such dam or reservoir owned within the State of New York for which no plans or reports relative thereto are on file in this Department, and to return this report form, together with prints or photographs explanatory thereof to this department.

1. The structure is on The Croton Falls Dam The West Branch flowing into The Croton River in the Town of Carmel County of Putnam and New York about 2mile up steam from the village of Croton Falls, Westchester Co.N.Y.
(Give exact distance and direction from a well-known bridge, dam, village main cross-roads or mouth of a stream)

2. Is any part of the structure built upon or does its pond flood any State lands?.....

3. The name and address of the owner is City of New York

4. The structure is used for Impounding water for water supply

5. The material of the right bank, in the direction with the current, is.....; at the spillway crest elevation this material has a top slope of.....inches vertical to a foot horizontal on the center line of the structure, a vertical thickness at this elevation of.....feet, and the top surface extends for a vertical height of.....feet above the spillway crest.

6. The material of the left bank is.....; has a top slope of.....inches to a foot horizontal, a thickness of.....feet and a height of.....feet.

7. The natural material of the bed on which the structure rests is (clay, sand, gravel, boulders, granite, shale, slate, limestone, etc.) hard rock

8. State the character of the bed and the banks in respect to the hardness, perviousness, water bearing, effect of exposure to air and to water, uniformity, etc.....

9. If the bed is in layers, are the layers horizontal or inclined?..... If inclined what is the direction of the horizontal outcropping relative to the axis of the main structure and the inclination and direction of the layers in a plane perpendicular to the horizontal outcropping?.....

.....

10. What is the thickness of the layers?.....

11. Are there any porous seams or fissures?.....

.....

12. The watershed at the above structure and draining into the pond formed thereby is 168.64 square miles.

13. The pond area at the spillway crest elevation is 982 acres and the pond impounds 1897 mill on cubic feet of water.

14. The maximum known flow of the stream at the structure was.....cubic feet per second on

.....
(Date)

15. Has the spillway capacity ever been exceeded by a high flow?.....no.....

Can any possible flood flow from the pond otherwise than through the wastes noted under 17 and 18 of this report?.....no..... If so, give the location, the length and the elevation relative to the spillway crest and the character and slopes of the ground of such possible wastes.....

.....

.....

16. State if any damage to life or to any buildings, roads or other property could be caused by any possible failure of the above structure. Describe the location, the character and the use of buildings below the structure which might be damaged by any failure of the structure; of roads adjacent to or crossing the stream below the structure, giving the lowest elevation of the roadway above the stream bed and giving the shape, the height and the width of stream openings; and of any embankments or steep slopes that any flood could pass over. Also indicate the character and use made of the ground below the structure.....

In case the dam should fail the water from the Reservoir would flow in the New Croton Reservoir, located about a mile down stream. Some roads would be washed out but neither the damage nor possible loss of life would be great.

17. WASTES. The spillway of the above structure is 700 feet long in the clear; the waters are held at the right end by a.....the top of which is.....feet above the spillway crest, and has a top width of.....feet; and at the left end by a....., the top of which is.....feet above the spillway crest, and has a top width of.....feet.

18. There is also for flood discharge 3 pipes 48 inches inside diameter and the bottom is 95.5 feet below the spillway crest; and a (sluice, gate outlet).....feet wide in the clear by..... feet high, and the bottom is.....feet below the spillway crest.

The spillway is built along the south hill side. Its center line makes with the center-line of the main dam an included angle of about 115 degr

no

19. APRON. Below the spillway there is an apron ~~xxxxx~~ X ..... (Material) ..... ~~xxxxxxxxxx~~ ..... ~~xxxxxxxxxx~~ ..... ~~xxxxxxxxxx~~ ..... ~~xxxxxxxxxx~~ ..... ~~xxxxxxxxxx~~ ..... ~~xxxxxxxxxx~~ ..... ~~xxxxxxxxxx~~ ..... ~~xxxxxxxxxx~~ .....

20. Has the structure any weaknesses which are liable to cause its failure in high flows? ..... No .....

21. SKETCHES. On the back of this report make a sketch to scale for each different cross-section of the above structure at the greatest depth; giving the height and the depth from the surface of the foundation, the bottom width, the top width (for a concrete or masonry spillway at two feet below the crest), the elevation of the top in reference to the spillway crest, the length of the section, and the material of which the section is constructed; on the spillway section show a cross section of the apron, giving its width, thickness and material, and show the abutment or wash wall at the end of the spillway, giving its heights and thickness. Mark each section with a capital letter. Also sketch a plan; show the above sections by their top lines, giving the mark and the length of each; the openings by their horizontal dimensions; the abutments by their top width and top lengths from the upstream face of the spillway section; and outline the apron. Also sketch an elevation of each end of the structure with a cross section of the banks, giving the depth and width excavated into the banks.

22. WATER SUPPLY. The waters impounded by the above structure have (~~not~~) been used for a public water supply since 1911 by The City of New York

For the plans, profiles, etc. of the Croton Falls Dam, see Report of the x A. Crs. for 1895 to 1907, Plates 127 to 131, inclusive.

x Aqueduct Commissioners.

The above information is correct to the best of my knowledge and belief.

Municipal Building, New York City
(Address of signer)

(Signature)

February - 1925
(Date)

(A person signing for owner should indicate his title or authority)
Chief Engineer, Bureau of Water Supply
Dept. W. S. G. & E.

Croton Falls Reservoir K — Card #1

Stop Planks	1/07	9880-Y
Increasing Height & Thickness of Walls of Waste Channel	1923	14263-Y
Graph of Available Capacity	10/07	9828-Y
" " Area of Water Surface	10/07	9827-Y
" " Available Capacity - Diverting Basin	10/07	9826 Y
" " Area of Water Surface " "	10/07	9825 Y
Arch Culvert # F.C (Road #C)	10/07	9824 Y
		9816-Y
Property Map - Towns of Carmel, Southeast, Somers	1/07	9823-Y
Diverting Dam - Profile	1/05	9822 Y
Land Deeded To N.Y.C. R.R.	3/06	9821 Y
Controlling Chamber for Sewer	8/10	9820 Y
		9818 Y
Waste Weir Details - Main & Diverting Dams	8/09	9819 Y
Main Dam - Upstream Gate Chamber. C.I. Covers.	3/08	9817 Y
Typical Highway Section & Fences (Wood)	5/06	9815 Y
Indicator Float Gauge	3/06	9814 Y
Wood Flume - Structural Steel Towers Supports for,	3/06	9811 Y, 9812 Y
		9813 Y
Diverting Dam, Gate Chamber - Removable Covers	5/06	9810 Y
		9806 Y
Connecting Channel - Plan & Profile	12/06	9809 Y

Croton Falls Reservoir "K" — Card #2

W.I. Ladder, C.I. Floor Plates, Guides for Sluice Gate Stems, Shields	5/06	9807 Y
		9804 Y
Main Dam - Sections of Ground in Valley, Borings-Location	5/06	9805 Y
Entrance to Connecting Channel - Plan & Sections	3/06	9802 Y
Connecting Channel, Plan & Profile	3/06	9801 Y
		9799 Y
Diverting Dam, Waste Weir, Waste Channel	5/06	9800 Y
		9797 Y
" " Elevations & Sections	5/06	9798 Y
" " Plan - Completed Works	5/06	9796 Y
Waste Channel, Part of Connecting Channel		9796 Y
Diverting Dam & Conn. Channel, Topography & Boring Location		9795 Y
		9793 Y
Main Dam - Waste Weir & Waste Channel	5/06	9794 Y
" " Conduit & Fountain	5/06	9792 Y
" " Downstream Gate Chamber	5/06	9791 Y
		9789 Y
" " Gate House	6/07	9790 Y
		9787 Y
" " Upstream Gate Chamber	5/06	9788 Y
		9786 Y
" " Elevation, Plan - Completed Works	6/07	9785 Y
Diverting Dam - Waste Weir Facing Blocks - Temporary River Channel		9783 Y
		9589 Y
Waste Channel & Gutter Improvements	1913	to 9591 Y
Diverting Dam - Stop Plank Chamber Superstructure & Bridge	1913	9781 Y

Croton Falls Reservoir		Card #
Map - N.Y. & Harlem R.R. Easement for 2nd Taking Plan	3/06	9682 to 9685
Bastion of Diverting Dam - Railing	3/10	9679
Diverting Dam - Sketch of Gate Stems in Gate Chamber	3/10	9678
At Bastion - Diverting Dam - Modification of Wing Wall	12/08	9677
Gates for Highway Fences	8/08	9676
Arch Culvert No 8-4 - C-4	8/07	9675
X Maximum Section of Main Dam & Sect. Thru. Gate Chambers.	6/07	9673
X Profile of Main Dam	1/05	9672
Main Dam - Gate Chamber - Sketch for Setting Sluice Gate Thimbles.	3/09	9671
X " " Location of Bastion	7/09	9670
Gate House - Location of Gates		10010
"K" General Map		9674
City Property	1915	10938-X, 10937-
Katherine B. Hobbs - Parcel to be acquired		10711-Y
Map showing the principal bodies of water within		15391-Y
Land rel. for Connecting Road	1931	23854-Y
Proposed Repairs to the Waste Channel of Croton Falls Reservoir	11/30/38	27499
" " " " " " " " "	5/14/41	28838

Croton Falls Reservoir		Card #
Arch. Elev. of Proposed Treat. Plant + Pump. Sta.	2/48	31070-
Screen Lifter	5/24/50	32307-
Hyd. Pump. Sta.		31207-26
X REPAIR OF CROTON FALLS SPILLWAY WALL	2/3/60	37509-37511
X Croton Falls Dam elevated drawing		37521-
NEW RAIL AT CROTON FALLS DAM	1972	

CROTON FALLS RESERVOIR "K"

CARD # 5

	ARCH BRIDGE ON PRIVATE ROAD PLAN + DETAILS	6/09	3466-X
	UPSTREAM STOP PLANK CHAMBER, DIVIRTING DAM	5/09	3464-X
	ARCH BRIDGE ON ROAD No. 1-A	3/09	3462-X
	CUT-OFF DAM FOR PAVING, CONNECTING CHANNEL	2/09	3461-X
X	DETAILS OF GAUGE HOUSE, MEASURING WEIR, MAIN DAM	2/09	3460-X
	" " GAUGE, FLOAT, WEIR ETC, " "	7/09	3458-X, 3459-X
	CONNECTING CHANNEL CROSS SECTION	1908	3457-X
	TWIN ARCH CULVERTS, ROAD No. 9 MIDDLE BRANCH	1908	3456-X
	ARCH BRIDGE. WEST BRANCH, ROAD No. 4	1908	3455-X
	" " , WASTE CHANNEL, DIVERTING DAM	1908	3454-X
	C.I. PIPE & SPECIAL PIPE CASTINGS " "	1908	3453-X
	MISCEL. IRON WORK FOR GATE CHAMBERS MAIN DAM	3/08	3452-X
	ARCH BRIDGE, MIDDLE BRANCH. ROAD No. 3	2/08	3451-X
	C.I. FRAMES & COVERS, UPSTREAM GATE CHAMBER MAIN DAM	1/08	3450-X
	MEASURING WEIR DETAILS, DIVERTING DAM	1/08	3449-X
X	PIPES & SPECIAL CASTINGS, MAIN DAM	1/08	3448-X
	STEEL DOORS & WINDOWS " "	9/09	3447-X

CROTON FALLS RESERVOIR, "K"

CARD # 6.

	ARCH BRIDGE, DETAILS WEST BRANCH	7/07	3446-X
	DETAILS OF CONCRETE FACE BLOCKS, MAIN DAM	1906	3440-X to 3445-X
	MAP LOCATION FOR OPEN CHANNEL, DIVERTING BASIN TO MAIN RES.	1906	3439-X
X	MAP OF LOCALITY	1907	3438-X
	TYPICAL CULVERTS & CONCRETE BRIDGE	5/06	3436-X, 3437-X
	WORKS FOR DIVERTING RIVER FLOW, MAIN DAM & DIVERTING DAM	9/06	3432-X, 3435-X
X	SECTIONS OF MAIN DAM, BASTION & ABUTMENT	5/06	3433-X, 3434-X
X	TOPOGRAPHY AT MAIN DAM SITE	5/06	3431-X
	CONTROLLING HOUSE - CONNECTING CHANNEL	1/06	3430-X
	BASTION OF DIVERTING DAM	5/06	3429-X
X	TOPOGRAPHY OF RESERVOIR SITE	10/04	3423-X to 3428-X
X	" IN VICINITY OF DAM SITE WEST BRANCH	8/05	3422-X
	CONNECTING CHANNEL UNDER N.Y.C. & H.R.R.	1/09	3420-X
	TOPOGRAPHY IN VICINITY OF DEEN'S BRIDGE	7/05	3419-X
	ELECTROZONE SEWER AT BREWSTER, PROFILE	[illegible]	[illegible]
	ENGINEER'S OFFICE	10/06	9692-Z to 9697-Z
	MASONRY SKETCHES - & COURT EXHIBIT OF COPING STONE	"	9687-Z to 9689-Z
	ROAD PLANCES	5/07	9690-Z 9691-Z 9695-Z 9696-Z

CROTON FALLS RESERVOIR "K" — CARD #3

NEW HIGHWAYS, TOWNS OF N. SALEM & SOMERS	7/06		3548 · X
6" WATER GATE — COFFIN VALVE CO. — BLUE PRINT	3/09		3533 X
60" SLUICE GATE " " " "	1909	3531 X	3532 · X
GATE STANDS, BALL BEARING, " " " "	1909	3529 X	3530 X
2'-6" x 5' SLUICE GATES " " " "	1909	3525 X	3528 X
SANITARY DAM, CROTON RIVER, DEENS BRIDGE	1909	3523 X	3521 X
ELECTROZONE PLANT; NEAR DEANS CORNERS	1909	3511 X	to 3516 X
MAP, CONNECTING CHANNEL & HIGHWAYS ON PARCELS 10, 11 & 13	1911	3498 X	3510 X
TABLETS; ORGANIZATION, ELEVATIONS	5/10	3508 X	3509 X
		3500 X	3511 X
REMOVAL OF ELECTROZNE PLANT TO NEW LOCATION	1909	3495 X, 3503 X	to 3507 X
JUNCTION OF ROADS 3 & 6	8/07		3502 · X
RELOCATION OF JUENGST ELEC. LIGHT LINE, NEAR DEANS CRNS	11/09		3499 · X
MAIN DAM, EASTERLY RETAINING WALL, LOWER WASTE CHANNEL	3/10		3494 · X
SURVEY OF WASTE CHANNEL	1905		3493 · X
TOPO. INTERSECTION ROAD 5A & CONNECTING CHANNEL	1908		3492 · X
" AT SOUTH END OF " "	1908		3491 · X
PLAN & PROFILE OF OLD CROTON TURNPIKE	2/37		3710 X

CROTON FALLS RESERVOIR "K" — CARD #4

FINAL GRADES. ROAD #1	2/09		3489 · X
REMOVAL OF ELECTROZONE PLANT TO NEW LOCATION — BLUE PRINTS	3/08	3485 X	to 3488 X
LAYOUT OF BRIDGE "J"	3/13		3484 · X
DETAILS OF CONTROL HOUSE, CONNECTING CHANNEL	3/10		3483 · X
MAP OF RES. & VACINITY	1910		3482 · X
GATEWAY TO PARK MAIN DAM, PLAN & DETAILS	3/10		3480 · X
DETAIL OF CORNICE, GATE HOUSE, MAIN DAM	4/10		3479 · X
			3463 · X
REINFORCEMENT IN TOP OF DAM IN CONCRETE BLOCKS	12/08	3472 X	3478 X
RAILING DETAILS, MAIN DAM	11/09		3477 X
PARKING BELOW DAM, " "	11/09		3476 X
BRIDGE OVER SPILLWAY CHANNEL, PLAN & SECTION	11/09		3475 · X
RELOCATION OF ELECTROZONE PLANT, PLANS & PROFILE	6/10	3421 X	3474 X
CONNECTING CHANNEL, WEIR & RR CROSSING	9/09	3465 X	3473 · X
MAIN DAM, DETAILS OF ABUTMENT AND BASTION	1909	3471 X	3469 · X
" " , DRAINAGE OF TOP	9/09		3470 · X
CONNECTING CHANNEL, CONTROLLING HOUSE DETAILS	6/09		3468 · X
" " ARCH BRIDGE ABUTMENT DETAILS	6/09		3467 · X

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Div. Engr.
Asst. Chief Engr.
COPY

Report on the Evaluation of the Condition of Croton Falls Dam

by

Merlin D. Copen, P.E., Consulting Engineer

January 1977

Introduction

Croton Falls Dam is located on the west branch of the Croton River in Putnam County, New York. The dam is a gravity structure having a maximum height of 173 feet, a top thickness of 23 feet and a maximum base thickness of 128 feet. It was constructed in 1906-1910 of cyclopean masonry faced with precast concrete blocks.

Leakage through the dam apparently began soon after its completion and has continued to some extent throughout the life of the structure. This has resulted in an unsightly and deteriorated appearance on the downstream face.

The purpose of this report is to present the findings of an independent consulting engineer regarding the present condition of the dam, need for additional investigations and measures required to reduce leakage and assure the safety of the dam in the future.

The writer was accompanied by Mr. Carl Picha, Division Engineer, throughout all of his inspection of the dam. Deputy Chief Engineer (Watersheds), Mr. George Mekenian, was also present during part of the inspection when his other duties would permit. The many acts of kindness and consideration of these gentlemen were greatly appreciated.

Conclusions and Recommendations

1. To evaluate the safety of the dam and its stability, a stress analysis based on modern principles should be made at the earliest possible opportunity.

2. To properly assess the internal condition (quality of the material) of the dam, the drilling program discussed in the body of this report is essential.

3. Based on the surface examination but contingent on the results of borings, a grouting program will likely be required to insure a continued safe life for this dam.

4. While caulking the cracks in the upstream face may temporarily reduce the leakage through the dam, a more permanent repair will be necessary to properly eliminate this problem.

5. The downstream face of the dam is very unsightly but the carbonate deposits and deteriorated face blocks have very little effect on the safety and continued usefulness of Croton Falls Dam. Cleaning and repairing this face would be primarily for esthetic reasons.

6. Because of the presence of detrimental forces and aging factors on water retention structures, it is very important, as such structures age, that thorough examination by experienced persons be conducted to ascertain their physical condition. Such examination and the necessary rehabilitation resulting therefrom will not only result in extended life of the structures but may also prevent future destruction of life and property because of potential failure.

Surficial Examination

Croton Falls Reservoir had been lowered about 50 feet at the time of this examination, thus permitting a careful examination of the upstream as well as the downstream face. With the use of a crane and basket the upstream face was examined from the top of the dam to the reservoir surface along three vertical cracks, approximately stations 1 + 93, 5 + 62 and 6 + 90. The entire upstream face was also carefully inspected from the surface of the ice on the reservoir.

With the exception of the above mentioned major cracks and concrete spalling associated with them, the upstream face is in generally good condition. Several short cracks are visible on the face and many small areas of concrete spalling. The mortar between concrete blocks is in generally good condition. The vertical cracks and attendant spalling are believed to be the result of concrete shrinkage. The other visible concrete spalling is probably caused by freeze-thaw action on weak or defective concrete face blocks.

One major vertical crack and several short vertical cracks are visible on the downstream face of the dam. The major crack is probably an extension of the crack on the upstream face at station 6 + 90. Calcium carbonate deposits and deteriorated face blocks give the entire downstream a very bad appearance. The deposits are a result of water filtering through the upstream face and leaching cement from the concrete in the interior of the dam. The deteriorated condition of the face blocks is probably the result of freeze-thaw action.

Extensive calcium carbonate deposits are visible on the copings near the top of the dam. These are probably the result of inadequate or improper drainage of the roadway. Some of the ornamental blocks at the top of the dam appear to be on the verge of falling as a result of concrete deterioration. (These blocks are shown as course F1 on Drawing 3445-X).

The only view of the interior concrete in the dam was obtained by examining the gallery near the top of the dam. The concrete in the gallery was quite porous with many areas of honeycomb. Several vertical cracks were found on both faces. In addition, open horizontal cracks were found in the gallery. The generally porous condition of the concrete was probably the result of inadequate consolidation. The vertical cracks were probably caused by concrete shrinkage. The horizontal cracks are probably the result of expansive forces such as those produced by the chemical reaction of some aggregates with cement.

Additional Investigations

To establish a basis for evaluating the safety of Croton Falls Dam, stress and stability analyses should be made as soon as possible. These studies should include all forces expected to act on the dam, i.e. concrete weight, water load, earth pressures on both faces, uplift pressure under and throughout the dam, and any other loads appropriate to this structure. Because it is possible that the interior concrete may have shrunk away from the face blocks, an analysis should be made assuming only the concrete between the face blocks can resist stress, as well as a study using the entire section.

Borings should be made to determine the strength and permeability of the concrete in the dam. A minimum of four borings will be necessary from the top completely through the dam into the foundation. The approximate locations and directions of these borings might be: (1) a vertical hole at station 3 + 00; (2) a hole at station 5 + 50 inclined slightly to cross the crack which is visible on the upstream face at station 5 + 62; (3) a hole at station 7 + 25 inclined to cross the vertical crack at station 6 + 90 in the vicinity of the major spalling; (4) a vertical hole at station 9 + 00. Water losses should be recorded during drilling and packer water pressure tests performed in the drill holes to help evaluate the porosity of the concrete. Cores should be extracted from all holes and tests performed on both mortar and composite cores to determine compressive, tensile and shear strengths. If desired, these borings can be utilized for piezometer gaugings.

Repairs

Based on the results of the borings a determination can be made regarding the necessity and extent of required grouting. It appears certain that grouting will be required in the known vertical cracks. If most of the concrete is porous and the strength is low because of leaching, a much more extensive grouting program should be considered.

Either a rigid or flexible grout would probably be satisfactory. Cement grout (rigid) is more compatible with the material in the dam and is usually less expensive. It will shrink, however, and because of its low strength may crack. Flexible grout (such as AM-9) will adequately fill the cracks and holes but has no structural value and is expensive. Grouting should be performed from the center of the dam toward the surfaces. As grouting approaches the faces, caulking will probably be required in major cracks.

As a final treatment for the upstream face, loose and deteriorated material should be removed from the major spalled areas and be replaced with epoxy concrete or similar product. The cracks should be opened in a V-shape and filled with a similar material. The entire upstream face should then be lightly sand blasted and sealed with epoxy paint or some similar material.

The need for any or all of these repairs must be determined from the results of the suggested investigations.

While the downstream face has a bad appearance, any cleaning, repairing or sealing should be performed for esthetic reasons since little structural benefit would result.

The cost and time required for the indicated investigations and repairs is appreciable. However, delay in making them will only result in more serious deterioration with more expensive repairs, replacements or even possible eventual failure of the dam.

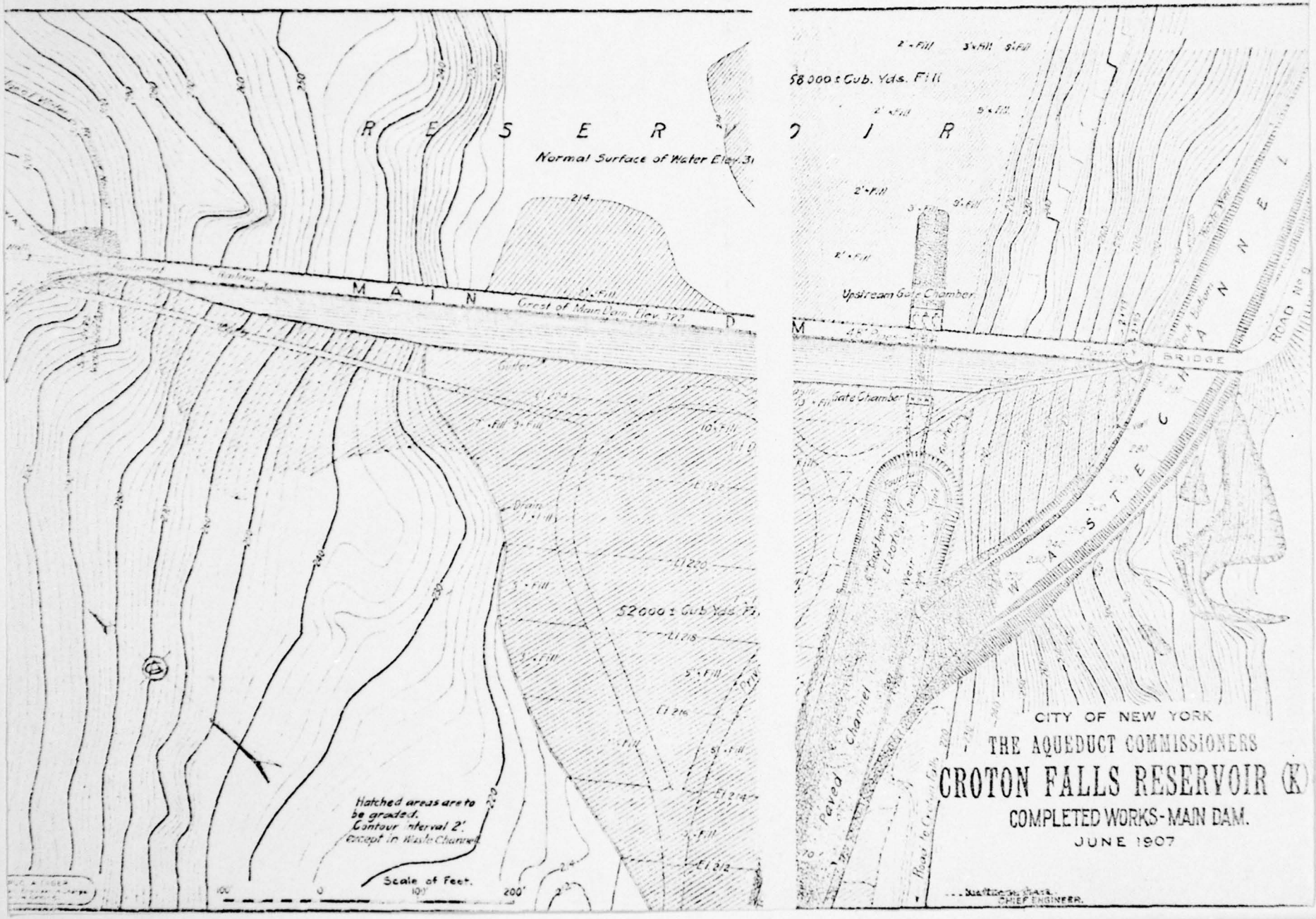
Other Observations

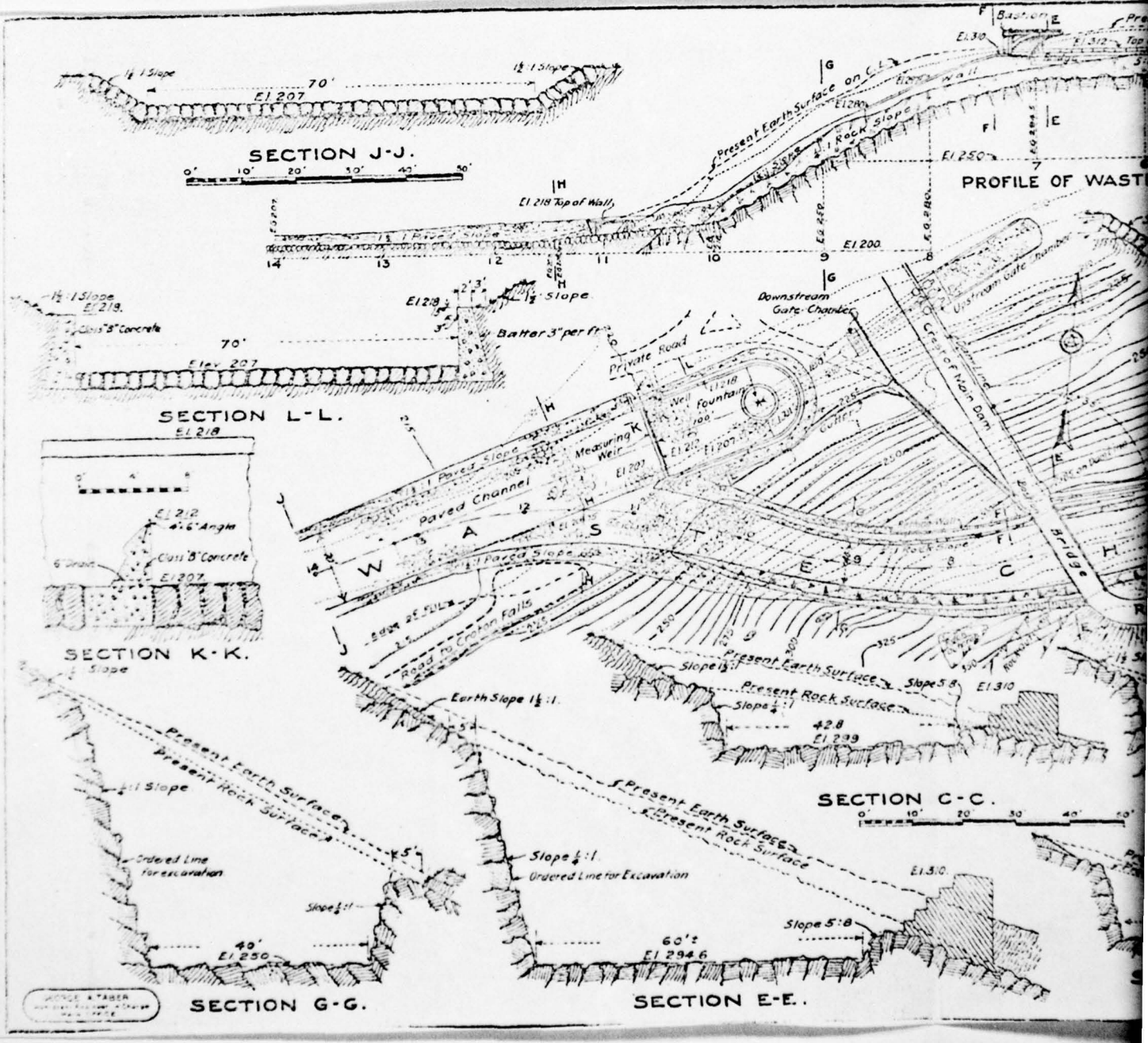
Cross River and Boyds Corner Dams were also visited. Cross River Dam has problems very similar to those found at Croton Falls but not so severe. Appropriate investigations and repairs, where necessary, may prevent these conditions from becoming more serious.

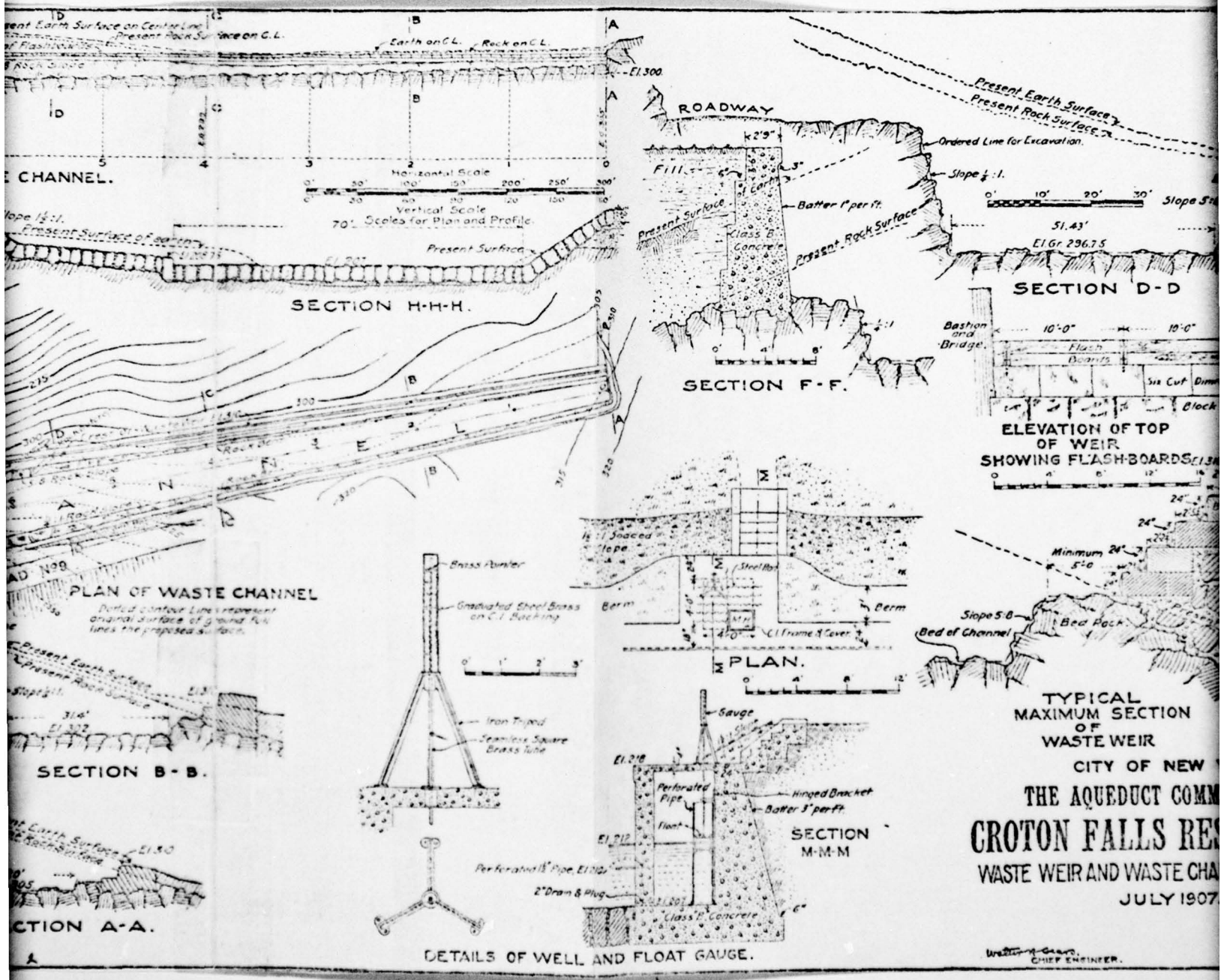
Boyds Corner Dam appears to be in good condition but has considerable growth on the downstream face, especially near the base. Application of an herbicide, when required, to eliminate this vegetation may prevent more serious problems in the future. Seepage water which accumulates at the toe of the dam should also be channeled and drained away.

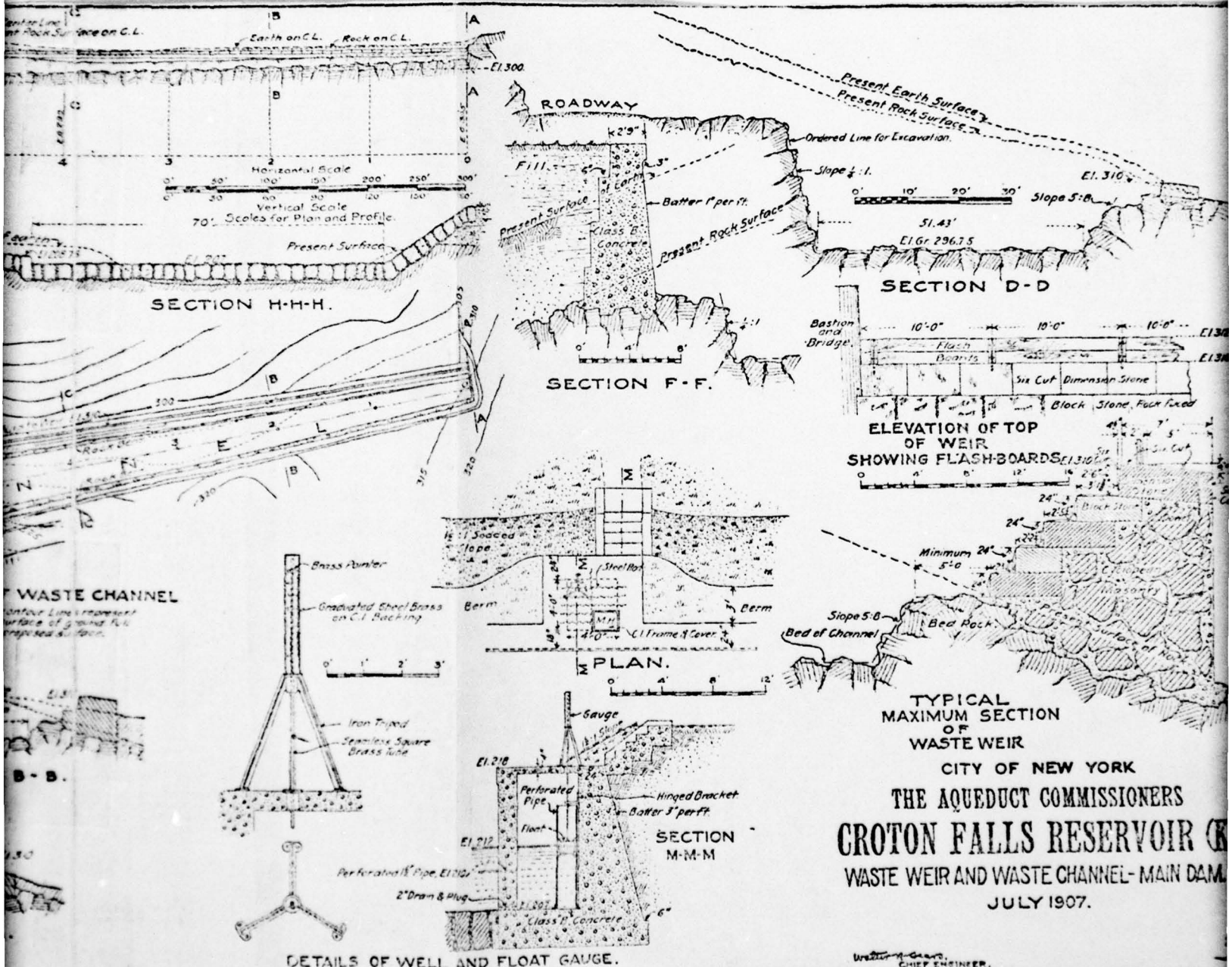
Appendix E
Construction Drawings

PLATE 129


RESERVOIR
Normal Surface of Water Elev. 31
MAIN DAM
Crest of Main Dam, Elev. 362
58000± Cub. Yds. Fill
52000± Cub. Yds. Fill
Upstream Gate Chamber
Gate Chamber
BRIDGE
ROAD No. 9
Paved Channel
Hatched areas are to be graded. Contour interval 2', except in Waste Channel
Scale of Feet.
CITY OF NEW YORK
THE AQUEDUCT COMMISSIONERS
CROTON FALLS RESERVOIR (K)
COMPLETED WORKS - MAIN DAM.
JUNE 1907
CHIEF ENGINEER.


SECTION J-J.
SECTION L-L.
SECTION K-K.
SECTION G-G.
SECTION E-E.
SECTION C-C.
PROFILE OF WASTE
Present Earth Surface on C.L.
Present Rock Surface
Present Earth Surface
Ordered Line for excavation
Ordered Line for Excavation
Paved Channel
Measuring Weir
Well
Fountain
Private Road
Road to Cohen Falls
Crest of Main Dam
Upstream Gate Chamber
Downstream Gate Chamber
Bridge
Earth Slope 1½:1.
Slope 5:8
Slope ¼:1
Slope 1:1
Batter 3" per ft.
70'
42.8
60'±
40'
El 207
El 218 Top of Wall
El 250
El 310
El 294.6
El 239
WASTE WEIR


E CHANNEL.
Present Earth Surface on Center Line
Present Rock Surface on C.L.
Earth on C.L.
Rock on C.L.
El. 300
Horizontal Scale
Vertical Scale
70' Scales for Plan and Profile.
Present Surface of Section
Present Surface
SECTION H-H-H.
PLAN OF WASTE CHANNEL
Dotted contour Lines represent original surface of ground the lines the proposed surface.
Present Earth Surface
Present Rock Surface
SECTION B-B.
SECTION A-A.
ROADWAY
Ordered Line for Excavation.
Fill
Earth
Present Surface
Batter 1" per ft.
Class 'B' Concrete
Present Rock Surface
Slope ¼ : 1.
Slope 5:8
51.43'
El. Gr. 296.75
SECTION D-D
SECTION F-F.
Bastion and Bridge.
Flash Boards
Sill Cut
Block
ELEVATION OF TOP OF WEIR SHOWING FLASH-BOARDS
Berm
Steel Rail
C.I. Frame & Cover
PLAN.
Minimum 24"
Slope 5:8
Bed Rock
Bed of Channel
TYPICAL MAXIMUM SECTION OF WASTE WEIR
Brass Funnel
Graduated Steel Brass on C.I. Backing
Iron Tripod
Seamless Square Brass Tube
Gauge
El. 218
Perforated Pipe
Hinged Bracket
Batter 3" per ft.
Float
El. 212
SECTION M-M-M
Perforated 1½" Pipe, El. 210
2" Dram & Plug
Class 'B' Concrete
DETAILS OF WELL AND FLOAT GAUGE.
CITY OF NEW
THE AQUEDUCT COMM
CROTON FALLS RES
WASTE WEIR AND WASTE CHA
JULY 1907.
CHIEF ENGINEER.



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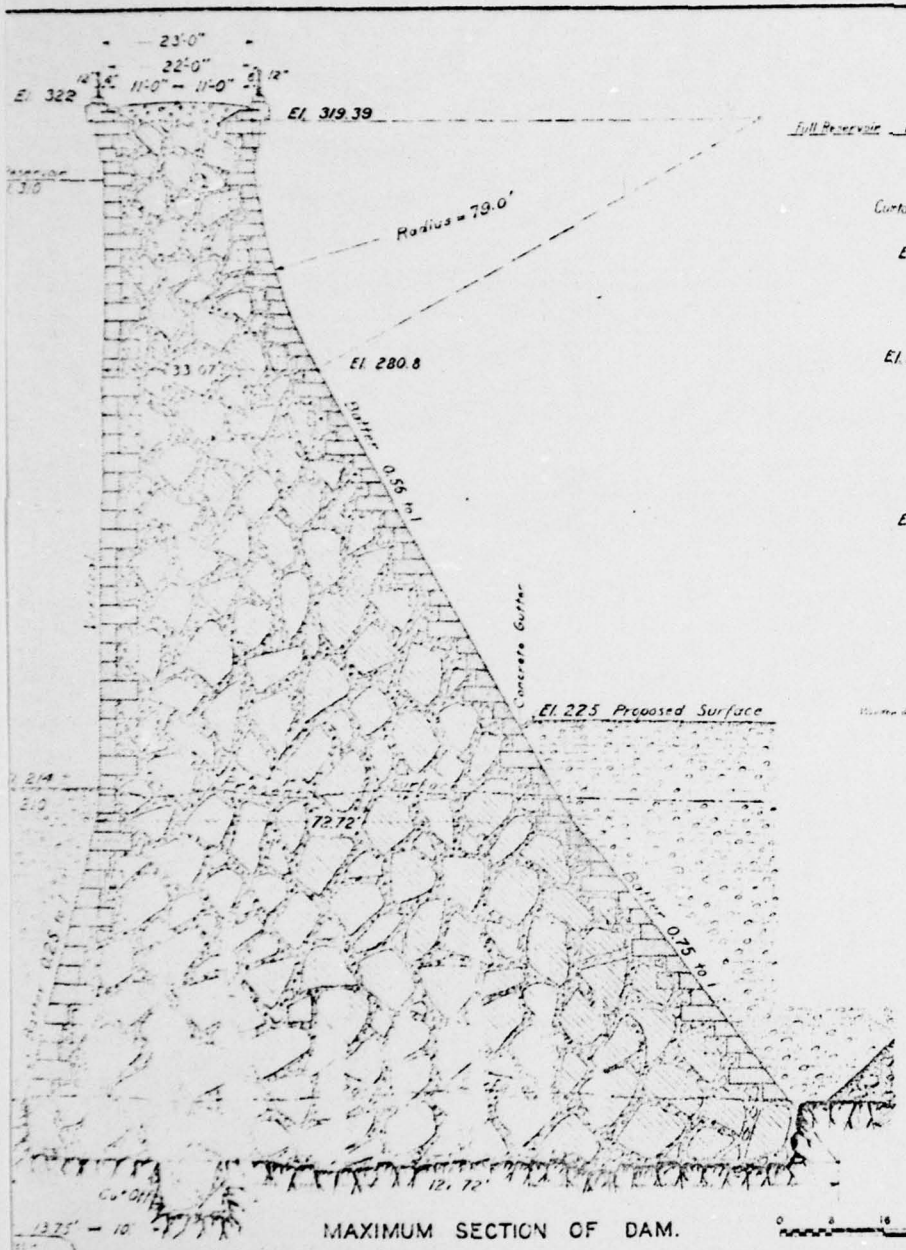
CROTON FALLS RESERVOIR (R

WASTE WEIR AND WASTE CHANNEL- MAIN DAM

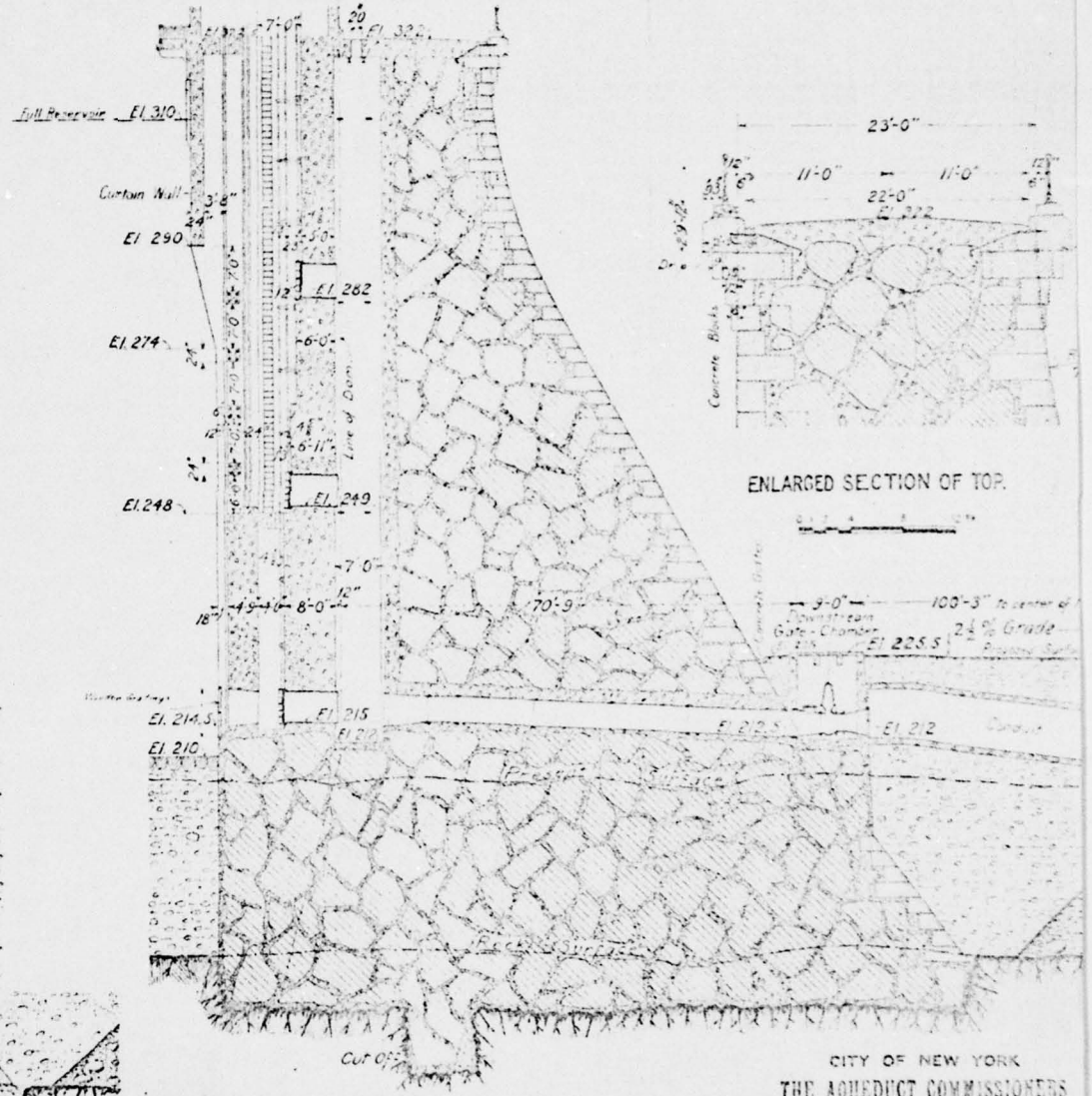
JULY 1907.

CHIEF ENGINEER.

PLATE



MAXIMUM SECTION OF DAM.



SECTION OF DAM
THROUGH GATE-CHAMBERS.

ENLARGED SECTION OF TOP.

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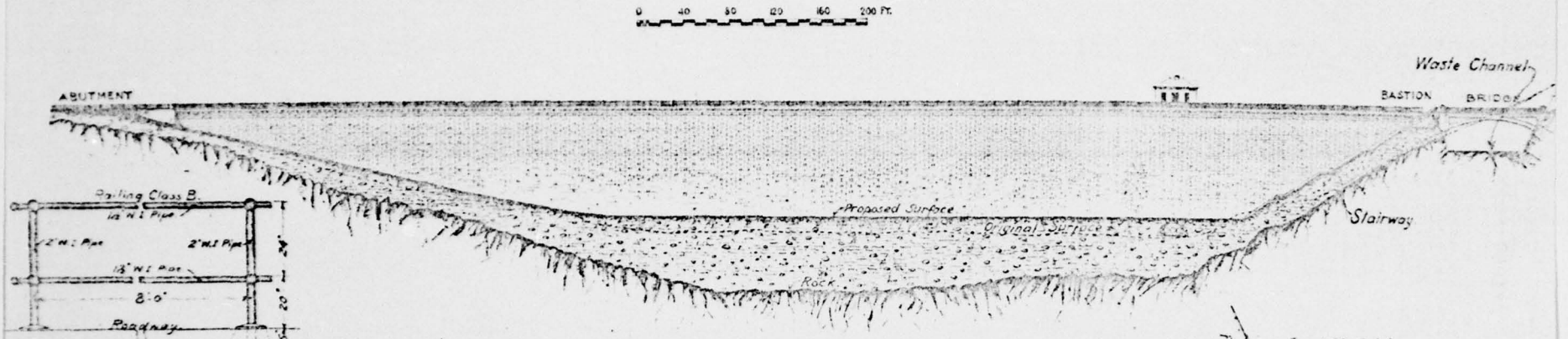
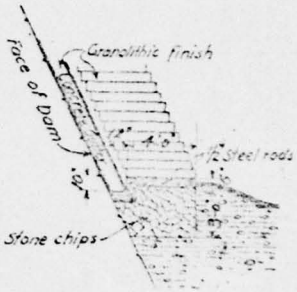
SECTIONS OF MAIN DAM
JUNE 1907

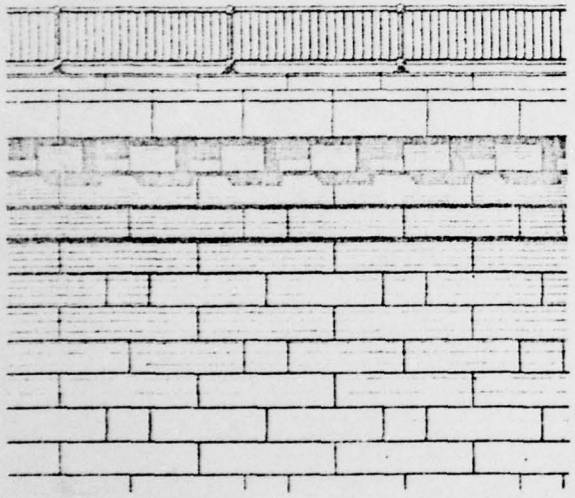


DOWNSTREAM FACE OF DAM.



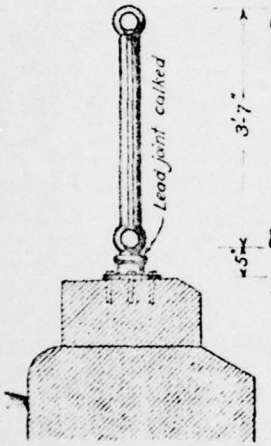
CONCRETE STAIRWAY AT FACE OF DAM

0 4 8 12 Ft.

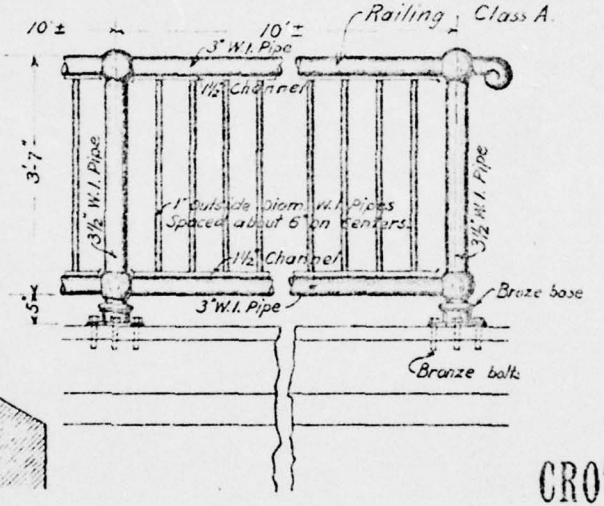


DETAIL OF DOWNSTREAM FACE OF DAM

0 4 8 12 Ft.



SECTION.



ELEVATION

RAILING ON TOP OF DAM

0 1 2 3 Ft.

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CROTON FALLS RESERVOIR (K)

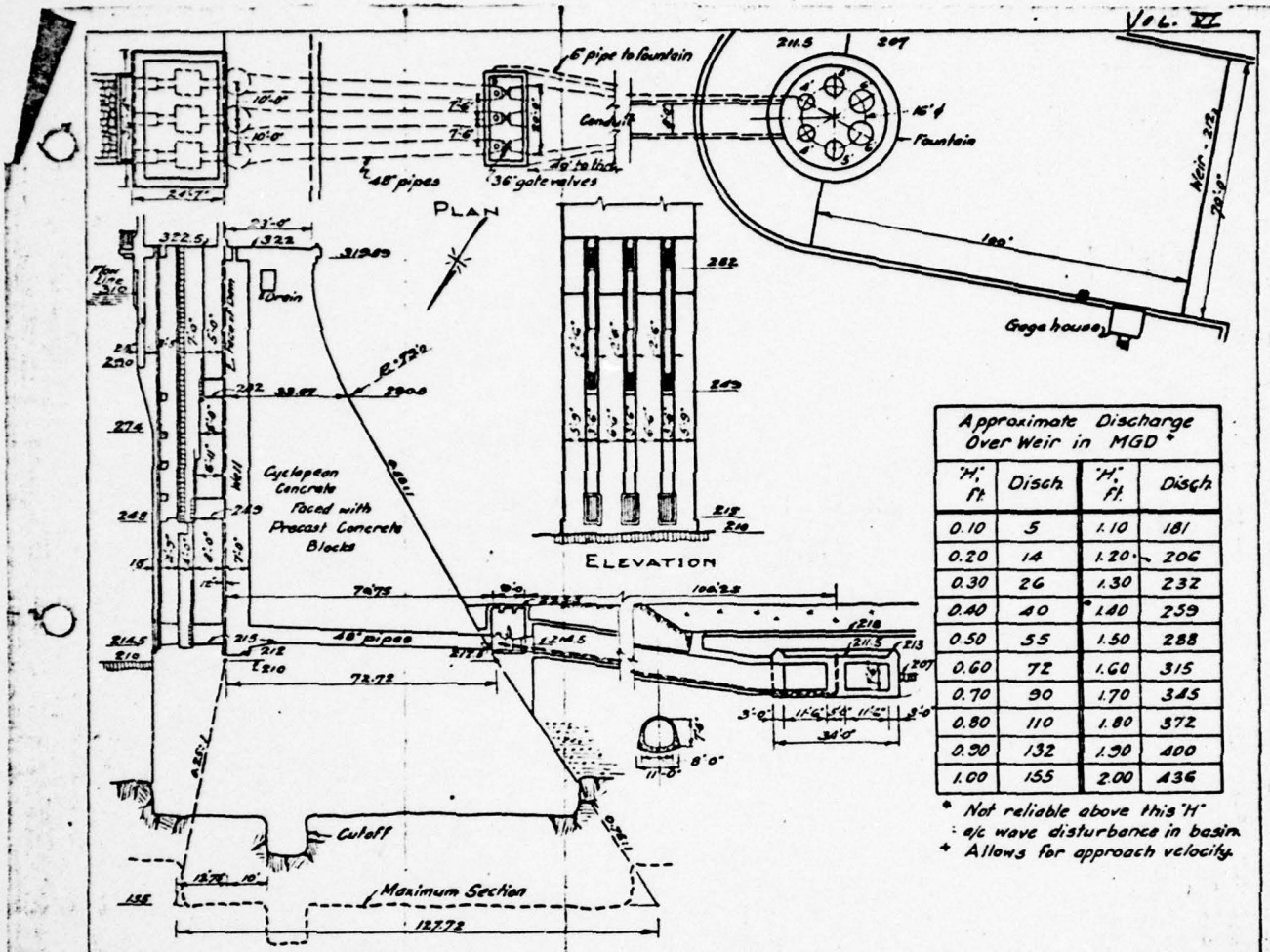
ELEVATION OF MAIN DAM.

JUNE 1907.

GEORGE A. FARBER
Asst. Engr. in Charge
Main Office

..... CHIEF ENGINEER.

VOL. XI



Approximate Discharge Over Weir in MGD +			
"H" ft.	Disch.	"H" ft.	Disch.
0.10	5	1.10	181
0.20	14	1.20	206
0.30	26	1.30	232
0.40	40	1.40	259
0.50	55	1.50	288
0.60	72	1.60	315
0.70	90	1.70	345
0.80	110	1.80	372
0.90	132	1.90	400
1.00	155	2.00	436

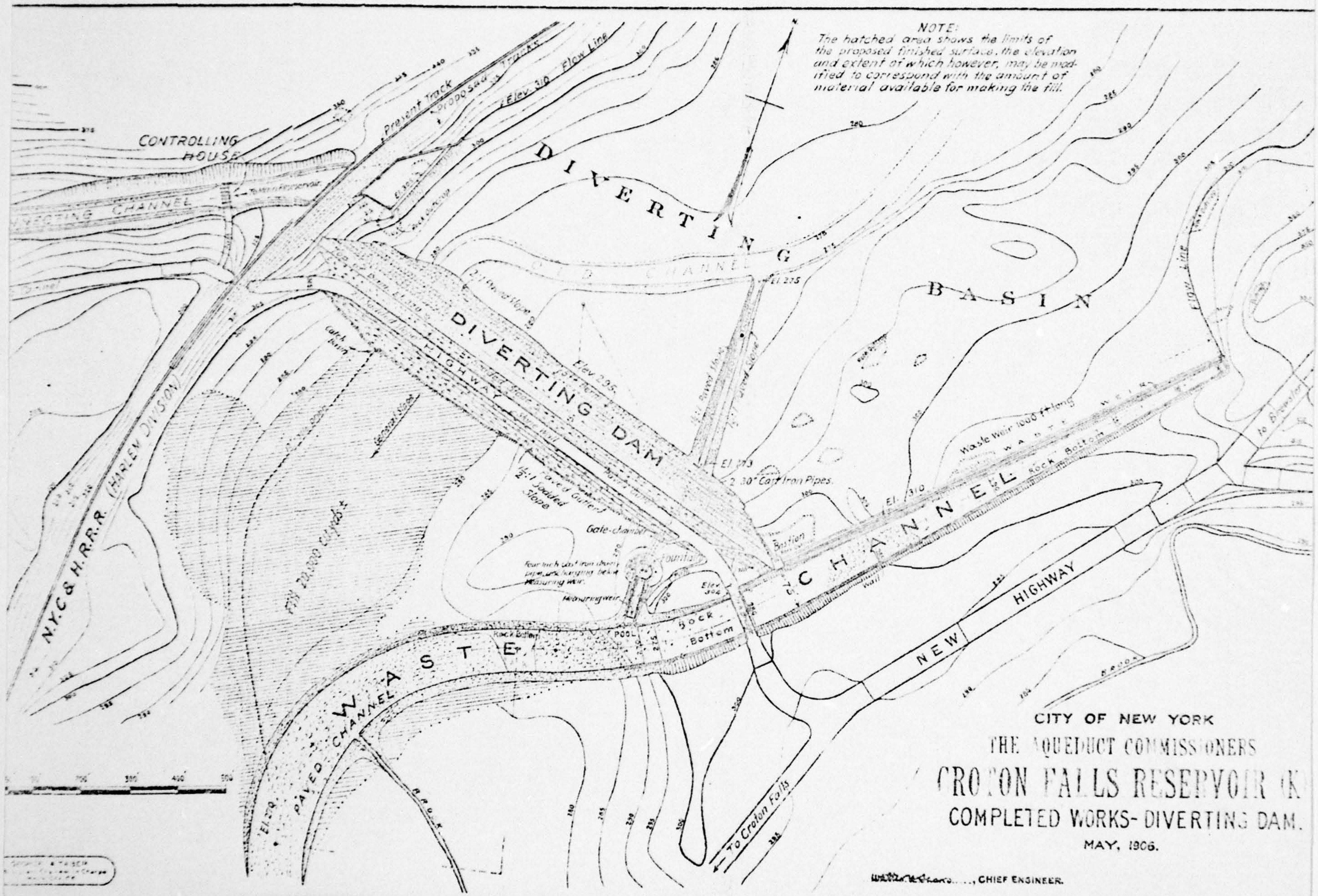
* Not reliable above this "H" : a/c wave disturbance in basin.
\+ Allows for approach velocity.

GENERAL NOTES:
Elevations refer to Croton Datum.
Elevation of spillway lip - 310.0
Elevation of flashboard crest - 311.92
Length of dam - 1077'
Length of spillway - 637' — 700'?

CROTON FALLS DAM

Scale: 1" = 30'

39507 - Z



CITY OF NEW YORK

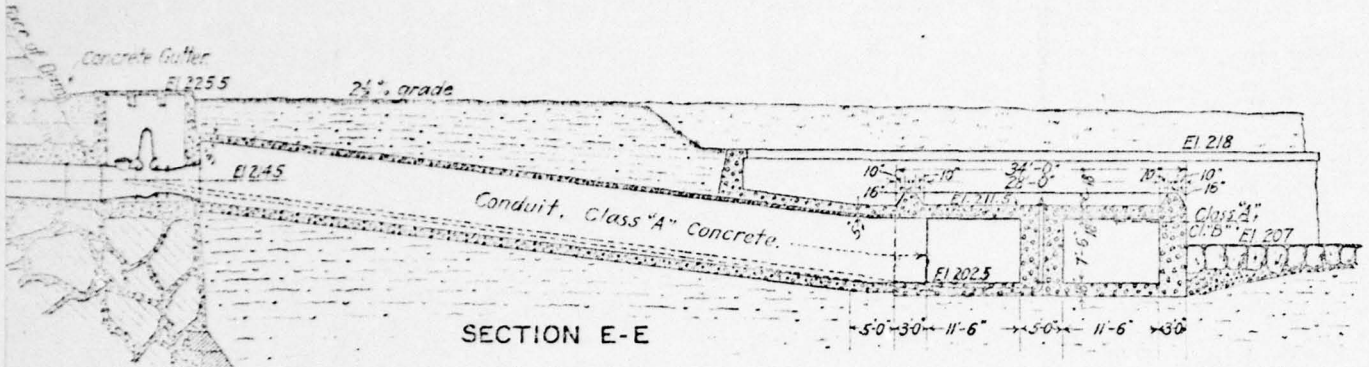
THE AQUEDUCT COMMISSIONERS

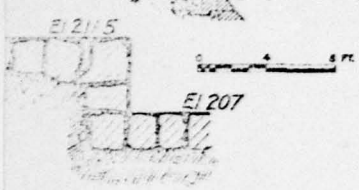
CROTON FALLS RESERVOIR (K)

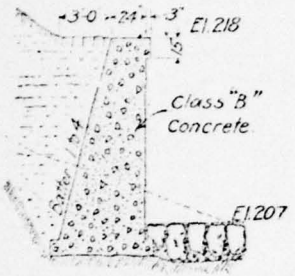
COMPLETED WORKS- DIVERTING DAM.

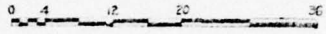
MAY, 1906.

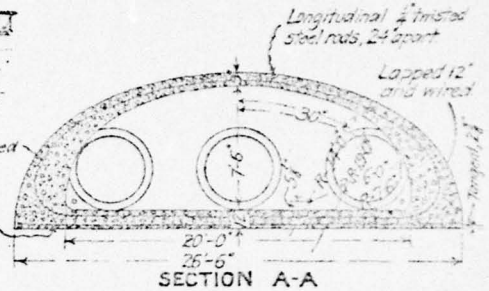
........, CHIEF ENGINEER.

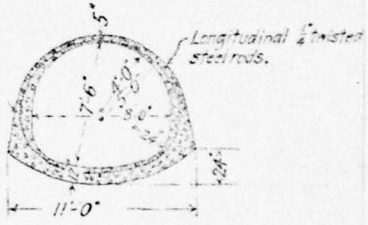












CITY OF NEW YORK

THE AQUEDUCT COMMISSIONERS

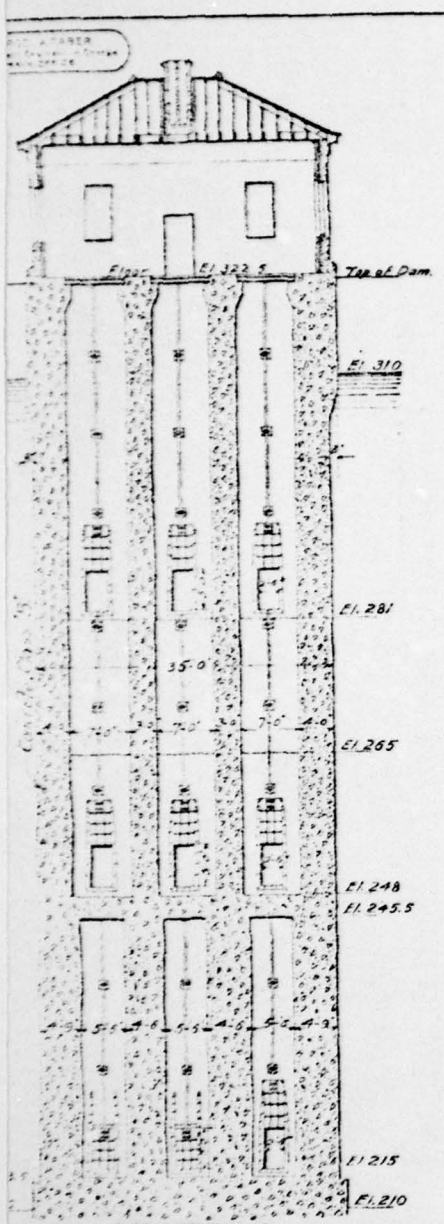
CROTON FALLS RESERVOIR (K)

CONDUIT AND FOUNTAIN – MAIN DAM

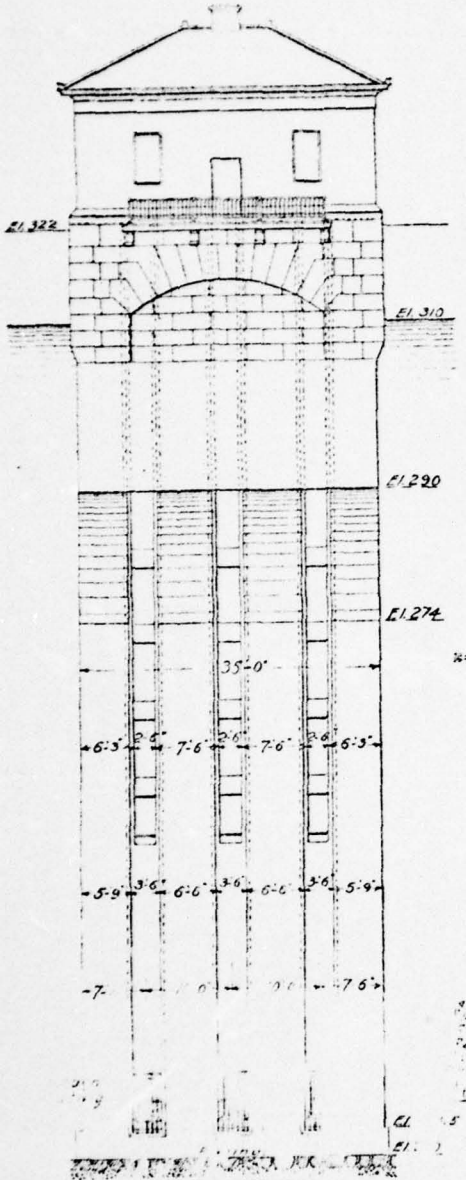
MAY 1906

..., CHIEF ENGINEER

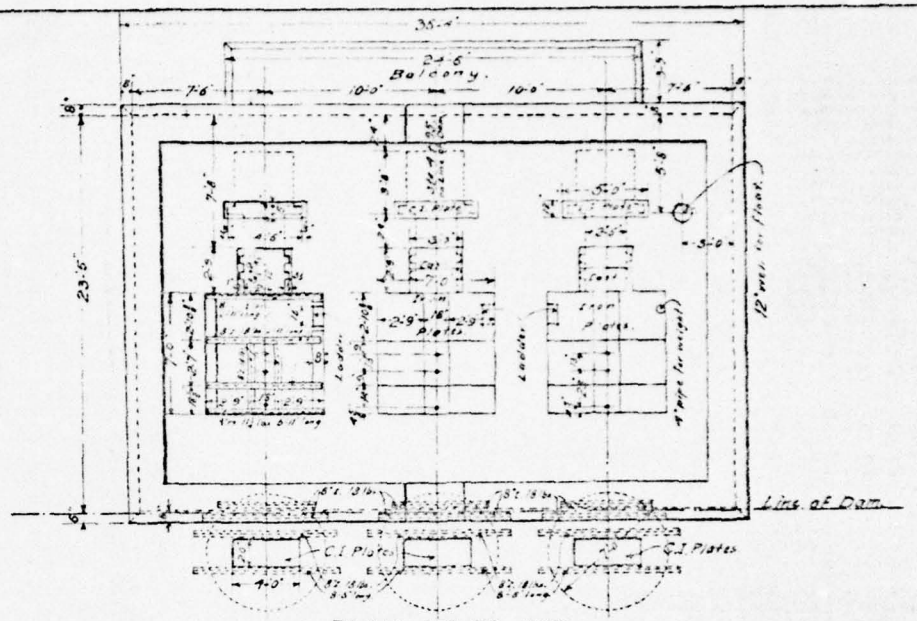
PLATE 132



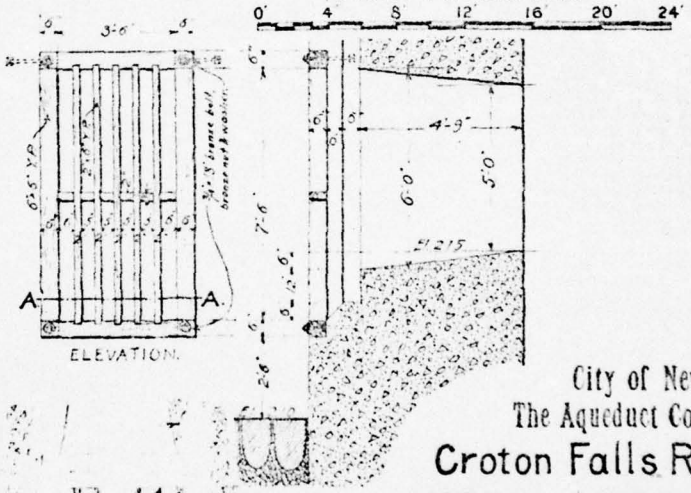
LONGITUDINAL SECTION.



ELEVATION.



PLAN AT EL. 322.



WOODEN GRATINGS.

0 2 4 6 FT.

City of New York.
The Aqueduct Commissioners.

Croton Falls Reservoir "K"

UPSTREAM GATE-CHAMBER-MAIN DAM

NOV. 5, 1906.

Walter H. Hard CHIEF ENGINEER.

Appendix F
Visual Checklist

CHECK LIST
VISUAL INSPECTION
PHASE 1

NAME DAM Croton Falls Dam COUNTY Putnam STATE New York ID# 39

TYPE OF DAM Cyclopean Masonry-Gravity HAZARD CATEGORY High

DATE(s) INSPECTION May 1-2, 1978 WEATHER Pt. Cloudy TEMPERATURE 45°-50°

POOL ELEVATION AT TIME OF INSPECTION 310.2 M.S.L. TAILWATER AT TIME OF INSPECTION Approx. 212.6 M.S.L.

INSPECTION PERSONNEL:

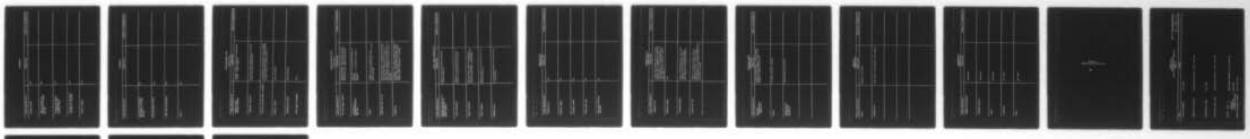
John C. Pierchoski, P.E.
John Birrell, New York City Water Supply
R. Jeffrey Kimball, P.E.
James T. Hockenmith

John C. Pierchoski, P.E. RECORDER

AD-A066 394 KIMBALL (L ROBERT) AND ASSOCIATES EBENSBURG PA F/G 13/2
NATIONAL DAM SAFETY PROGRAM CROTON FALLS DAM, (NY39) LOWER HUDS--ETC(U)
JUN 78 R J KIMBALL DACW51-78-C-0025

UNCLASSIFIED NL

2 OF 2
ADA
066394



END
DATE
FILMED
5 79
DDC

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS	N/A	
UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE	N/A	
SLOUGHING OR EROSION OF EMBANKMENT AND ABUTMENT SLOPES	N/A	
VERTICAL AND HORIZONTAL ALINEMENT OF THE CREST	N/A	
RIPRAP FAILURES	N/A	

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
JUNCTION OF EMBANKMENT AND ABUTMENT, SPILLWAY AND DAM	N/A	
ANY NOTICEABLE SEEPAGE	N/A	
STAFF GAGE AND RECORDER	N/A	
DRAINS	N/A	

CONCRETE/MASONRY DAMS

CROTON FALLS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATION:
SURFACE CRACKS CONCRETE SURFACES	Roadway pavement shows some longitudinal cracks. (crest roadway)	
STRUCTURAL CRACKING	One major crack through entire dam seeps water constantly (see photos)	
VERTICAL AND HORIZONTAL ALIGNMENT	No noticeable settlement on mis-alignment (checked with abney level) Some cracking at both bastions (inside gallery).	
MONOLITH JOINTS	None observable	
CONSTRUCTION JOINTS	None observable	
STAFF GAGE OR RECORDER:	310.2'	

CONCRETE/MASONRY DAMS

CROTON FALLS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIO
ANY NOTICEABLE SEEPAGE	Several seeping cracks show up on the downstream face. None except the major structural crack appear significant.	
STRUCTURE TO ABUTMENT/EMBANKMENT JUNCTIONS	North end - no noticeable seepage or movement. South end - no noticeable seepage or movement.	
DRAINS	Roadway over crest drains into an interior gallery which drains toward each end of the dam.	
DOWNSTREAM FACE OF DAM	65% of the precast concrete facing blocks have spalled away to a depth of 1" to 2". Spalling not serious but is caused by water seeping through and freezing on face. Upstream face exhibits very little such spalling.	
FOUNDATION	According to the plans, bedrock is massive and stable. No noticeable movement anywhere. Plans show 15' to 20' of bedrock removed before placement of footings.	

OUTLET WORKS CROTON FALLS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATION
CRACKING AND SPALLING OF CONCRETE SURFACES IN OUTLET CONDUIT	Three 48" cast iron pipes apparently in good condition.	
INTAKE STRUCTURE	Gatehouse in good condition with intakes at elevation 215,249 and 282.	
OUTLET STRUCTURE	Three CI pipes flow into powerhouse - and into a fountian. Retaining wall around fountain pool deteriorating.	
OUTLET CHANNEL	Wide and open to the back water of the Muscoot Reservoir.	
EMERGENCY GATE	Is not opened because it does not have a trash screen.	

GATED SPILLWAY
CROTON FALLS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE SILL	N/A	
. APPROACH CHANNEL	N/A	
. DISCHARGE CHANNEL	N/A	
BRIDGE AND PIERS	N/A	
GATES AND OPERATION EQUIPMENT	N/A	

UNGATED SPILLWAY
CROTON FALLS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATION
CONCRETE WEIR	A 700' long spillway weir is on left abutment and is composed on cyclopean masonry with a granite cap stone. In good condition. A side channel weir is present beneath bridge at approx. elev. 297.5'	
APPROACH CHANNEL	None	
DISCHARGE CHANNEL	Water is discharged into a 700' long channel cut into rock then into a concrete lined cascading spillway. Both appear to be in good condition.	
BRIDGE AND PIERS	Bridge at junction between rock cut channel and concrete lined channel along axis of dam. Another bridge near stilling basin. Both bridges exhibit some structural cracking.	

DOWNSTREAM CHANNEL
CROTON FALLS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATION
CONDITION (OBSTRUCTIONS, DEBRIS,ETC.)	No major obstructions, clean of debris except for minor amounts. Wide to the backwater of Muscoat Reservoir.	
SLOPES	No slope failures noticed.	
APPROXIMATE NO. OF HOMES AND POPULATION	Several homes and a school.	

RESERVOIR
CROTON FALLS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	Appears to be stable.	
SEDIMENTATION	Very little, not noticeable from surface.	

INSTRUMENTATION
CROTON FALLS

VISUAL EXAMINATION	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
MONUMENTATION/SURVEYS	None known	
OBSERVATION WELLS	None known	
WEIRS	None known	
PIEZOMETERS	None known	
OTHER	None known	

Appendix G
Engineering Data Check List

CHECK LIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION
PHASE I

NAME OF DAM Croton Falls Dam

ID# #39

ITEM	REMARKS
AS-BUILT DRAWINGS	None known
REGIONAL VICINITY MAP	Construction Drawings - City of New York
CONSTRUCTION HISTORY	None known
TYPICAL SECTIONS OF DAM	Construction Drawings - City of New York
OUTLETS - PLAN	Construction Drawings - City of New York
- DETAILS	
- CONSTRAINTS	None known
- DISCHANCE RATINGS	
RAINFALL/RESERVOIR RECORDS	City of New York

ITEM	REMARKS
DESIGN REPORTS	None known
GEOLOGY REPORTS	None known
DESIGN COMPUTATIONS HYDROLOGY & HYDRAULICS DAM STABILITY SEEPAGE STUDIES	None known
MATERIALS INVESTIGATIONS	
BORING RECORDS -	Construction Drawings - City of New York
LABORATORY	None known
FIELD	
POST-CONSTRUCTION SURVEYS OF DAM	None known
BORROW SOURCES	Unknown

ITEM	REMARKS
MONITORING SYSTEMS	None known
MODIFICATIONS	Spillway - Construction Drawings - City of New York
HIGH POOL RECORDS	City of New York
POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS	Merlin D. Copen, P.E. - City of New York
PRIOR ACCIDENTS OR FAILURE OF DAM DESCRIPTION REPORTS	None known
MAINTENANCE OPERATION RECORDS	City of New York

	REMARKS
SPILLWAY PLAN SECTIONS DETAILS	Construction Drawings - City of New York
OPERATING EQUIPMENT PLANS & DETAILS	Construction Drawings - City of New York

CHECK LIST
HYDROLOGIC AND HYDRAULIC
ENGINEERING DATA

DRAINAGE AREA CHARACTERISTICS: 168.64 acres mostly forested and developed

ELEVATION TOP NORMAL POOL (STORAGE CAPACITY): 310.0'- 14.189 billion gal.

ELEVATION TOP FLOOD CONTROL POOL (STORAGE CAPACITY): N/A

ELEVATION MAXIMUM DESIGN POOL: unknown

ELEVATION TOP DAM: 322.0

CREST:

	SPILLWAY WEIR	SIDE CHANNEL WEIR
a. Elevation	310.0	Approx. 297.5
b. Type	broad crested weir	concrete paved control section
c. Width	2 feet	-
d. Length	700'	60'
e. Location Spillover	left abutment	along crest near left abutment
f. Number and Type of Gates	none	none

OUTLET WORKS:

a. Type three 48" cast iron pipes
b. Location center of dam
c. Entrance inverts 215,249 and 282
d. Exit inverts 212
e. Emergency draindown facilities through 212 invert - may not work

HYDROMETEOROLOGICAL GAGES:

a. Type Rain gage
b. Location chlorination house near toe
c. Records daily and monthly records

MAXIMUM NON-DAMAGING DISCHARGE Elev. 313.24' - October 15, 1955

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* Lower Hudson River Basin Croton Falls Dam Putnam County, New York Inventory No. N.Y. 39	5. TYPE OF REPORT & PERIOD COVERED Phase I Inspection Report National Dam Safety Program 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. Jeffrey Kimball, P.E.	8. CONTRACT OR GRANT NUMBER(s) DACW-51-78-C-0025
9. PERFORMING ORGANIZATION NAME AND ADDRESS L. Robert Kimball and Associates 615 W. Highland Avenue Ebensburg, Pennsylvania	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Army 26 Federal Plaza / New York District, CofE New York, New York 10007	12. REPORT DATE 30 June 1978 13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*	15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

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18. SUPPLEMENTARY NOTES

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

Dam Safety
National Dam Safety Program
Visual Inspection
Hydrology, Structural Stability
Putnam County
Croton River
Croton Falls Dam
NYC Water Supply System

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

This report provides information and analysis on the physical condition of the dam as of the report date. Information and analysis are based on visual inspection of the dam by the performing organization.

Croton Falls Dam was judged to be unsafe-non-emergency due to a seriously inadequate spillway.

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