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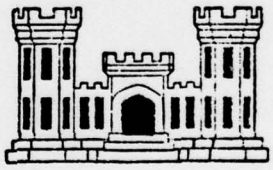
HUDSON RIVER BASIN

NEW CROTON RESERVOIR DAM
WESTCHESTER COUNTY, NEW YORK
INVENTORY NO. 46

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM



NEW YORK DISTRICT CORPS OF ENGINEERS

AUGUST 15, 1978

HUDSON RIVER BASIN

NEW CROTON RESERVOIR DAM
WESTCHESTER COUNTY, NEW YORK
INVENTORY NO. 46

(6) **PHASE I INSPECTION REPORT**
NATIONAL DAM SAFETY PROGRAM.

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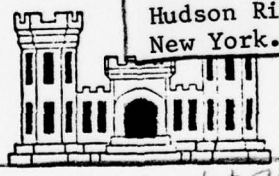
New Croton Reservoir Dam (Number 46), Hudson River Basin, Westchester County, New York. Phase I Inspection Report.



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NEW YORK DISTRICT CORPS OF ENGINEERS

(11) 15 AUGUST 15, 1978

CROTON RIVER BASIN
NEW CROTON DAM
INVENTORY NO. 46
PHASE I INSPECTION REPORT

CONTENTS

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam:	NEW CROTON (I.D. NO. 46)
State Located:	NEW YORK
County Located:	WESTCHESTER
Stream:	CROTON RIVER
Date of Inspection:	JULY 13, 1978

ASSESSMENT

The examination of documents and visual inspection of New Croton Dam and its appurtenant structures did not reveal conditions which are considered to be unsafe at the present time.

The discharge capacity of the spillway is considered to be hydraulically adequate for the estimated Standard Project Flood of 93,800 cfs. The estimated Probable Maximum Flood of 220,000 cfs could be discharged over the spillway without overtopping the dam, if the spillway were structurally adequate.

Although the spillway is adequate from a hydraulic point of view, past performance indicates that it may be subject to severe damage under flood conditions approaching those for the Standard Project Flood. It is therefore recommended that additional investigations be performed to assess the structural adequacy of the spillway to discharge the Standard Project Flood. The additional investigations should be performed on a priority basis in accordance with, but not necessarily be limited to, the requirements of the applicable sections of Chapter 4 of the RECOMMENDED GUIDELINES FOR SAFETY INSPECTIONS OF DAMS, and should include analyses which consider three dimensional effects, tension, and dynamic or vibration effects. A detailed evaluation of the hydrology and hydraulics of the project should also be made at the same time to ascertain the project design floods and the resulting pool levels.

No remedial measures are recommended at the present time; however, the need for either strengthening or otherwise modifying the spillway should be based on the results of the additional investigations.

In addition to the investigation recommended above, the following improvements are suggested:

- Establish an observation program for monitoring the performance of the spillway structure.

- Repair or replace defective gates and regularly inspect and service all gates in Gate Houses 1 and 2 and New Croton Gate House.

- Remove debris and vegetation from the spillway structure, spillway and tailrace channels.

- Remove vegetation and debris from the slopes of the earth embankment.

- Clean the drainage gallery located in the gravity dam.

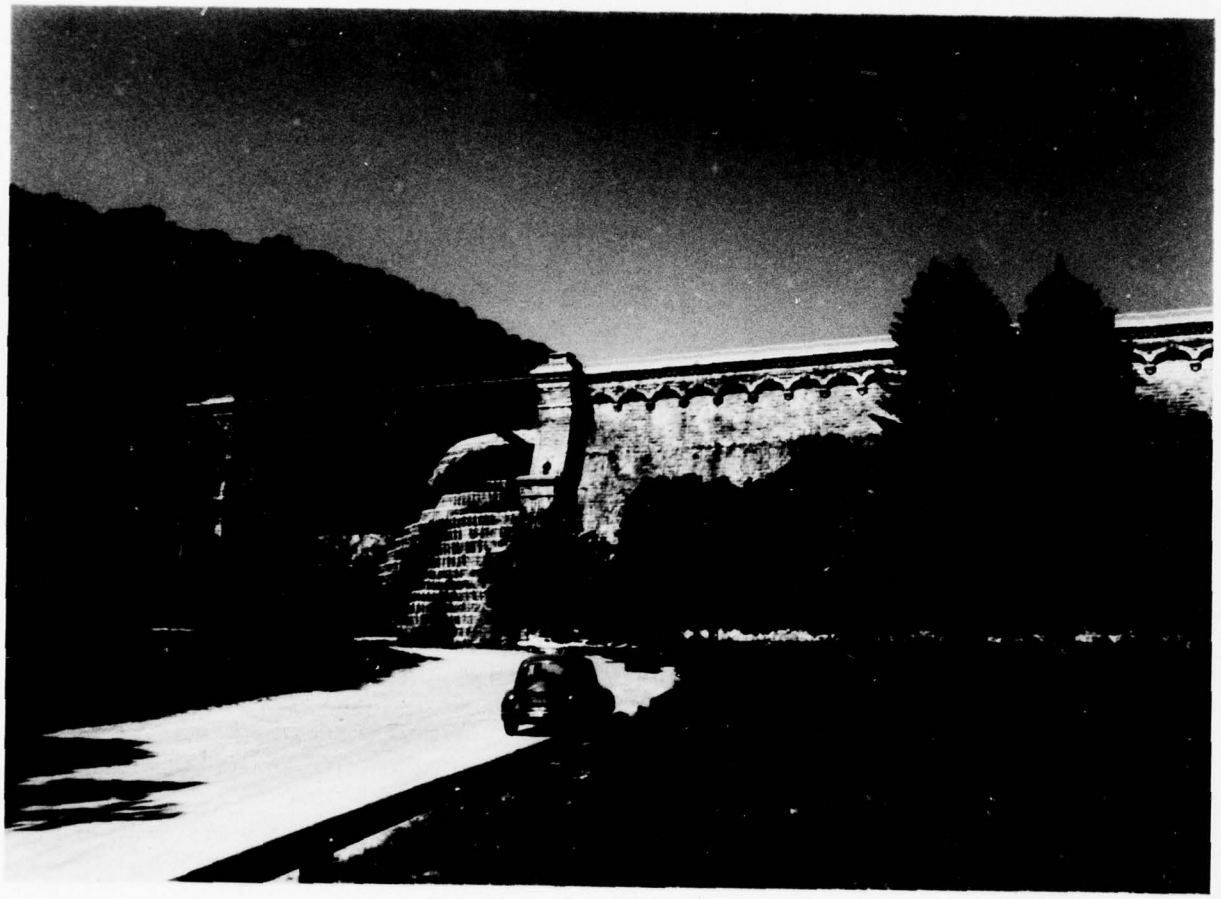
- Repair cracks in the road pavement on the top of dam.

- Improve safeguards against vandalism.

Eugene O'Brien
New York No. 29823

Approved By: Col. Clark H. Benn
New York District Engineer

Date: 29 August 1978



GENERAL VIEW OF SPILLWAY, BRIDGE AND MASONRY DAM

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
NEW CROTON DAM, INVENTORY NO. 46
CROTON RIVER BASIN
WESTCHESTER COUNTY, NEW YORK

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority

The Phase I Inspection reported herein was authorized by the DEPARTMENT OF THE ARMY, NEW YORK DISTRICT, CORPS OF ENGINEERS by letter dated 31 March 1978, in fulfillment of the requirements of the National Dam Inspection Act, Public Law 92-367, 8 August 1972.

b. Purpose of Inspection

The purpose of this inspection and report is to investigate and evaluate the existing conditions of the subject dam in order to: identify deficiencies and hazardous conditions; determine if they constitute hazards to human life or property; and notify the State of New York of these results along with recommendations for remedial measures where necessary.

1.2 DESCRIPTION OF THE PROJECT

a. Description of the Dam and Appurtenant Structures

The New Croton Dam, the highest dam at the time of its completion, and still the highest masonry dam in existence, was one of the outstanding engineering achievements of its time. In 1973 the U.S. Department of Interior designated the dam a National Historic Place and in 1975 the American Society of Civil Engineers declared it a National Historic Civil Engineering Landmark.

The main features of the project are a non-overflow masonry dam and a masonry spillway with a stepped downstream face.

The gravity dam is built of rubble masonry and faced with cut blocks of granite. The structure is 1168 feet long with an upstream face that is vertical above El 140 and has an inclination of 7 vertical on 1 horizontal below this level. The downstream face is curved and its slope changes from nearly vertical at the crest to 1 on 1 at the base. The top of the dam is at elevation El 216 ft, the ground level is at El 75 ft and the deepest foundation level is at El 81 ft. The maximum height from deepest foundation level to crest is 297 feet and from finished ground to crest is 141 feet. The width is 18 feet at the crest, 83 feet at ground level and 203 feet at maximum foundation level. Water is released through two gate houses; one is located at the north and the other at the south end of the dam. The crest of the dam carries a public roadway.

A 200 foot bridge, which spans the spillway and spillway channel connects the road from Gate House No. 2 to the right valley wall. A gallery, which runs along the center of the crest below the roadway, collects drainage water from the road and carries it to an outlet near Gate House No. 2. South of Gate House No. 1, a small earth embankment section with a masonry core connects the masonry dam to the left abutment.

The spillway, which is built of rubble masonry and faced with blocks of cut granite, is 1000 feet long and varies in height from about 10 feet at the upstream end to 160 feet adjacent to the dam. In plan, the spillway is composed of a long straight portion near its upstream end and of a curved portion adjacent to the dam. This curved portion of the spillway, which is the highest part of the structure, is concave from the reservoir side; that is, it forms a reversed arch. The crest of the overflow section, which is 950 feet long, is at El 196. The upstream face of the spillway is vertical or nearly vertical while the downstream face has a curved profile formed of 4 to 5 ft wide steps with 6 to 7 foot high risers, except at El 140 feet where the step widens from 5 ft at its upstream end to 47 ft at the dam. The large granite blocks used in the construction of the stepped downstream face and the crest are anchored down to the lower course.

During the 1955 October flood, when 3.84 feet of head was measured over the flashboards (top of flashboards, El 202) cracks developed in the spillway structure and significant quantities of seepage were observed. Repairs, carried out in 1956, included caulking of the upstream face and drilling and grouting the curved portion of the structure near the dam. As a result of the repairs, the seepage through the cracks has decreased significantly. Following the flood, six feet of flashboards and a concrete parapet wall were removed, except for a 50 foot segment near Gate House 2. By removing the flashboards and parapet wall, the crest level was reduced from El 202 feet to the present El 196 feet and the length of overflow section from 1000 to 950 feet. The top rows of stones forming the crest of the overflow spillway have been replaced.

The approximately 60 foot wide spillway channel runs parallel with the masonry spillway structure. The channel, which is excavated into the gneiss forming the right side of the valley, is composed of a series of plateaus and risers.

The tailrace channel is 150 feet wide near the spillway but narrows down to about 80 feet further downstream. The floor and right wall of the channel are of hard and durable gneiss; on the left side, the channel is bordered by a masonry retaining wall. The beginning of the tailrace channel, downstream of the spillway and 48-inch blow-off outlets, is protected by a concrete apron.

During the 1955 flood a portion of the left retaining wall was destroyed and a deep hole eroded in the tailrace channel. To a lesser degree, the concrete apron also became damaged. During the following year, the damaged portion of the wall was re-built and the eroded hole in the front of the wall backfilled with concrete.

The regulating outlets contained in Gate House No. 2 (on the north end of the dam) are composed of three inch diameter blow-off pipes discharging to the Croton River; each blow-off includes an intake sluice gate, a balance valve and an outlet stopcock valve. The intake of the blow-offs is at invert El 99.5 feet. There are 12 inch bypass lines leading from the balance valve chamber to the downstream valve vault with connection to a release fountain that is not in service at present. The bypass line has a metered branch which is for releasing water to the Croton River to serve downstream demands.

Gate House No. 1 is located on the south side of the dam and has a connection to the Old Croton Aqueduct. The regulating facilities in this gate house receive water from three inlets located at the top (El 186) the middle (El 167) and at the bottom (El 100). The gates in this gate house are closed and sealed in the downstream direction but water is released into the upstream portion of the old aqueduct which carries it to the New Croton Gate House, about three miles upstream. The Old Croton Aqueduct is connected to the New Croton Gate House by an 8.5 ft diameter pipe.

The New Croton Gate House, which is the head station of the New Croton Aqueduct, one of the major components of the Water Supply System of the City of New York, receives water from four inlets in addition to the water delivered by the Old Croton Aqueduct. Water is taken here directly from the lake through intakes which have their inverts located at El 184.5, El 166 and El 140 and from an intake located upstream of the Old Croton Dam which has an invert at El 140. The Catskill Aqueduct, another major New York City Water supply line, passes under the New Croton Reservoir. There is a facility for releasing water from the aqueduct into the reservoir, but this facility has not been used for years.

Two 48-inch low level outlet pipes, located in the spillway structure at invert El 53.4, are not operational, since they were plugged with concrete at the end of construction.

It should be noted that the lowest existing intake is at El 100 (blow-offs in Gate House No. 2) whereas the lowest ground level in the reservoir is approximately at El 50. Therefore the reservoir cannot be dewatered completely.

b. Location

New Croton Dam is located on the Croton River about three miles northeast of its confluence with the Hudson River. The dam is a few hundred

yards east of the intersection of Croton Dam Road, which passes over the crest of the dam, with Route 129. The nearest settlement is Croton-on-Hudson, located southeast of and about 2 miles downstream of the dam along Route 129.

c. Size Classification

The dam is 174 feet high and therefore it is classified as "large" dam (over 100 feet high).

d. Hazard Classification

The dam is in the "high" hazard potential category.

e. Ownership

New Croton Dam is owned by the New York City Bureau of Water Supply (BOWS); the operation and maintenance of the dam and related structures are carried out by the Katonah Section BOWS.

f. Purpose of Dam

The dam impounds water for the use of the City of New York and, to a lesser degree, the town of Croton-on-Hudson.

g. Design and Construction History

The dam and its appurtenant structures were designed by the Aqueduct Commission of the City of New York in the early 1890's under the direction of its chief engineer, A. Fteley. The construction contract was awarded to James S. Coleman in 1892. The works started in September of the same year and were completed in 1906.

The south half of the dam was originally designed as an earth dam with a center masonry core wall. During construction, in November 1901, cracks, reportedly resulting from unexpectedly poor foundation conditions, were discovered in the core wall. The earth dam, which had been about half completed, was replaced by a masonry structure similar to the northern section.

h. Normal Operating Procedures

Water is released from the Croton Reservoir either into the New Croton Aqueduct either through the New Croton Gate House or into the Croton River over the spillway. The amount of water released into the New Croton Aqueduct varies between 120 and 450 cfs. The spillway operates 50 to 250 days each year but the amount spilled does not exceed 4000 cfs in an average year.

The reservoir level is kept near spillway crest level (El 196) during most of the year and drawn down about 15-20 feet during the winter months to expose the roots of water weeds to freezing temperatures. This lowering, in addition to the releases into the New Croton Aqueduct, can be accomplished

by opening the blow-offs located in Gate House 2. The 12-inch bypass lines located in Gate House 2 can be used to release water into the Croton River but in recent years this facility was not used since spillage and leakage of the spillway satisfied downstream demands.

1.3 PERTINENT DATA

a.	Drainage Area (square miles)	375
b.	Discharge at Dam Site (cfs)	
	Maximum known flood, October 16, 1955.	
	USGS Gaging Station 0.5 mi downstream, estimated from flood marks	45,400
	Estimated using measured head and spillway discharge relationship	22,600
	Ungated spillway at pool El 206	93,600
	Ungated spillway at maximum pool, El 216	259,400
	Maximum capacity of New Croton Aqueduct and Gate House No. 2 Outlets (Estimated)	1,900
	Total Discharge, at El 206	95,500
	Average daily discharge	280
c.	Elevation (feet above MSL-Croton Datum)	
	Top of dam	216
	Spillway crest	196
	Tailrace channel	50
	Invert of blow-offs at Gate House 2	99.5
	Invert of inlets at Gate House 1 (Connected to New Croton Gate House)	100,167,186
	Invert of inlets at New Croton Gate House	140,166,184.5
	Invert of inlets at Old Croton Dam	154.5
d.	Reservoir	
	Length of pool (spillway crest), miles	9.5
	Length of shoreline (spillway crest), miles	38
	Surface area (spillway crest), acres	2,260
e.	Storage, (acre-feet)	
	Spillway crest	72,990
	At reservoir level 206	96,000
f.	Dam	
	Type: Masonry Gravity	
	Length, ft (including elevated part of spillway)	1,218

Upstream slope: vertical above El 140 and 7 on 1 below El 140.
Downstream slope: varies from nearly vertical at top to 1 on 1 near base

Crest Elevation, feet	216
Crest width, feet	18
Grout curtain:	None, but the south side of the foundation was grouted during construction

g. Spillway

Type:	Ungated-overflow masonry with stepped block-stone facing on downstream side
Length, feet	950
Crest elevation MSL - Croton Datum, feet	196
Crest elevation MSL - Sandy Hook Datum	195.55
Upstream channel	None
Downstream channel	80-150 feet wide Rock or stone side walls, concrete apron in front of Gate House 2. Discharges into Croton River

h. Regulating Outlets

The New Croton Gate House regulates the water released into the New Croton Aqueduct. The location and number of gates, invert elevation of intakes and sizes of outlets are shown on Plate 9. It is understood that the gates at El 165.5 are closed (two are sealed) and are not in use.

The release capacity of the facilities at the New Croton Gate House is approximately 460 cfs.

The water released at Gate House No. 1 is carried to the New Croton Gate House by the Old Croton Aqueduct and it contributes to the flow into the New Croton Aqueduct. The capacity of the facilities feeding at Gate House No. 1 is 290 cfs.

Gate House No. 2 contains three 48-inch blow-off lines, including intake gates, balance valves and stopcock valves. The maximum capacity of the blow-offs was reported to be 1400 cfs at full reservoir (spillway crest level).

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

The design adopted for the New Croton Dam is based on the design prepared for the Quaker Bridge Dam with only minor modifications. The Quaker Bridge site was 1.13 miles downstream of the present New Croton dam. Design analyses made for the Quaker Bridge Dam are contained in Ref. 11. Edward Wegmann's book, Ref. 3, also contains information on the design of New Croton Dam. Ref. 24 reports that the spillway was designed for maximum reservoir elevation of El 206 ft and that no uplift or ice pressure had been considered. The available project drawings do not entirely represent as-built conditions, but the differences are minor.

A number of technical papers, articles and reports contain information on the original design and design changes (References 1, 2, 3, 10, 11, 12, 13, 14, 15, 16 and 17). Stability and design analyses were made by BOWS Design Division and by the engineering firm of Malcolm Pirnie in connection with the repairs carried out following the 1955 flood; these are in the BOWS New York files.

2.2 CONSTRUCTION RECORD

There are no formal construction records but the Aqueduct Commissioner reports (References 1 and 2) describe the construction in considerable detail. Ref. 3, 12, 13, 14, 15, 16, 17, 18, 19, 20 and 21 also contain data on the construction.

Information on maintenance and repairs is contained in the annual reports of the Chief of Engineer of the Department of Water Supply, Gas and Electricity, Ref. 9 and in Ref. 24 and 26.

2.3 OPERATION RECORD

The reservoir level is read and recorded every four hours and the rainfall is recorded daily. The depth of water in the New Croton Aqueduct is continually recorded and the combined inlet gate openings are recorded every four hours. The USGS maintains a gaging station on the Croton River downstream of the dam. No record is kept of the gate openings and releases in Gate Houses 1 and 2. The seepage through the spillway had been measured and recorded for several periods in the past; no measurements are taken at present.

2.4 GEOLOGY AND FOUNDATION

A considerable amount of data related to exploratory work and foundation conditions is contained in References: 1, 2, 5, 7, 10, 12, 13, 14, 16 and 17.

An exploratory program was carried out in connection with the site selection for a large dam on the Croton, between the Hudson and the Old Croton Dam, in the late 1880's. The program included borings and test pits along the river and, at suitable dam sites, across the valley. In 1891, the site was selected for the new dam at about 3-1/2 miles downstream of the Old Croton Dam. Further exploratory work was done using borings and test pits during construction to define the location and extent of zones of weaknesses.

The bedrock in the general area of the Croton reservoir is composed of Precambrian formations of schistose gneiss and pyroxenite; they also contain limestone, marble and amphibolite members. Reference 7 indicates no fault in the vicinity of the dam.

The rock at the dam site on the north side of the valley is hard, competent gneiss, which occasionally contains sheared and fractured zones. On the south side, the bedrock is limestone of variable condition; beds of competent rock alternate with fractured and decomposed layers. In addition to weak zones, the limestone also contains cavities. The largest of these, discovered during construction of the dam, had dimensions of 12 x 14 x 20 feet. The water in the limestone was under artesian pressure; in one instance 90 feet pressure was observed. The dip of the strata both in the gneiss and limestone formations is nearly vertical and strikes perpendicular to the dam. The river valley is filled with alluvial deposits consisting of sand, gravel and cobbles, to a maximum depth of 125 feet. The gneiss outcrops on the north side but the limestone is covered by about 30 feet of surficial deposits on the south abutment. The foundation was excavated to sound rock throughout the foundation area of the dam and spillway.

2.5 EVALUATION OF DATA

Project drawings, hydrologic, reservoir operation and maintenance data have been made available by BOWS New York and Katonah Section Offices. The district and section engineers were extremely cooperative and helpful in providing information and observations.

The data available is considered adequate for the Phase I inspection and evaluation of the project.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS .

a. General

The visual inspection of New Croton dam, spillway and auxiliary structures was made on July 13, 1978. The weather was clear and sunny; temperature in the 70-80° F range. Minor rainfall occurred in the area three days before the inspection; the last significant rainfall occurred nine days earlier. At the time of the inspection the reservoir level was at El 195.6 ft, 5 inches below the spillway crest level.

b. Gravity Dam

The masonry gravity dam structure shows no sign of distress. The horizontal and vertical alignment of the dam appears to be unchanged; there are no significant cracks, erosion or spalling on the downstream face, crest or upstream face exposed above the water.

The small earth dam segment at the south abutment appears to be in good condition. There were no depressions, erosions, cracks, sliding or sloughing observed.

The following adverse conditions were noted:

(A)* Minor seepage was observed in the morning at several locations on the downstream face. The seepage appeared to emerge from joints between facing stones. The seepage decreased considerably or disappeared in the afternoon when the face was exposed to the sun, apparently as a result of evaporation and expansion of the stones and mortar. It was reported that there is a noticeable increase in seepage on the downstream face of the dam during the cold weather of the winter months. Some calcium deposits were also observed on the face of the dam; the calcium was dissolved from the mortar and deposited by minor seeps.

(B)* There is an almost continuous crack along the centerline of the roadway and also there are some minor parallel longitudinal cracks. The concrete pavement has no longitudinal contraction joint. The gallery underneath the roadway has only minor cracks, which do not seem to coincide with the cracks in the pavement.

The locations of the observations marked with an asterisk are shown on Plate 11 by the corresponding capital letters in parenthesis.

(C)* The floor of the drainage gallery is covered with debris, sand, mud and puddles of water, particularly in the south portion where the headroom decreases.

(D) In Gate House Nos. 1 and 2, at the north and south ends of the masonry dam, cracks were observed on the surfaces of the concrete floors and roof beams. Almost all arched beams were cracked at the centerline of the span but the cracks appear to be minor and shallow.

(E) The surface of the earth dam portion is overgrown with vegetation, particularly on the upstream side, which makes visual observations of the surface condition difficult.

c. Spillway

The granite blocks composing the face and crest of the spillway structure are in good condition. Some minor cracks were observed but these are mostly limited to joints between stones. There are no visible indications of deformations, changes in alignment, tilting, differential movements and sagging. The structure appears to be well maintained.

The following observations of adverse nature were made:

(F)* Seepage emerges on the downstream face of the spillway at various levels and locations. The seepage appears to be concentrated on the high, curved portion of the structure near the gravity dam.

(G)* Debris and vegetation are evident on the structure at various locations, but a considerable amount of these were observed on the wide platform on El 140.

d. Spillway and Tailrace Channels

The floor and right wall of the spillway and tailrace channels are formed by excavated rock surfaces. The gneiss at this location is hard and resistant to erosion. The rock formation, however, contains some weaker, fractured zones and some minor shear zones. Past floods have eroded the weaker portions of the rock to variable depths, making the channel surfaces uneven. The left side of the spillway channel is formed by the masonry spillway structure itself and the left side of the tailrace channel by a masonry retaining wall. Both the spillway and the retaining wall are in good condition.

Unfavorable conditions observed are as follows:

(H)* Debris, trees and shrubs were found in the upper portion of the spillway channel.

(I)* Deep, eroded pockets and grooves are present at some locations in the spillway channel. There are also some eroded troughs and pockets at the toe of the structure.

(J)* Some seepage appears to emerge at the contact of the masonry structure and its foundation along the spillway channel.

(K)* The concrete apron downstream of the spillway channel and Gate House No. 2 blow-offs suffered moderate damage (cracks, eroded portions).

(L)* The floor of the tailrace channel is irregular; there are a number of deep depressions and also large pieces of eroded rocks are deposited there. There is some undermining at the downstream end of the concrete apron.

e. Regulating Outlets

The regulating facilities in the New Croton Gate House are well maintained and are in good operating condition. There is an emergency standby gasoline engine-generator set which is automatically tested once each week.

Gate House No. 1 (South) is rarely visited by maintenance and operation personnel; although its door is welded shut, it is vulnerable to vandalism. Observations:

(M) Gate stand surfaces have extensive paint peeling and some rusting.

(N) Gate stems and gears need lubrication.

(O) There are stoplog grooves at each gate chamber, but no stoplogs are stored at the dam site.

(P) Some of the roof and floor grating panels were broken and missing. The floor is strewn with debris.

Gate House No. 2 (North) contains the three 48-inch blow-off pipes which are the primary means of lowering the reservoir. The following are observed in connection with this equipment:

(Q)* The sluice gate of the north blow-off pipe was open and hung with the operating stand removed. The balance valve was closed and said to be operable but leaking.

The stem of the sluice gate of the middle blow-off pipe was in the raised position (open about 58-inches) and bent about 4 inches out of vertical alignment at the top. The balance valve was said to be operable but leaking.

The sluice gate of the south blow-off was closed, had a bent stem and was unoperable. The balance valve was reported to be operable but leaking.

(R)* The stopcocks located in the lower vault were either wet or leaking at the stem glands. The stands and gate housings had peeling paint and were rusty.

(S)* Because of the leakage at the balance valves, the stopcocks cannot be fully dewatered and consequently cannot be balanced. For this reason six men are said to be required to operate each valve which results in overstressing the gears and other components.

The branch valve and meter of the 12-inch bypass line, which is protected by a cover plate, is reported to be in operational condition.

(T)* At the discharge fountain, five nozzles were missing and the overflow outlet cover had been dumped into the outlet pit.

(U)* Past observations show and Reference 10 suggests that the water jet from the south blow-off can damage the retaining wall located in the left side of the tailrace channel.

f. Reservoir Area

There were no slides, rockfalls or other signs of instability noted in the vicinity of dam spillway or gatehouses.

3.2 EVALUATION OF THE OBSERVATIONS

The deficiencies described in the previous paragraphs did not indicate hazardous conditions under the circumstances prevailing during the inspection. Some of the deficiencies can be either tolerated or corrected by the maintenance forces. A number of the deficiencies observed, however, may lead to further deterioration; therefore, these deficiencies need to be corrected.

The more significant observations related to deficient conditions which require more than routine maintenance work are the following:

The seepage through the spillway and its foundation (Observations (F) and (J)) indicate a somewhat damaged condition of the structure resulting from the 1955 flood. The seepage suggests the presence of cracks and water pressures of unknown distribution inside of the structure. At freezing temperatures, seepage water may cause frost damage.

The irregular surface of spillway and tailrace channels (Observations (I), (L) and (K)) decreases the hydraulic efficiency of these features and causes increased vibrations when these channels are carrying flood waters.

The proper functioning of the blow-offs are essential when rapid lowering of the reservoir is required (Observations (Q), (R), (S) and (U)).

Recommendations concerning the correction of the deficiencies are given in Chapter 7.2.

SECTION 4 - OPERATION AND MAINTENANCE PROCEDURES

4.1 PROCEDURES

Water is released continuously from the New Croton Reservoir into the New Croton Aqueduct. The amount of this release varies between 270 and 420 cfs. The water is taken in through inlets located at different levels at the New Croton Gate House and at Gate House No. 1. The selection of intake level to be used is based primarily on the level of fish in the lake.

The reservoir is kept near the level of spillway crest during most of the year, except for the winter months when the water level is lowered by 15-20 feet to expose the roots of mill-foil, a water-weed, to freezing temperature.

Inasmuch as the 12-inch bypass line in Gate House 2 and its metered branch discharge line have not been used in recent years, it appears that the spillway discharge and leakage satisfy the downstream needs along Croton River.

4.2 MAINTENANCE OF DAM AND SPILLWAY

The dam, spillway and appurtenant structures are maintained by the forces of the Katonah Section of the BOWS. The area immediately downstream of the dam, where the release fountain is located, is a park which is owned and maintained by the county. A watershed inspector visits the dam frequently and the Section and District Engineers visit periodically and at other times when the inspector reports an unusual observation. There is no established program for inspections and there are no operation and maintenance manuals for the project.

Vandalism appears to be a serious problem. Attention, time and resources of the operation and maintenance forces are diverted and they may not be able to sufficiently observe and correct deficiencies brought by natural causes.

4.3 MAINTENANCE OF OPERATING FACILITIES

The New Croton Gate House is attended at all times and the facilities are operational and well maintained.

The doors of Gate House No. 1 are welded shut to prevent vandalism; this makes periodic inspection, repair and operation cumbersome. The facilities, although mostly operable, are not regularly maintained.

4.4 WARNING SYSTEMS

There are no warning devices installed at any of the project features but the frequent observations and recording by the attendants who are on duty 24 hours a day at the New Croton Gate House and also the observations at the USGS gaging station could provide warning to the operators in case of sudden rise of reservoir level or spillway discharge. There are no measuring instruments of any kind at the dam and spillway.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 DRAINAGE AREA CHARACTERISTICS

The New Croton Reservoir is located on the Croton River and has a total drainage of 375 square miles. The basin is roughly rectangular in shape, with its north-south axis approximately twice as long as the east-west axis. The basin consists of steep hills running in a general north-south direction, interspersed with flat valleys containing lakes, reservoirs and swamps. These lakes and swamps are believed to provide a substantial storage capable of modifying peak runoffs.

5.2 SPILLWAY CAPACITY

New Croton Dam has a side channel type spillway, with its crest at El 196.0 feet, and a length of 950.0 feet. The flat crest is 7.0 ft. wide followed by a stepped downstream face. The capacity at a head of 10.0 ft., which is reported to be the design head (Reference 24), is estimated to be 93,600 cfs (60.5 bgd). The maximum head possible between the spillway crest and the top of the dam is 20.0 feet, at which the estimated spillway discharge is 259,400 cfs. Data is available on the head-discharge relationship of the spillway; up to a head of 3.0 feet. The spillway rating table, which is shown in the Appendix, has been computed on the basis of the assumption that the spillway would act as a broad-crested weir up to 6.0 feet head, and as a sharp-crested weir above 6.0 feet head.

5.3 RESERVOIR CAPACITY

The total reservoir capacity at the spillway crest is 23,780 million gallons (72,990 acre-feet). The storage capacity curve, based on a table furnished by BOWS, is shown in the Appendix. The capacity curve has been extrapolated to an elevation corresponding to the top of the dam and indicates a surcharge storage of approximately 32,000 acre-feet, which is equivalent to a runoff depth of almost two inches over the drainage area.

5.4 FLOODS OF RECORD

The greatest floods in the Croton River Basin, in the last 80 years, were in August and October 1955. Indirect discharge measurements taken at the Croton River gaging station, downstream from the dam, indicated a peak flow of 45,400 cfs in October. Water level measurements, made every four hours, furnished by the City of New York, Department of Water Supply, indicate that a maximum head of 4.0 feet over the spillway may have occurred on October 16. It is noted that there appears to be an inconsistency between the USGS estimate of 45,400 cfs flow, which would correspond to a head of

5.9 feet, and the measured head, which would correspond to a computed flow of only 22,600 cfs (assuming the then flashboard equipped spillway acted as a sharp crested weir).

The records of precipitation, taken at the dam, indicate that 8.76 inches fell during the period October 14-16, with 6.1 inches falling on the 15th.

5.5 OVERTOPPING POTENTIAL

The computed design capacity of the New Croton Dam spillway (at 10.0 feet head) of 93,600 cfs given in Paragraph 5.2 has been compared with generalized flood criteria as explained below. A Probable Maximum Flood (PMF), for the 375 square mile drainage area of 220,000 cfs was obtained from maps of Probable Maximum Flood Potential for selected sizes of drainage areas (Reference 28). The PMF inflow is 2.35 times the design capacity, but would not overtop the dam as the head required to pass a discharge of this quantity is estimated to be 17.87 feet.

A second criterion for evaluating a design flood is the Standard Project Flood (SPF). Derivations of the SPF in the Lower Hudson Basin are available in a report made for the U.S. Corps of Engineers (Reference 29). Data in this report indicated that the SPF potential was 250 cfs per square mile or 93,800 cfs for the total drainage area. This discharge requires 10.02 head and is essentially equal to the design and outflow capacity.

5.6 EVALUATION

Since the New Croton Dam spillway is capable of passing the estimated SPF inflow peak, computed on the basis of the guidelines supplied by the U.S. Corps of Engineers, it is considered to be adequate from a hydraulic and hydrologic viewpoint.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations

Visual observations of the gravity dam did not indicate any condition which would adversely effect its safe functioning or structural stability. The masonry dam showed only insignificant cracks and minor seepage.

The facing stones of the spillway are sound but seepage appears at several locations on its stepped downstream face. While the seepage indicates the presence of cracks, the quantity of the seepage suggests that the size of the cracks is relatively small. At reservoir levels below or slightly above spillway crest level the structure is expected to be stable.

b. Design and Construction Data

A design report containing design analyses had been prepared for the Quaker Bridge Dam; this design was later adopted for the New Croton Dam. No original design analyses or computations were found for the spillway. References 24 and 27 report that the spillway was designed for a reservoir elevation of El 206 without considering seepage forces. The effects of vibrations were not considered in these analyses. Data on the construction is contained in the following References: 1, 2, 3, 12, 13, 14, 15, 16, 17, 18, 19, 20 and 21.

There were some cracks observed in the spillway structure after construction but these were minor and the seepage was negligible. During the 1955 flood the spillway structure was subject to high reservoir head and violent vibrations. As a consequence, cracks and substantial seepage developed. Most of the cracks were vertical and normal to the curvature, but some were inclined or horizontal. Some horizontal displacement had also been observed. Following the flood, the crest level was lowered and the spillway repaired by caulking the upstream face and grouting the damaged portions of the gravity structure. Following the repairs, the quantity of seepage decreased significantly. The Department of Water Supply, Gas and Electricity and the engineering firm of Malcolm Pirnie performed conventional, two dimensional sliding and overturning analyses using various uplift assumptions for the modified (present) spillway section; these analyses indicated that the stability was adequate. The results of these analyses showed that, at certain loading conditions, the resultant fell outside the middle third.

c. Operating Records

The reservoir operation record shows that the spillway releases water for 50 to 250 days a year, but the depth of water over the spillway crest is usually a few inches and it seldom exceeds 1.0 - 1.5 feet. The maximum spillway discharges occurred during August and October 1955. At 8 and 12 a.m. on October 16, 1955 the measured head over the spillway crest was 3.84 feet corresponding with an elevation of 205.84 feet.

d. Post Construction Changes

The spillway level was lowered from El 202 to El 196 by removing the wooden flashboards and concrete parapet wall and by changing the cap stones forming the overflow crest. This was done for the entire length of spillway with the exception of a 50± feet long section adjacent to Gate House No. 2 where a four foot high concrete wall remains, reducing the length of the overflow portion from 1000 feet to 950 feet. The purpose of this wall segment is to divert the overflow jet from the wall of the gate house and to reduce the possibility of damage to the bridge by the overflow.

e. Seismic Stability

The dam is located in seismic Zone 1, therefore, no seismic analyses are warranted.

SECTION 7 - ASSESSMENT/RECOMMENDATIONS

7.1 DAM ASSESSMENT

a. Safety

The Phase I investigation of New Croton Dam and appurtenant structures did not indicate conditions which are considered to be unsafe at the present time. On the basis of prior performance as well as engineering judgement, the non-overflow masonry dam is considered to be stable. Although the masonry spillway appears to be stable under normal operating conditions, there is evidence that under severe flood conditions the curved portion of the spillway has been damaged in the past and may be again subject to severe damage.

The discharge capacity of the spillway is considered to be adequate from a hydraulic point of view only, for the estimated Standard Project Flood of 93,800 cfs. The estimated Probable Maximum Flood of 220,000 cfs could be discharged over the spillway with overtopping the dam, if the spillway were structurally adequate.

During the October 1955 flood, when the highest pool level was measured at El 205.84 and may have been as much as El 206±, substantial damage occurred to the spillway. Although flashboards were removed and the spillway modified, the estimated pool level under the Standard Project Flood of 93,800 cfs would be at approximate El 206. Inasmuch as the "full scale test" of the spillway in October 1955 proved unsatisfactory, it is likely that operation of the spillway under the same head, but with substantially greater discharge, would again cause severe damage to the structure.

The development of damage during the October 1955 flood may be explained as follows: the spillway structure, which is built in the form of a reversed arch, was exposed for nearly four hours to unusually high head and strong vibrations. (Reference 27 reports that violent vibrations of the whole structure were observed). Cracks, mostly tension cracks, developed and pulsating water pressures propagated along the cracks inside of the structure reducing its resistance to further cracking. Observations indicate that some horizontal sliding also occurred. The vibrations could have been caused by turbulent flow in the spillway channel, as well as by the waterjet landing on the steps of the downstream face. In the spillway channel, the overfall jet was forced to turn 90 degrees at the toe of the structure and then flow along the curved channel, the floor of which is composed of roughened steps.

In the event of the Standard Project Flood (Discharge: 93,800 cfs) the water level over the spillway would be close to the 1955 levels.

Vibrations resulting from the greater discharge could be worse than those experienced in 1955. The Probable Maximum Flood (Discharge: 220,000 cfs) would create a head of 17.87 feet over the spillway resulting in a pool of El 213.87 feet - well above the 1955 levels. The consequences of such flood cannot be predicted.

b. Adequacy of Information

The information related to the design, construction, modifications, repair and performance of the gravity dam and spillway structures is adequate for the Phase I investigation.

For the proper operation and maintenance of the structure the following items would be required:

a. Up-to-date project drawings

b. Operation and maintenance manuals

c. Inspection schedule and record of inspections

d. Program of performance monitoring and schedule for the monitoring

e. Systematic seepage measurements

c. Urgency

There is no assurance that a major flood will not occur during the next few years; therefore, additional investigations recommended below should be carried out on priority basis.

d. Need for Additional Investigations

The spillway structure is not considered unsafe under normal operating conditions; however, its performance would be questionable during severe floods. It is therefore recommended that additional investigations be performed to assess the structural adequacy of the spillway to discharge the Standard Project Flood.

The additional investigations should satisfy but not be limited to the requirements of the appropriate sections of Chapter 4 of the Recommended Guidelines for Safety Inspection of Dams. The investigations should include stress-deformation analyses of the structure under dynamic loading conditions and consider three dimensional and tension effects. The investigations should also include periodic and systematic measurements of seepage, horizontal and vertical deformations, changes in inclinations of the structure and also a detailed examination of the hydraulic performance of the spillway and its channel. Other investigations may be

considered, such as vibration measurements on the spillway structure during yearly floods or determining its dynamic response characteristics by induced vibrations. The placement of permanently installed vibration recording devices and piezometers, possible dynamic response types, may be considered.

More refined hydrologic studies should be made to obtain a more reliable estimate of the Standard Project Flood and the Probable Maximum Flood. These studies should consider the exact characteristics of and consider the effects of possible future changes in the characteristics of the Croton watershed.

7.2 REMEDIAL MEASURES

No remedial measures are recommended at the present time; however, the need for either strengthening or otherwise modifying the spillway should be based on the results of the additional investigations.

The following measures are recommended:

a. The spillway and tailrace channels should be cleared and their surface made smoother by removing loose rocks and filling depressions with concrete. The apron downstream of the spillway should be repaired.

b. The gates and valves of the three blow-offs in Gate House No. 2 should be repaired or replaced. These facilities are essential for lowering the reservoir. In connection with the repair of the low level outlet facilities the relocation of the left tailrace retaining wall may be considered. Reportedly, this wall is subject to damage when the south blow-off is operated.

c. On the basis of meteorological predictions, early flood warnings should be obtained regularly. When the occurrence of a severe flood is anticipated, the reservoir level should be lowered.

d. A program of measurements in connection with the structural performance of spillway should be established. The program should include seepage measurements, placing of surface reference points and the measurements of the movements of these by precise survey, installation of joint meters and inclinometers. Measurements of this nature should be taken regularly but particularly before, during and after flood seasons and during and after yearly floods. It is recommended that vibrations of the spillway and its foundation be recorded by portable devices during yearly floods.

e. Repair cracks in the roadway on the crest of the dam.

f. Clean the drainage gallery located below the roadway in the dam.

g. Remove vegetation from the earth dam.

h. Remove debris and vegetation from spillway channel.

i. Clean debris from Gate House No. 1 and service (cleaning, painting, greasing) the equipment.

j. Check for proper alignment and adequacy of stem guide brackets of all gates in the New Croton Gate House. Rehabilitate stem guide brackets for Gate No. 24.

k. Improve safeguards against vandalism.

DRAWINGS

APPENDIX A

List of Drawings and Sketches Reviewed in Connection with Phase I Investigation of New Croton Dam

1. City of New York Department of Water Supply, Gas and Electricity - Map Showing Sources of Water Supply, September 1956

Drawings Contained in the Aqueduct Commissioners Report of 1887-1895, Reference 1

2. Watershed of the Croton River, Section of the New Croton Dam Reservoir; Profile and Plan of the New Croton Aqueduct - Sheet 1

3. Topographical Map of the Croton Watershed - Sheet 2

4. Map Showing the Croton Watershed and Subdivisions - Sheet 3

5. New Croton Dam at Cornell Site - Contour Plan of Dam, Sheet 21

6. New Croton Dam at Cornell Site - Downstream Elevation, Sheet 22

7. New Croton Dam at Cornell Site - Section of Gravity Dam, Sheet 23

8. New Croton Dam at Cornell Site - Section of Dam and Gate Chamber - Sheet 24

9. New Croton Dam at Cornell Site - Section of Earth Dam, Sheet 25

10. New Croton Dam at Cornell Site - Sections of Spillway, Sheet 26

11. The Aqueduct Commissioners General Map of Dam Sites Investigated in 1888-1891 - Sheet 27

12. The Aqueduct Commissioners Cross Sections of Croton Valley at Dam Sites - Sheets 28 and 29

13. New Gate House at Old Croton Dam - Sheet 30

14. The Aqueduct Commissioners Dams, New York City Water Works, Sections - Sheet 41

15. The Aqueduct Commissioners 48-inch Standard Stopwatch Valves - Details - Sheet 68

Drawings contained in the Aqueduct Commissioners Report of 1895 to 1907, Reference 2

16. Old Croton Aqueduct, Reconstruction of Submerged Portion Between Old and New Croton Dams, Sections - Plate 77

17. New Croton Dam, Contour Plan - Plate 78

18.* New Croton Dam, Sections of Overfall and Spillway - Plate 79

19.* New Croton Dam, Sections of Earth Dam - Plate 80

20.* New Croton Dam, Plan - Plate 81

21.* New Croton Dam, Downstream Elevation - Plate 82

22.* New Croton Dam, Sections of Spillway and Dam - Plate 83

23. New Croton Dam, Sluice Gates - Plate 84

24. New Croton Dam, Sluice Gate Structures - Plate 85

25. New Croton Dam, Balanced Valves - Plate 86

26. New Croton Dam, Flashboard Equipment on the Spillway - Plate 87

27. Quaker Bridge Dam - Sections Used in Design Analyses - Plates 88, 89 and 90

28. New Croton Reservoir - Plan - Plate 73

29. New Croton Dam, Maximum Section at Station 6+38 - No. 293

30.* New Croton Gate House - Plan - No. 39509-2

31. New Croton Gate House - Plan, Sections, Data - No. 17810

* Drawings reproduced in this report

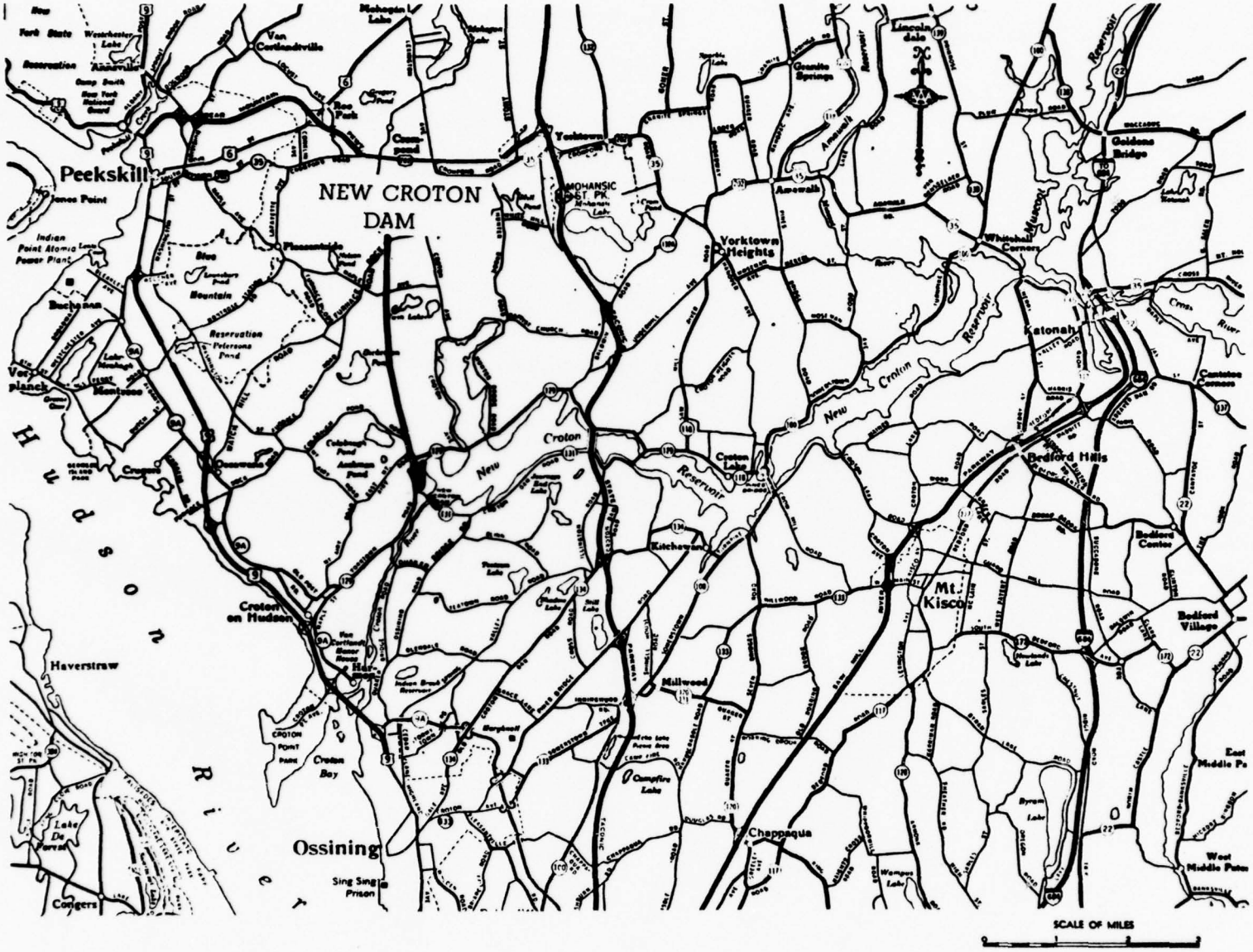
32*. New Croton Dam - Gate House No. 2 - Plan and Sections - No. 17811

33*. New Croton Dam - Gate House No. 1 - Plan and Sections - No. 17812

34. New Croton Dam - Sketch Showing Gate Arrangement and Numbering in Gate House No. 1

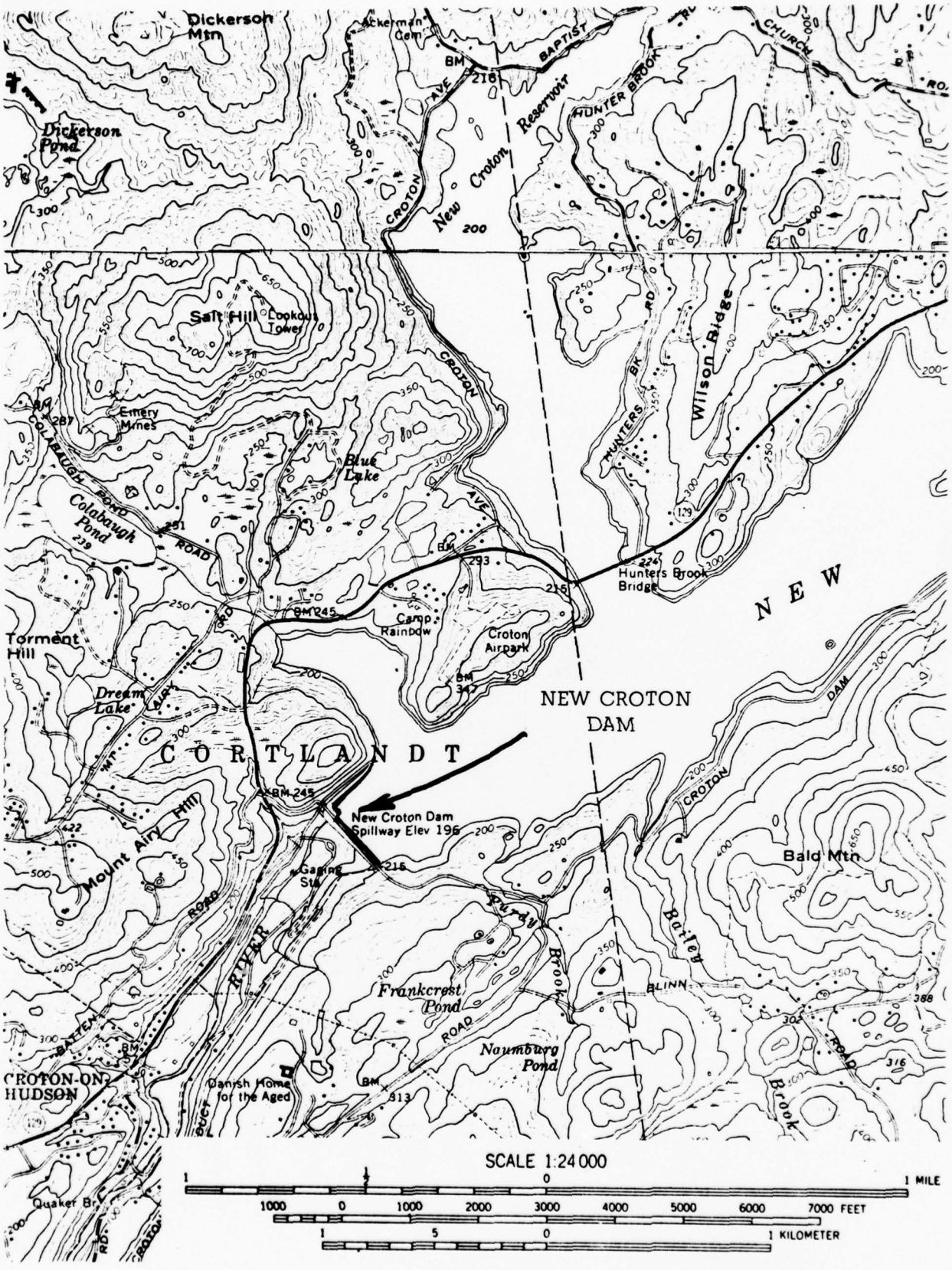
35*. Plans and Sections of the New Croton Gate House, Gate House 1, New and Old Croton Aqueduct (1947)

36. New Croton Aqueduct and Gate House, Depth Gage (1945)



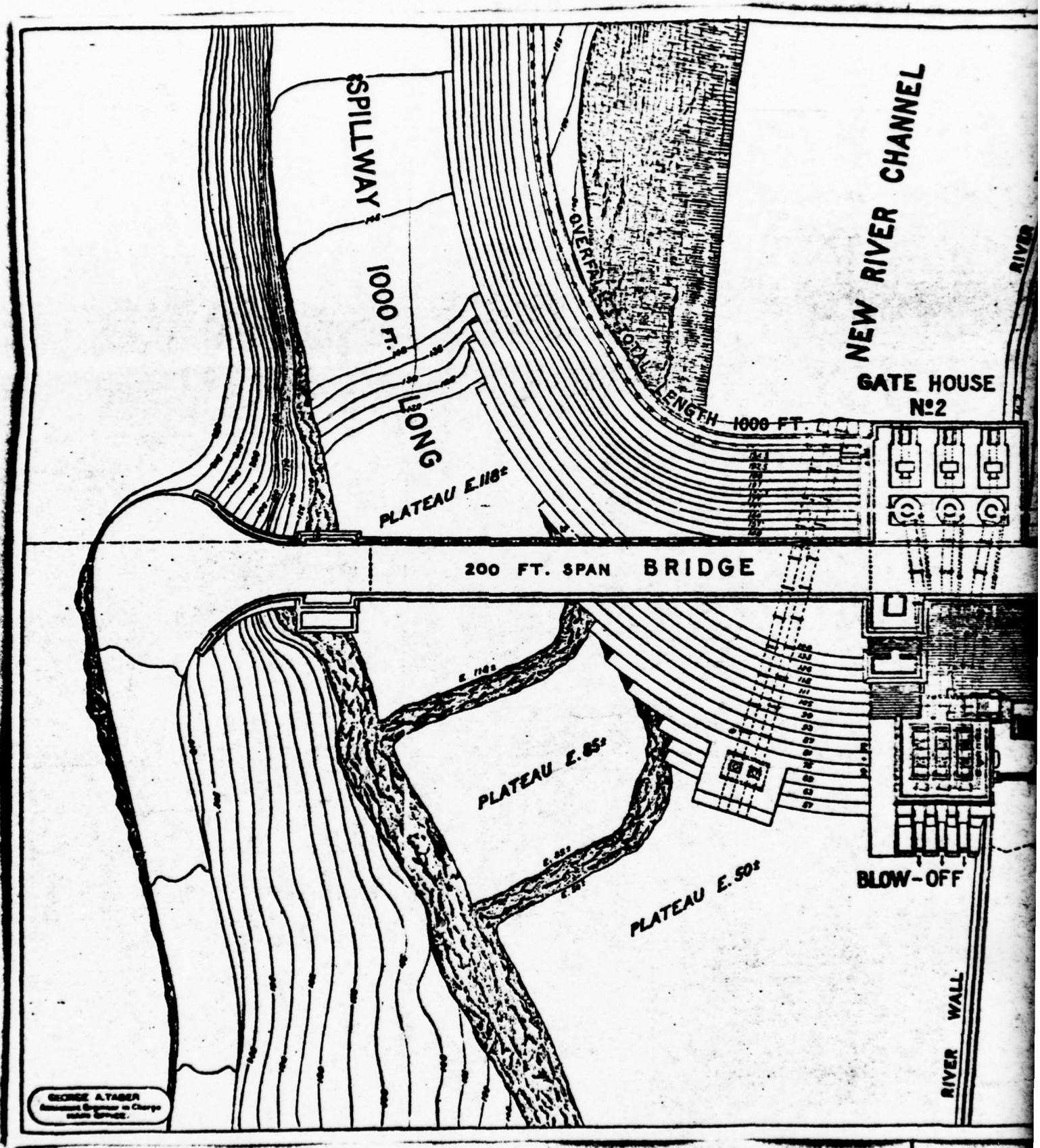
VICINITY MAP
NEW CROTON DAM

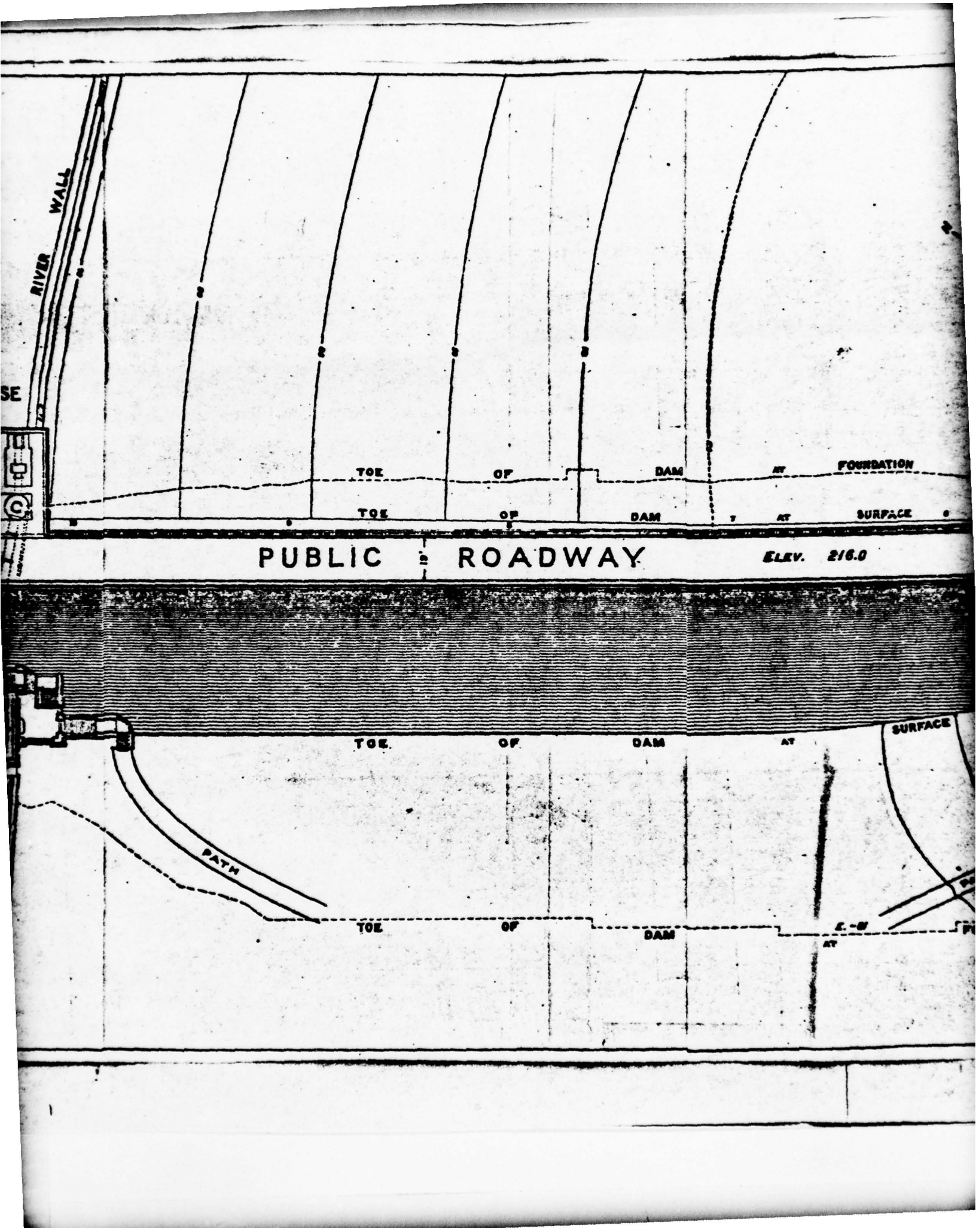
PLATE NO. 1

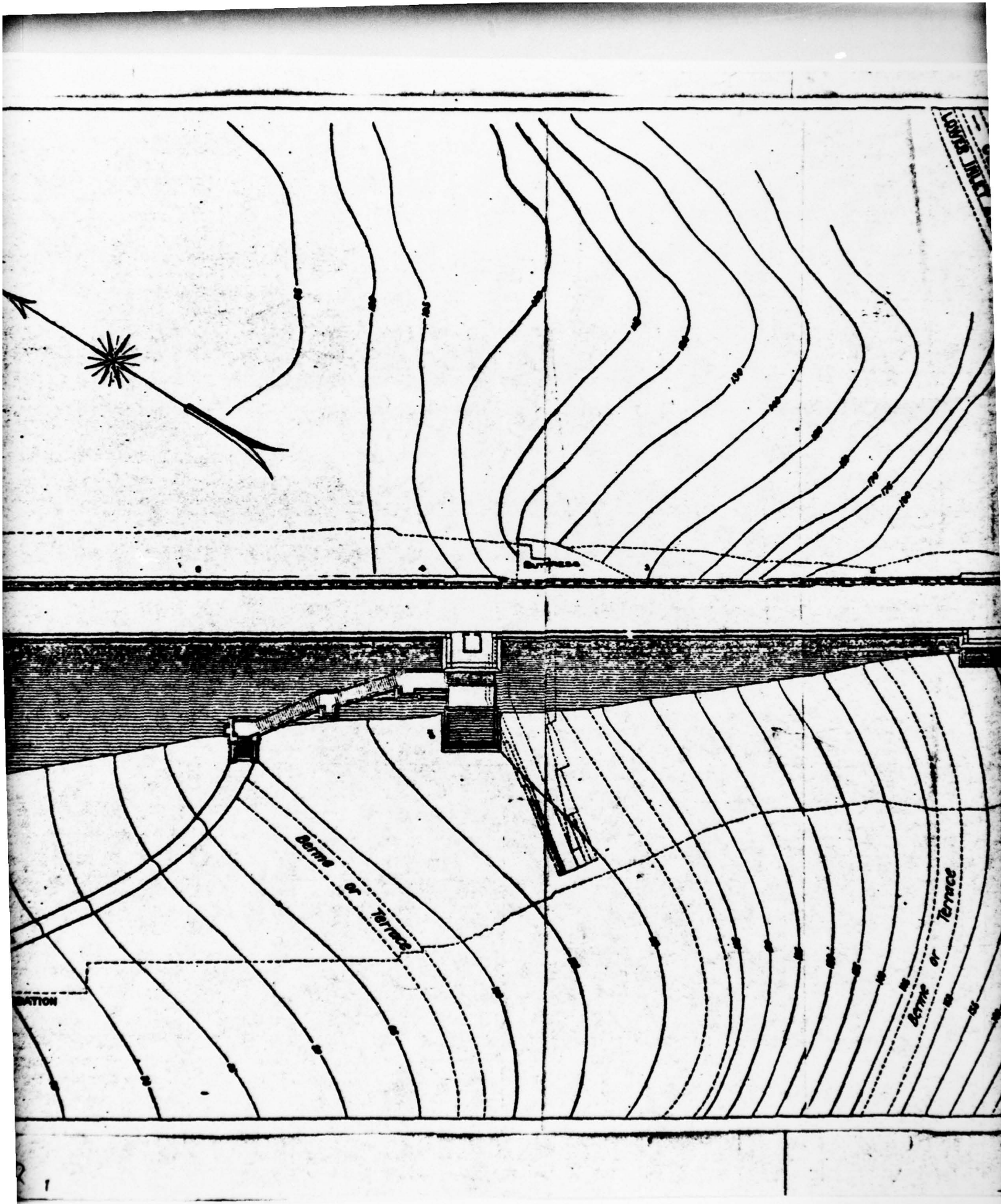


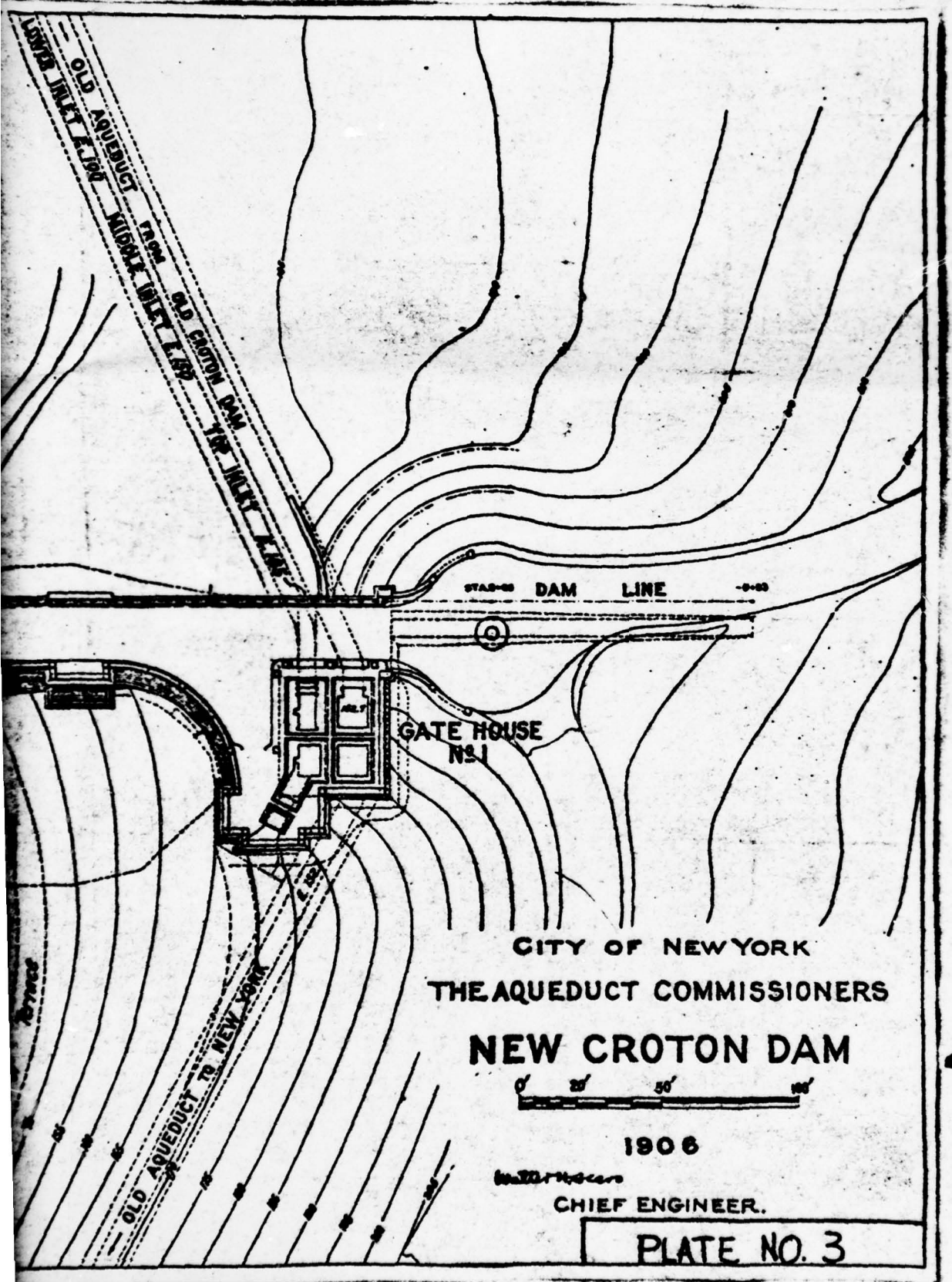
TOPOGRAPHIC MAP
NEW CROTON DAM

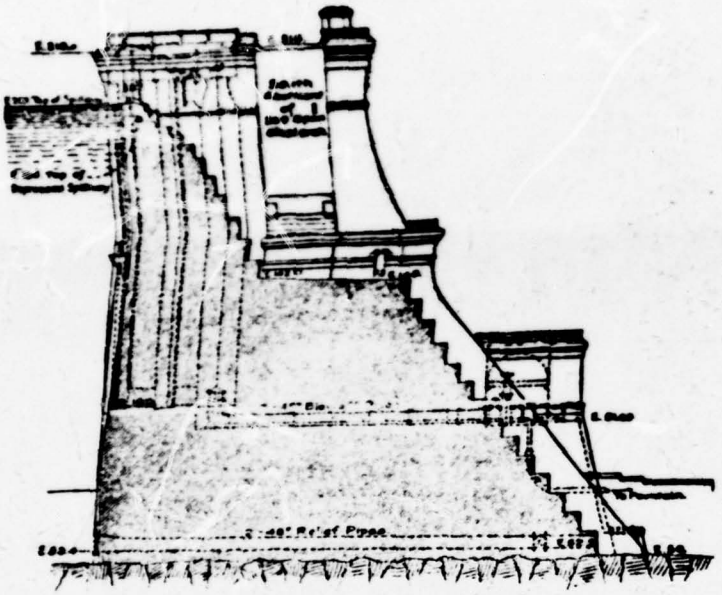
PLATE NO. 2


SPILLWAY
1000 FT. LONG
OVERFLOW CREST LENGTH 1000 FT.
NEW RIVER CHANNEL
GATE HOUSE
Nº2
PLATEAU E.118±
200 FT. SPAN BRIDGE
PLATEAU E.85±
PLATEAU E.50±
BLOW-OFF
RIVER WALL


RIVER WALL
SE
TOE OF DAM AT FOUNDATION
TOE OF DAM AT SURFACE
PUBLIC ROADWAY
ELEV. 216.0
TOE OF DAM AT
SURFACE
PATH
TOE OF DAM AT


LOWER INLET
Berme or Terrace
Berme or Terrace
Berme or Terrace

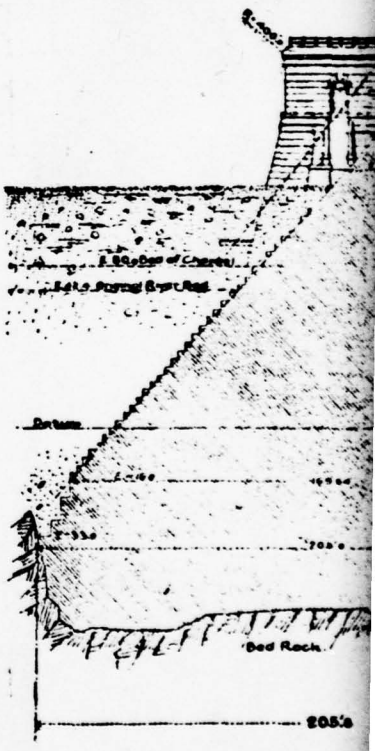

OLD AQUEDUCT FROM OLD CROTON DAM
LOWER INLET E.L.190 MIDDLE INLET E.189 TOP INLET E.187
STA 0+00 DAM LINE 0+00
GATE HOUSE No. 1
OLD AQUEDUCT TO NEW YORK
CITY OF NEW YORK
THE AQUEDUCT COMMISSIONERS
NEW CROTON DAM
0' 25' 50' 100'
1906
CHIEF ENGINEER.
PLATE NO. 3



SECTION THROUGH SPILLWAY.

LOOKING SOUTH.

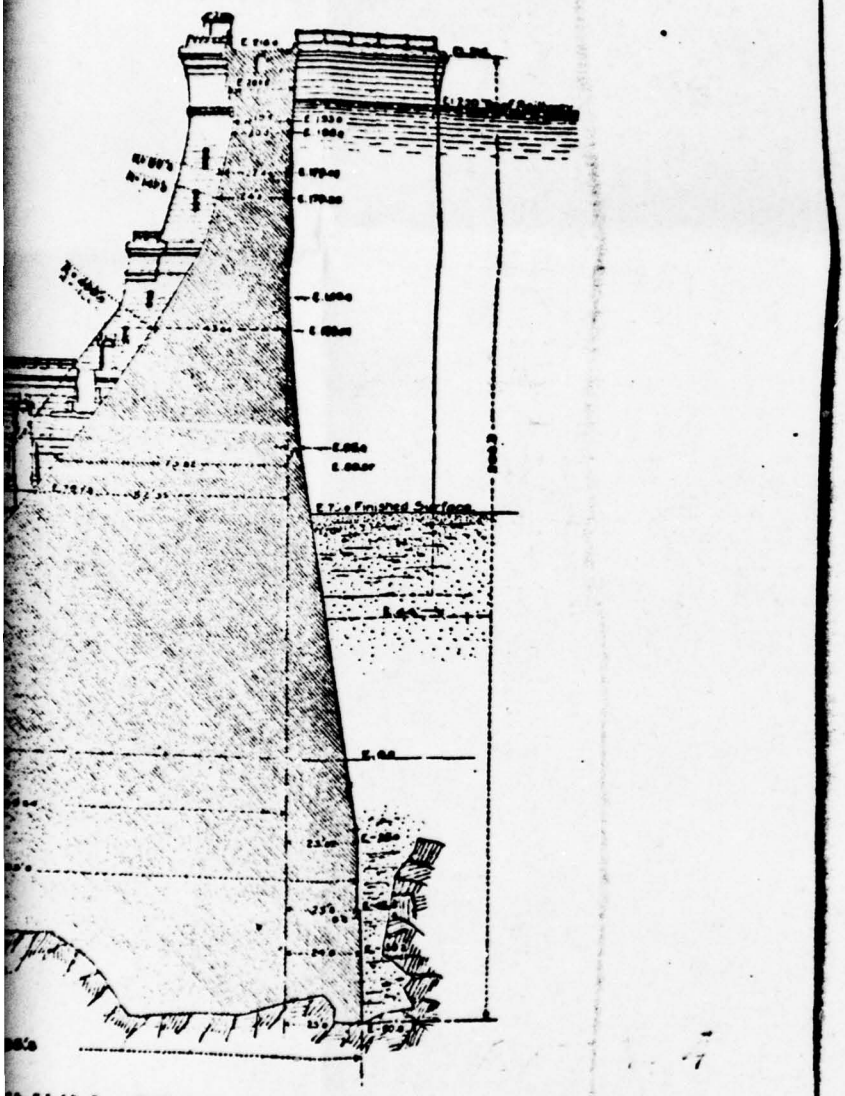
SCALE.



MAXIMU

AT

LOO



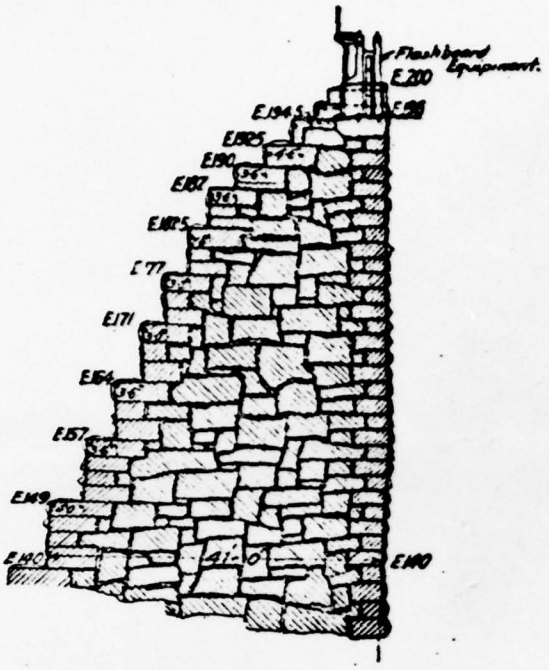
IMUM SECTION
AT STA. 6+38.
OOKING NORTH.

SCALE.

CITY OF NEW YORK
THE AQUEDUCT COMMISSIONERS
SECTIONS OF NEW CROTON DAM
SCALE AS GIVEN
DECEMBER 1906.

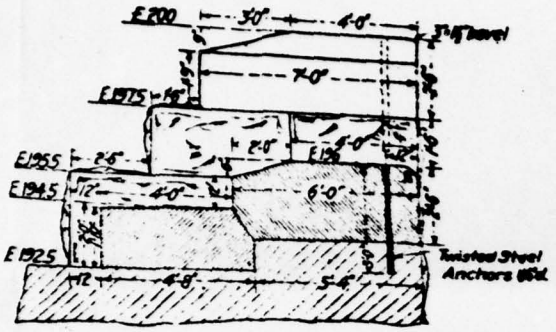
Walter H. Sears
CHIEF ENGINEER.

PLATE NO. 4

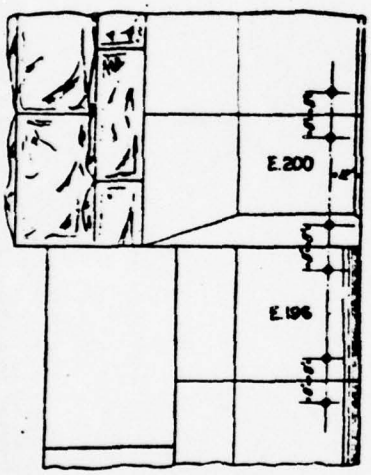


SECTION AT N. END OF
DEPRESSED SPILLWAY

SECTION NEAR JUNCTION WITH DAM.



DETAIL OF WEIR STONES



PLAN

0 1 2 3 4 6 8

City of New York.
The Aqueduct Commissioners.

NEW CROTON DAM

SECTIONS OF

OVERFALL AND SPILLWAY

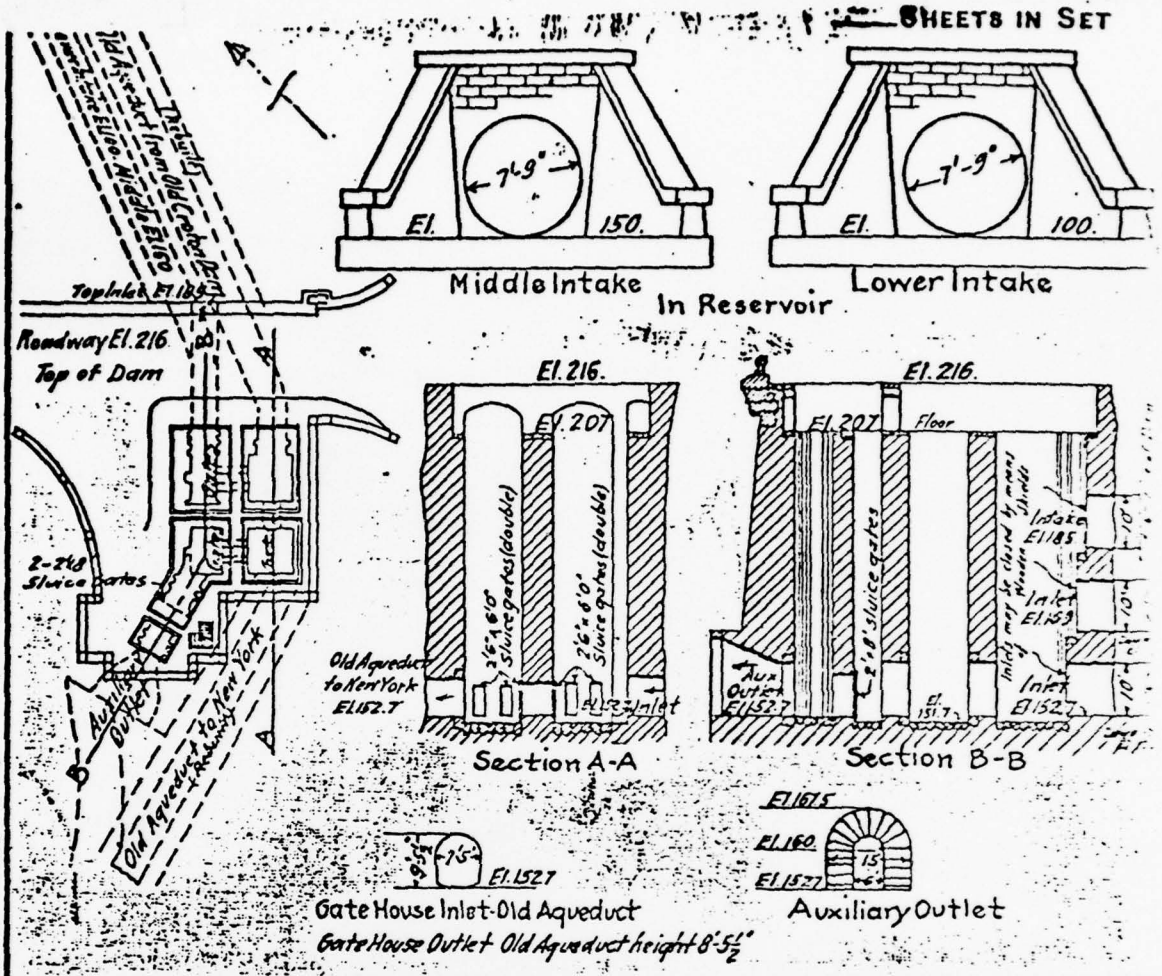
AUG. 1907

CHIEF ENGINEER

PLATE NO. 5

2

SHEETS IN SET



Inlets			Outlets			Gates			Stopcocks			Remarks
Number	Shape and Dimension	Elevation of Invert	Number	Shape and Dimension	Elevation of Invert	Number	Size	Elevation of Invert	Number	Diam	Elevation of Invert	Elevation Spillway 200. El. Flashboards 202 The 2'6"×6'0" sluice gates are double, ie. placed on each side of gate way Take notice that the Lower and Middle Intakes in Reservoir run upwards to the Gate House Inlets.
1	eliptical	185.	1	Old Aqueduct	152.7							
1	eliptical	169.				12	2'6"×6'0"	152.7				
1	eliptical	152.7										
1	Old Aqueduct	152.7	1	Auxiliary	152.7	2	7'×8'	152.7				
	See above for diagram			see above for diagram								

CITY OF NEW YORK

THE AQUEDUCT COMMISSIONERS

DATA ON CROTON WATERWORKS

NEW CROTON DAM

GATE HOUSE No 1.

PLATE NO 6

ACCESSION NO.

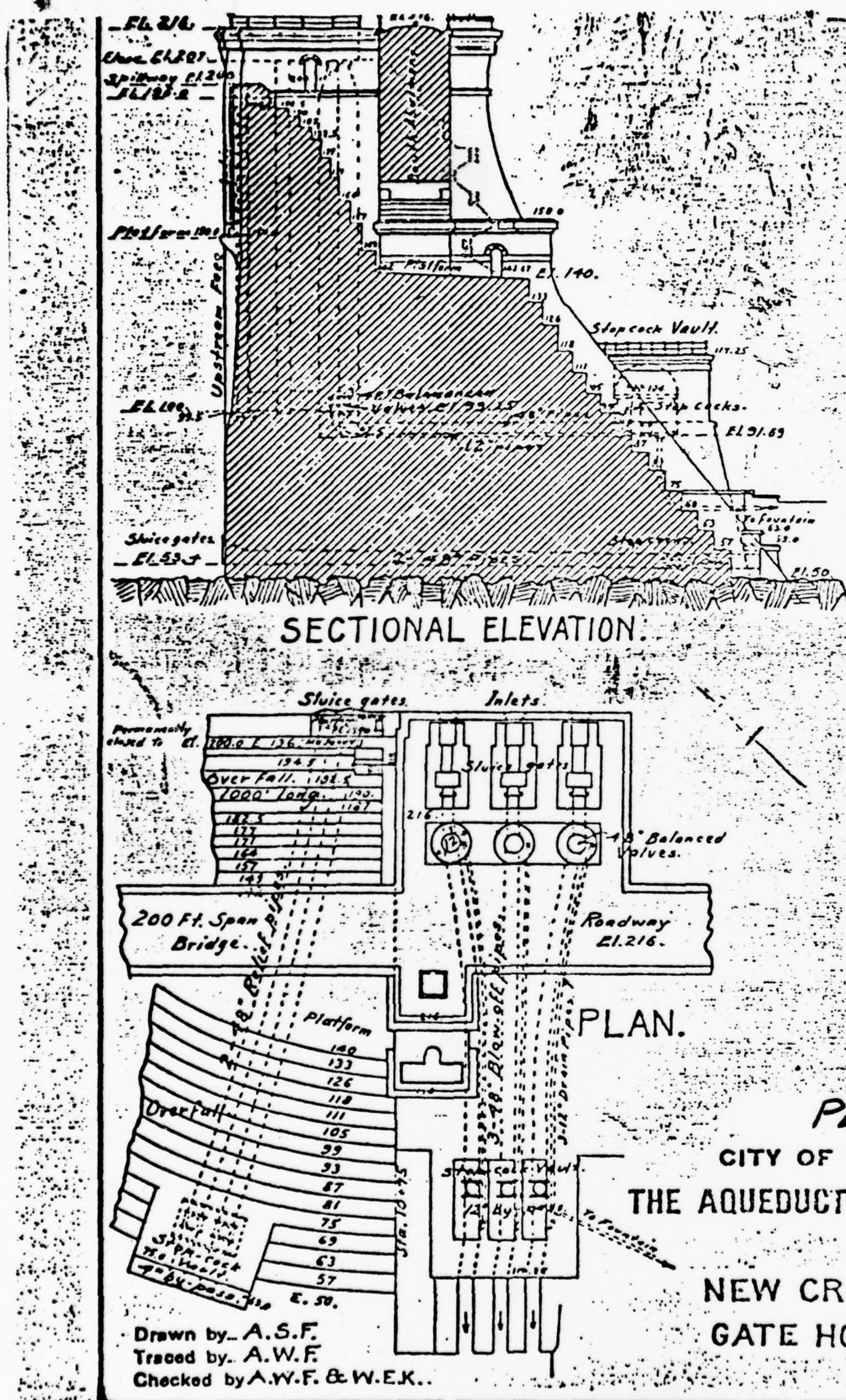
Drawn by A.S.F.

Traced by S.F.

Checked by

CASE DRAWER SECT. 17

____SHEETS IN SET



Inlets: Number	Inlets: Shape and Dimension	Inlets: Elevation of Invert	Outlets: Number	Outlets: Shape and Dimension	Outlets: Elevation of Invert	Gates: Number	Gates: Size	Gates: Elevation of Invert	Stopcocks: Number	Stopcocks: Diam.	Stopcocks: Elevation of Invert	Remarks.
3	3'0"x5'0"	99.5	3	48" pipes	91.69	3	3'x6'	100.	3	48"	91.75	3-48" Balanced valves-El. 99.25
2	2'6"x5'0"	53.4	2	48" pipes	52.2	2	2'6"x5'0"	53.4	3	12"	91.75	By-Pass.
									2	48"	52.2	
									[illegible]	12"	[illegible]	By-Pass.

Drawn by A.S.F.
Traced by A.W.F.
Checked by A.W.F. & W.E.K.

PLATE NO. 7

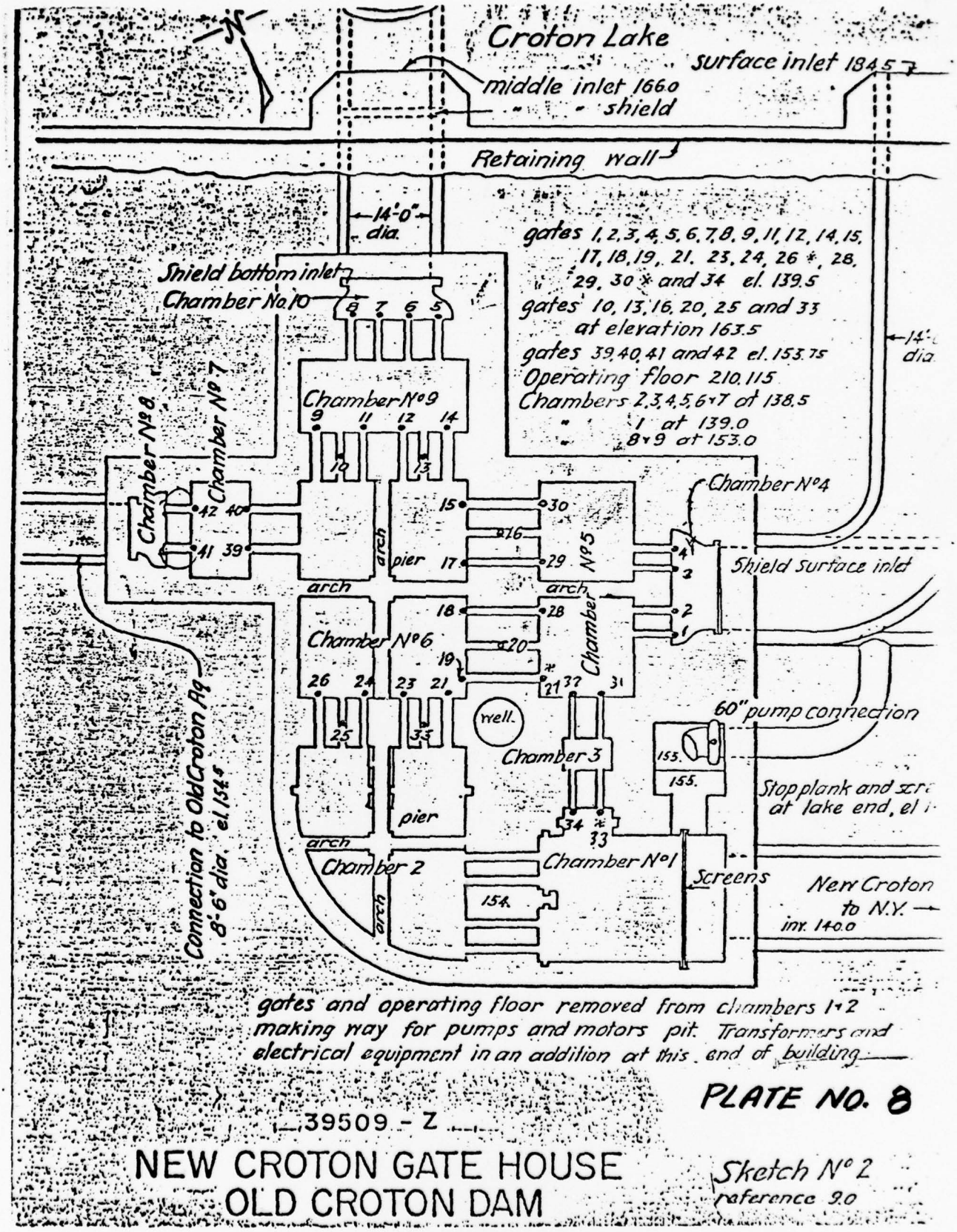
CITY OF NEW YORK

THE AQUEDUCT COMMISSIONERS

NEW CROTON DAM

GATE HOUSE No. 2.

ACCESSION NO.____



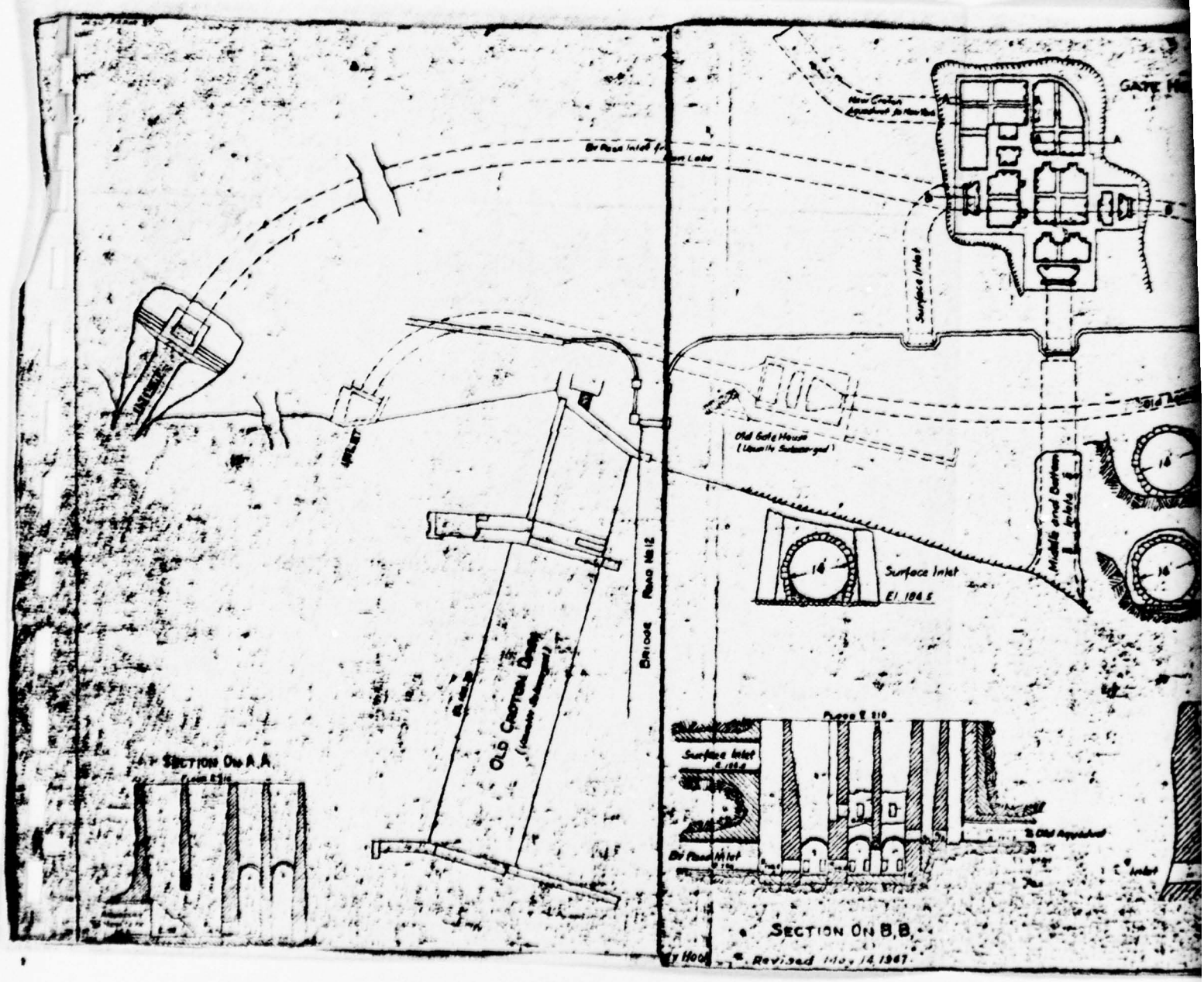
gates and operating floor removed from chambers 1 & 2 making way for pumps and motors pit. Transformers and electrical equipment in an addition at this end of building

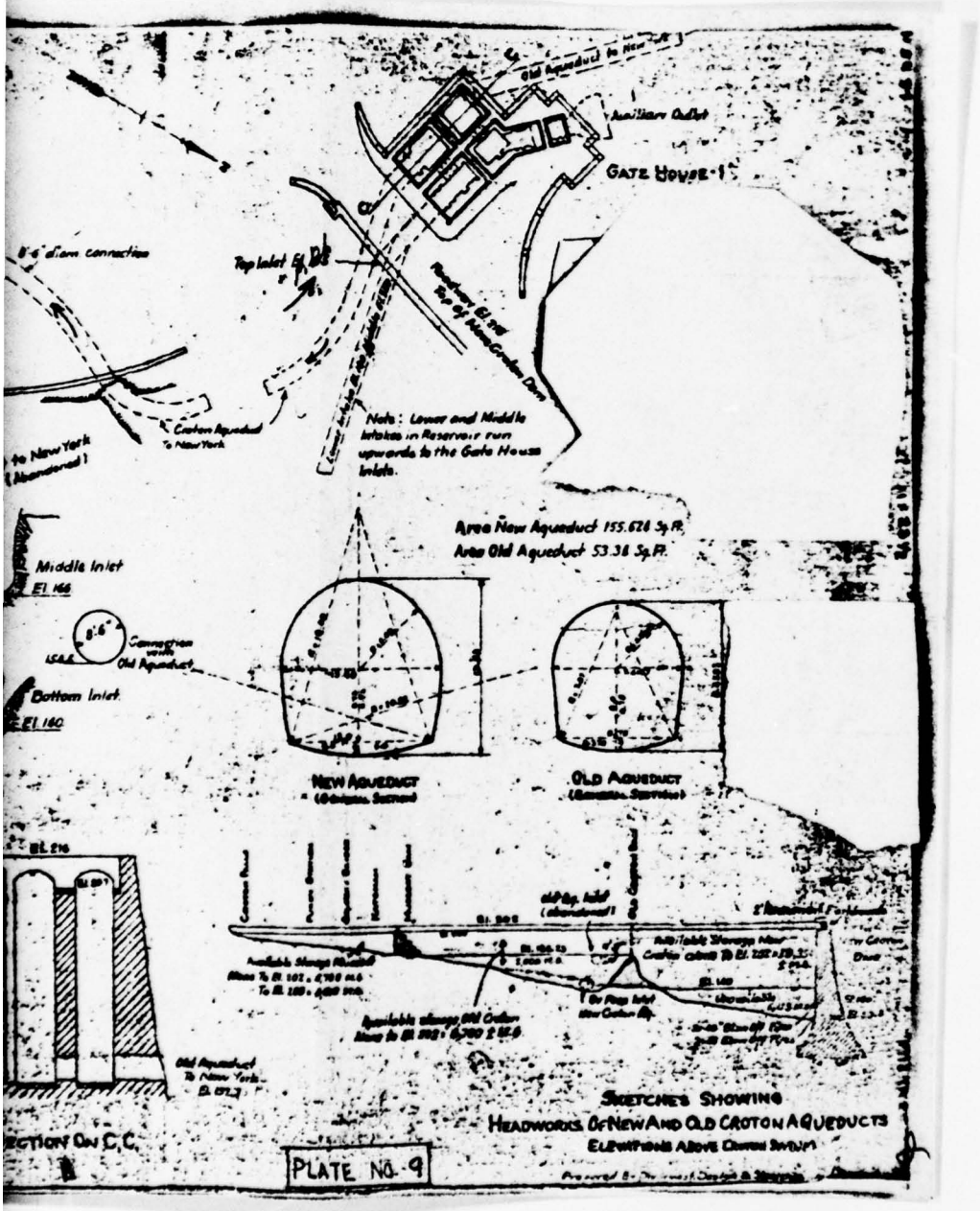
PLATE NO. 8

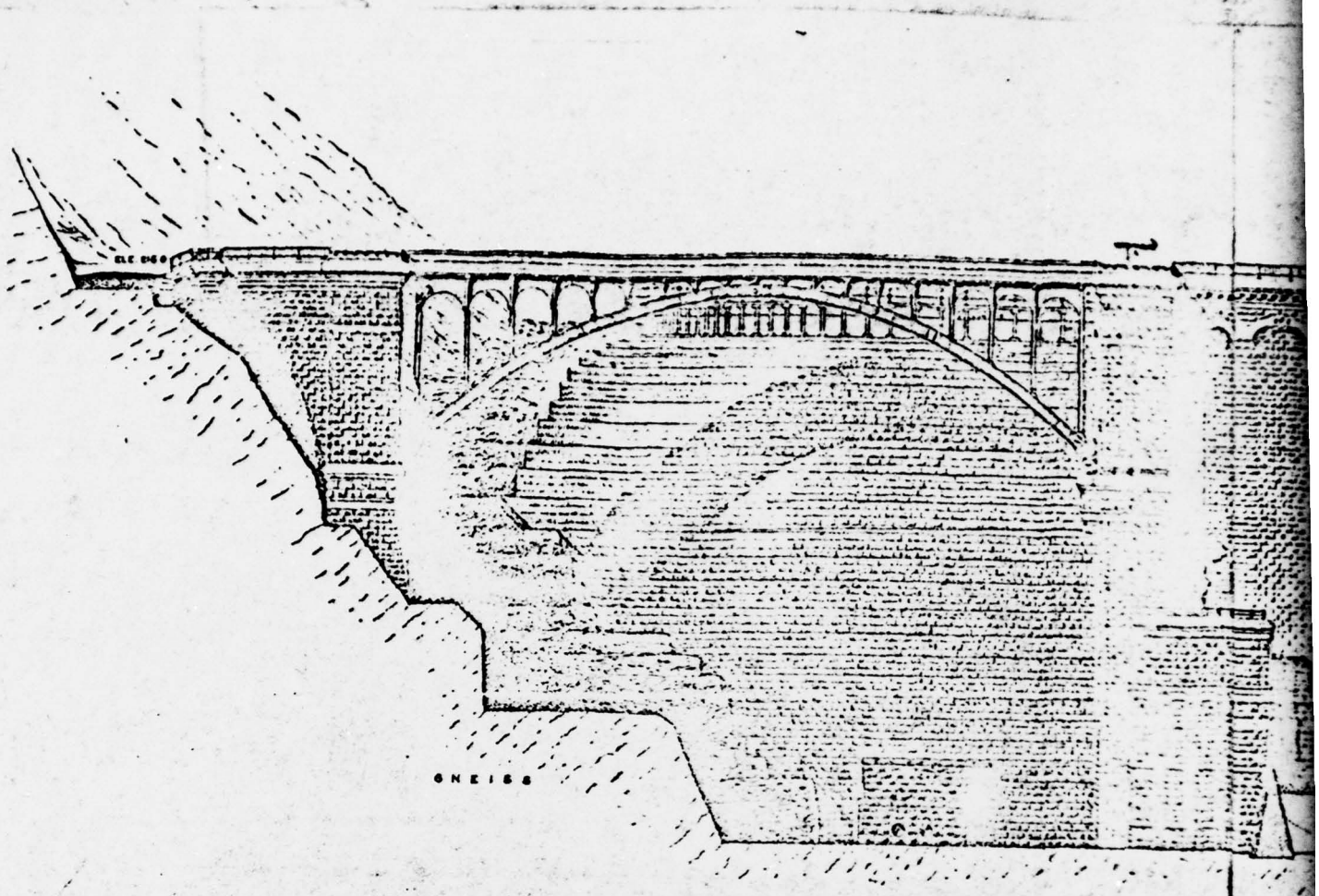
39509 - Z

NEW CROTON GATE HOUSE
OLD CROTON DAM

Sketch No 2
reference 9.0

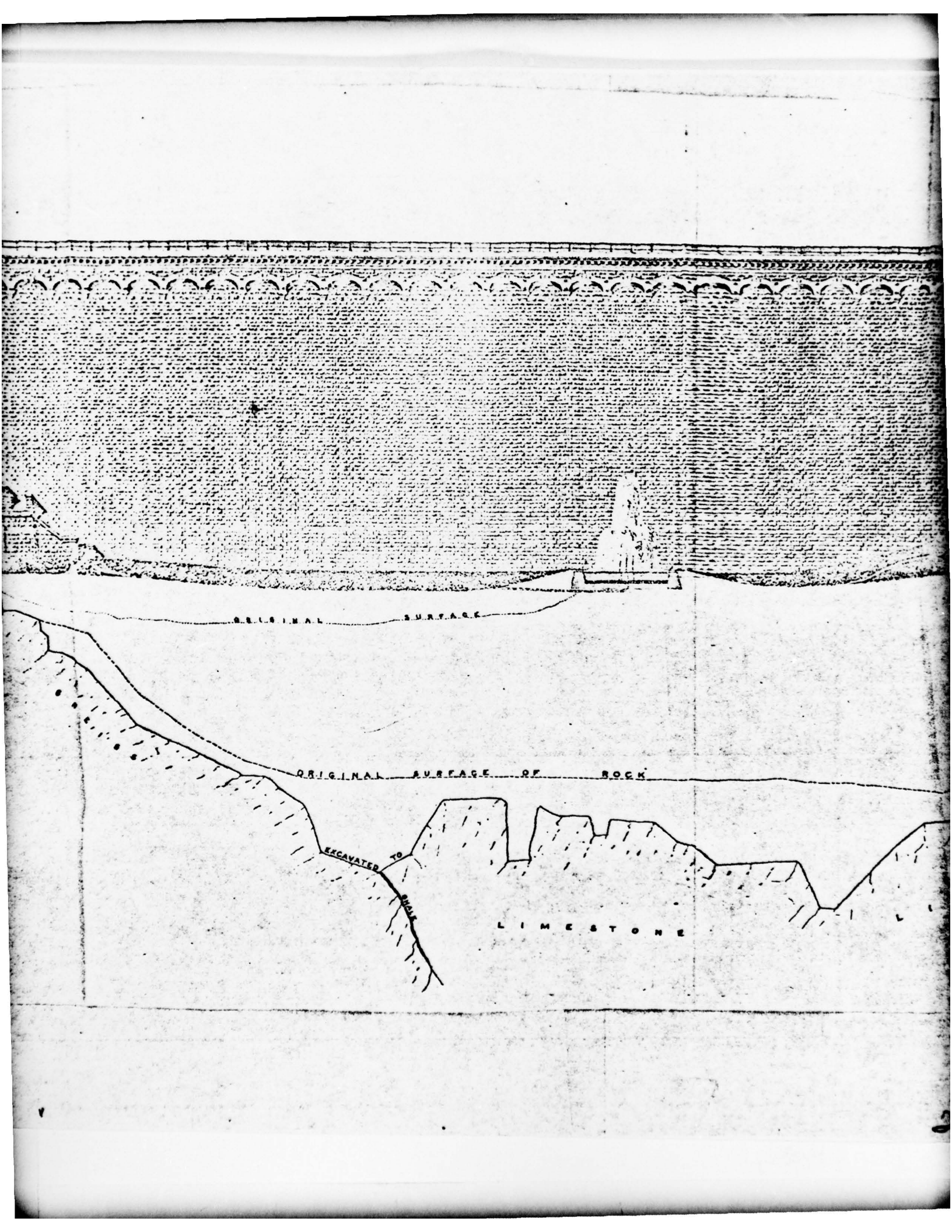

Old Gate House
(Usually Submerged)
Surface Inlet
El 184.5
Surface Inlet
Bridge Road No 12
Old Croton Drive
SECTION ON A.A.
SECTION ON B.B.
Revised Nov. 14, 1967

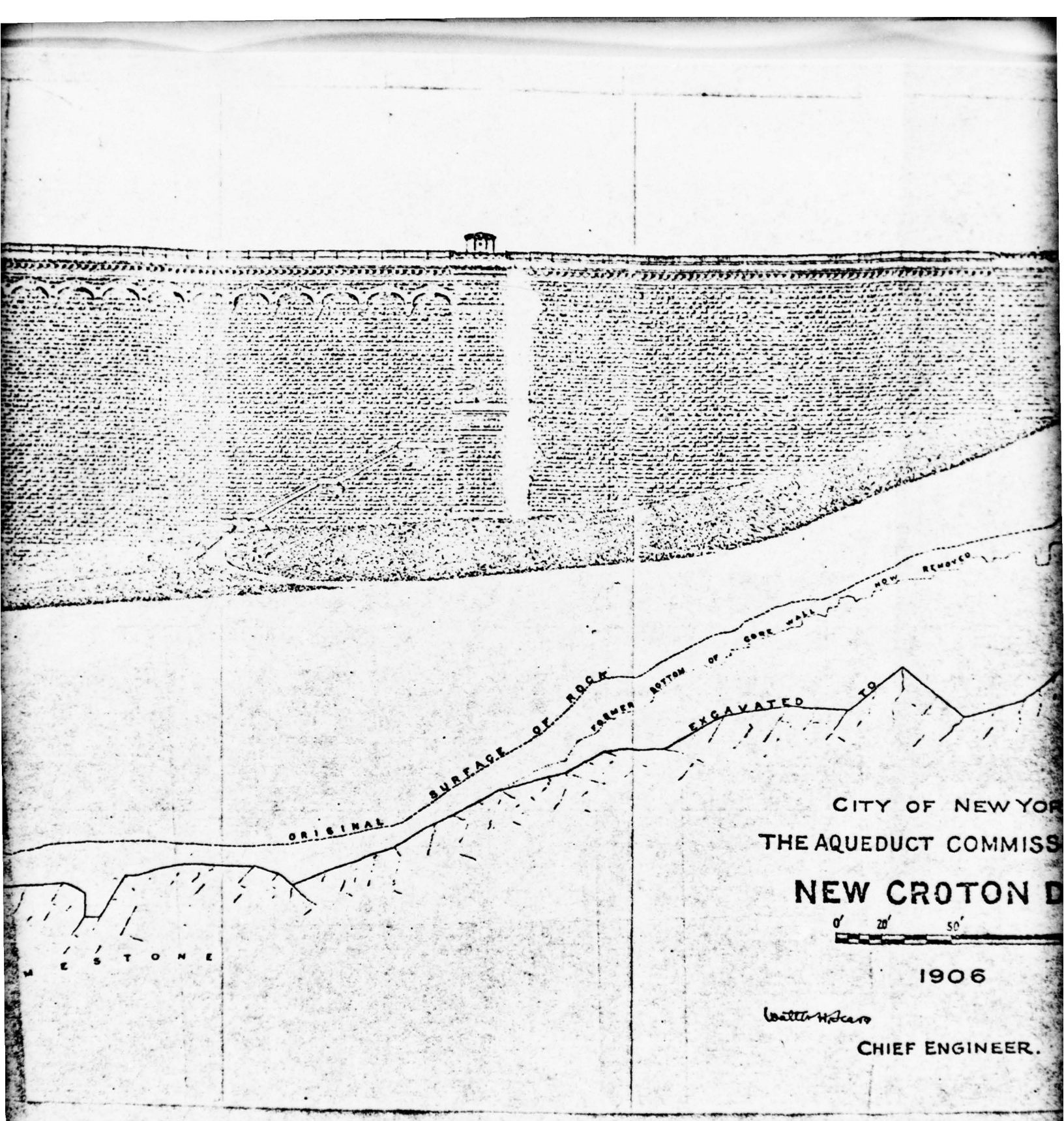

Auxiliary Outlet
GATE HOUSE-1
8'-6" diam connection
Top Inlet El. 168
Note: Lower and Middle Intakes in Reservoir run upwards to the Gate House Intake.
Croton Aqueduct To New York
Area New Aqueduct 155.626 Sq.Ft.
Area Old Aqueduct 53.38 Sq.Ft.
Middle Inlet El. 166
8'-6" Connection with Old Aqueduct
Bottom Inlet El. 160
NEW AQUEDUCT
OLD AQUEDUCT
El. 216
Old Aqueduct To New York El. 171.3
SKETCHES SHOWING
HEADWORKS OF NEW AND OLD CROTON AQUEDUCTS
ELEVATIONS ABOVE CHANNEL SILLS
PLATE NO. 9



REMARKS

Length of Dam Proper	1168 Feet.
" " Spillway	1000 "
Total Length	2168 Feet.
Lowest point of foundation	123 feet below bed of River.
Top of Dam	173 feet above " - "
Total Height	296 feet.
Thickness at base	206 Feet.
" " Top	19.5 "
Width of Roadway over Dam	19 "


ORIGINAL SURFACE
ORIGINAL SURFACE OF ROCK
EXCAVATED TO
LIMESTONE



CITY OF NEW YOR

THE AQUEDUCT COMMISS

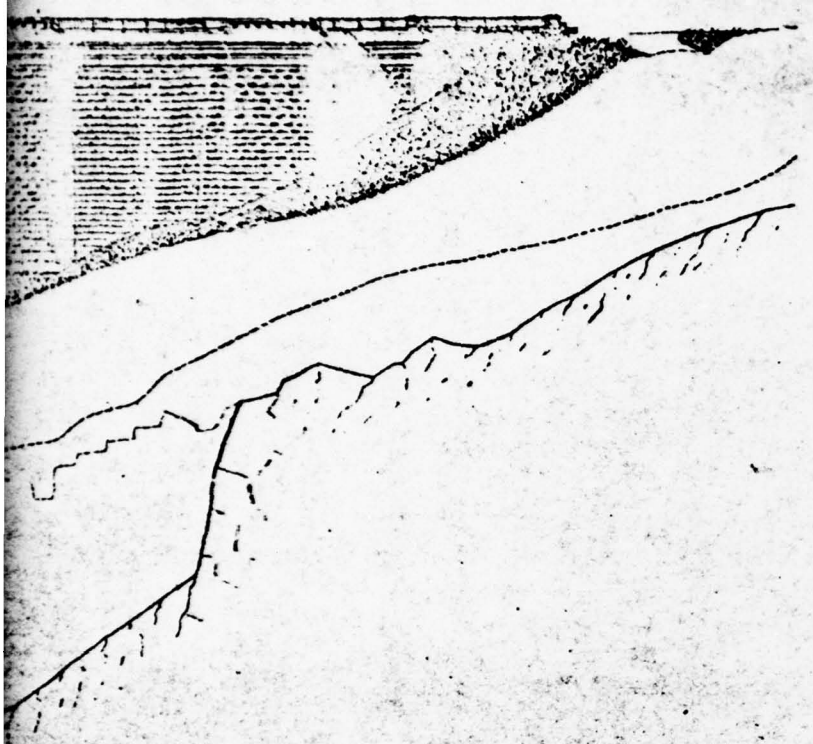
NEW CROTON D

0' 20' 50'

1906

Walter H. Sears

CHIEF ENGINEER.



YORK

ISSIONERS

N DAM

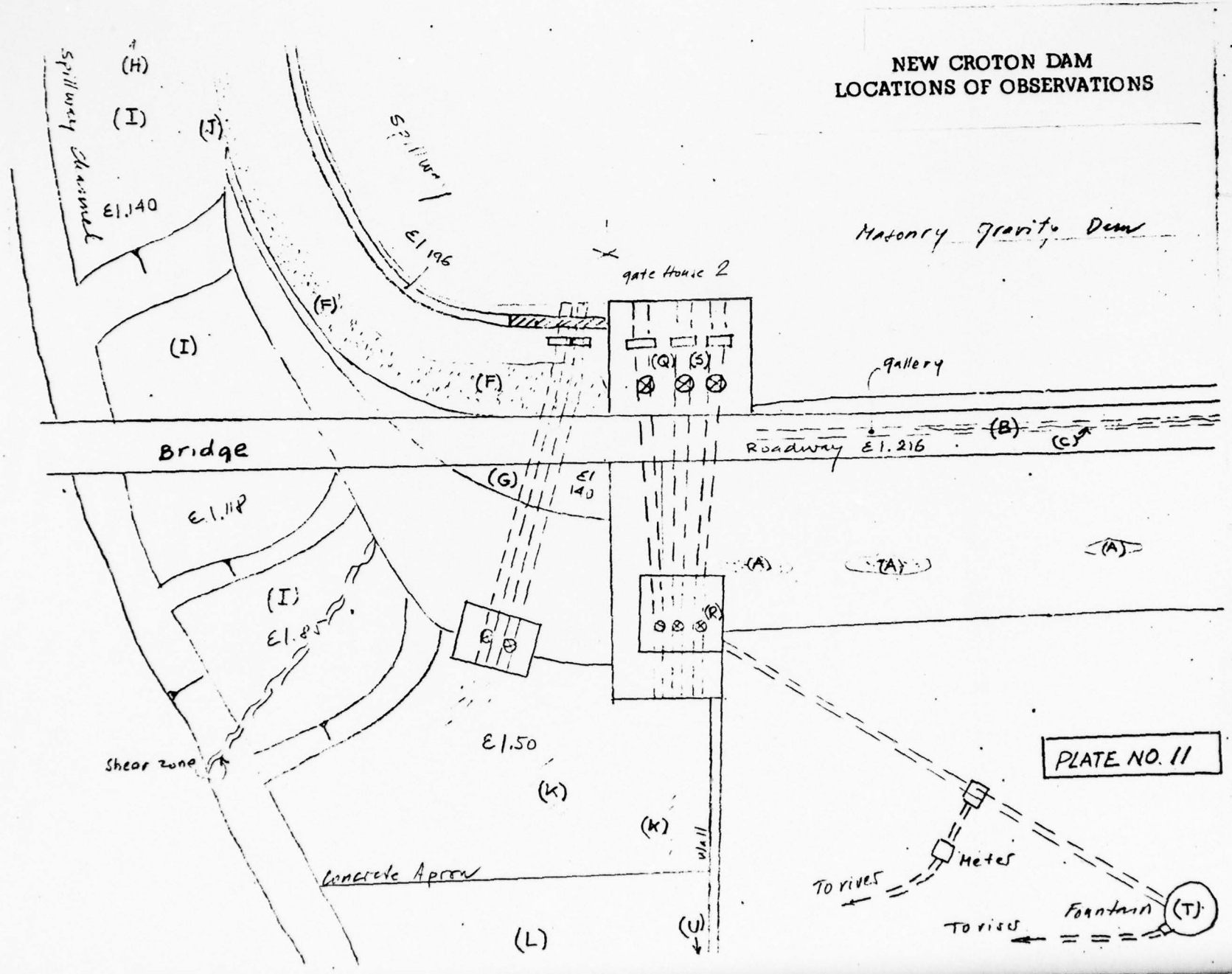
100'

R.

PLATE NO. 10

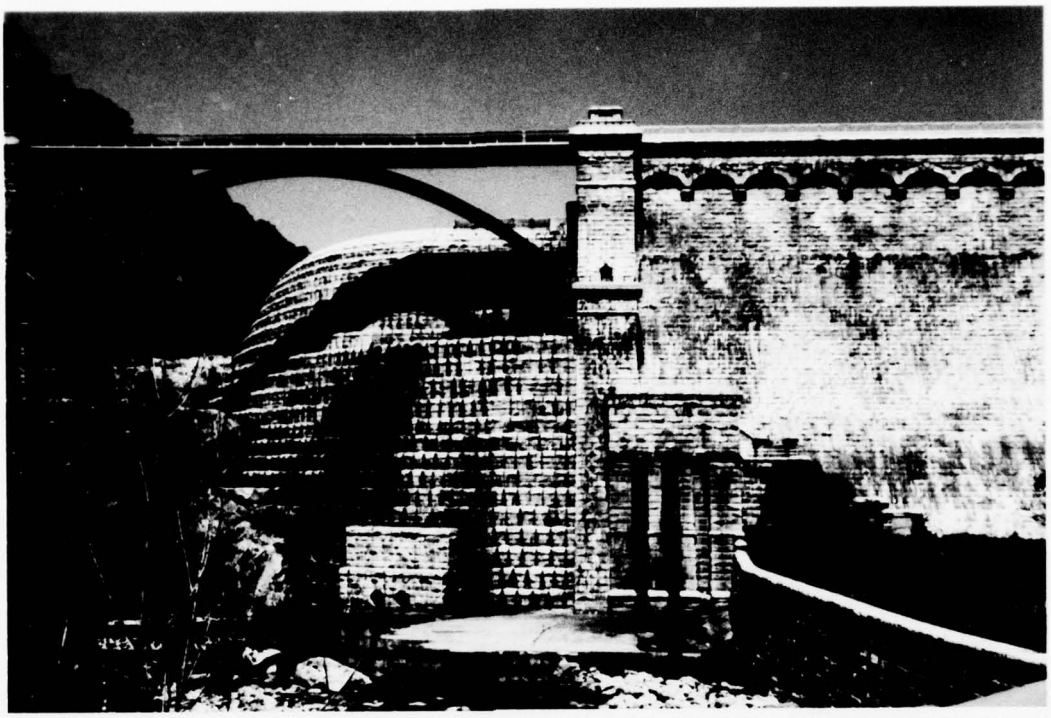
3.

4


NEW CROTON DAM
LOCATIONS OF OBSERVATIONS
Masonry Gravity Dam
Spillway Channel
Spillway
El 196
gate House 2
gallery
Bridge
Roadway El. 216
El 140
El. 118
El. 85
El. 50
Shear zone
Concrete Apron
Wall
To rives
Meter
Fountain
To river
(H)
(I)
(J)
(F)
(Q)
(S)
(B)
(C)
(G)
(A)
(R)
(K)
(L)
(U)
(T)
PLATE NO. 11

PHOTOGRAPHS

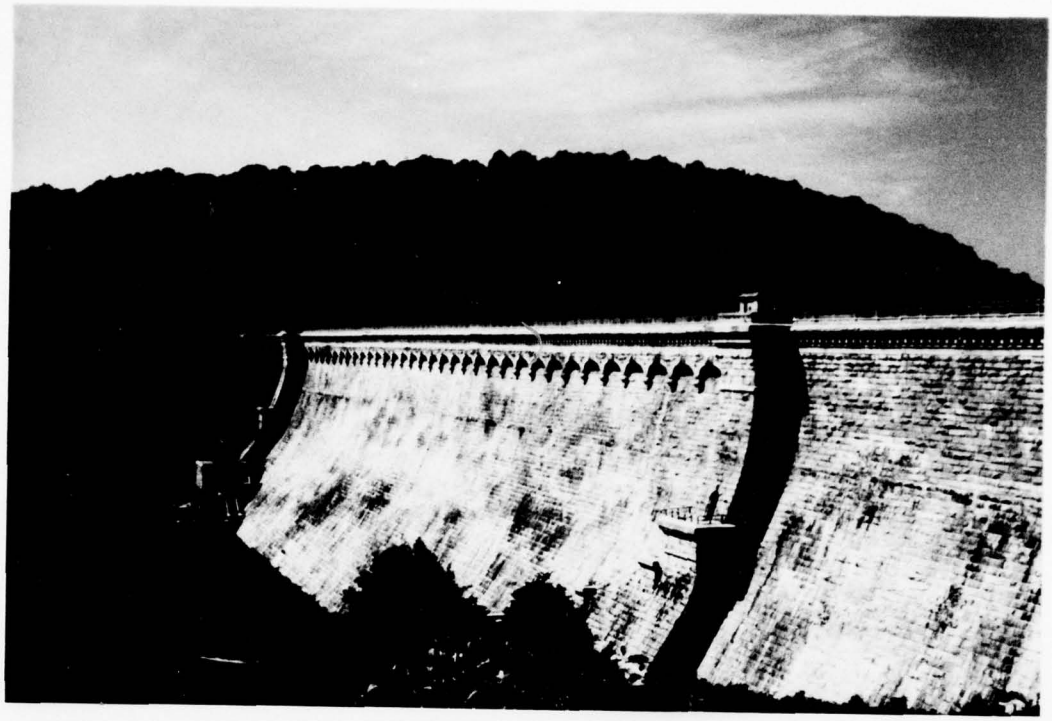
APPENDIX B



DOWNSTREAM VIEW OF SPILLWAY BRIDGE AND OUTLET STRUCTURES. THE PICTURE SHOWS SEEPAGE ON THE DOWNSTREAM FACE OF SPILLWAY, OBSERVATION (F) AND DAMAGED CONCRETE APRON, OBSERVATION (K).

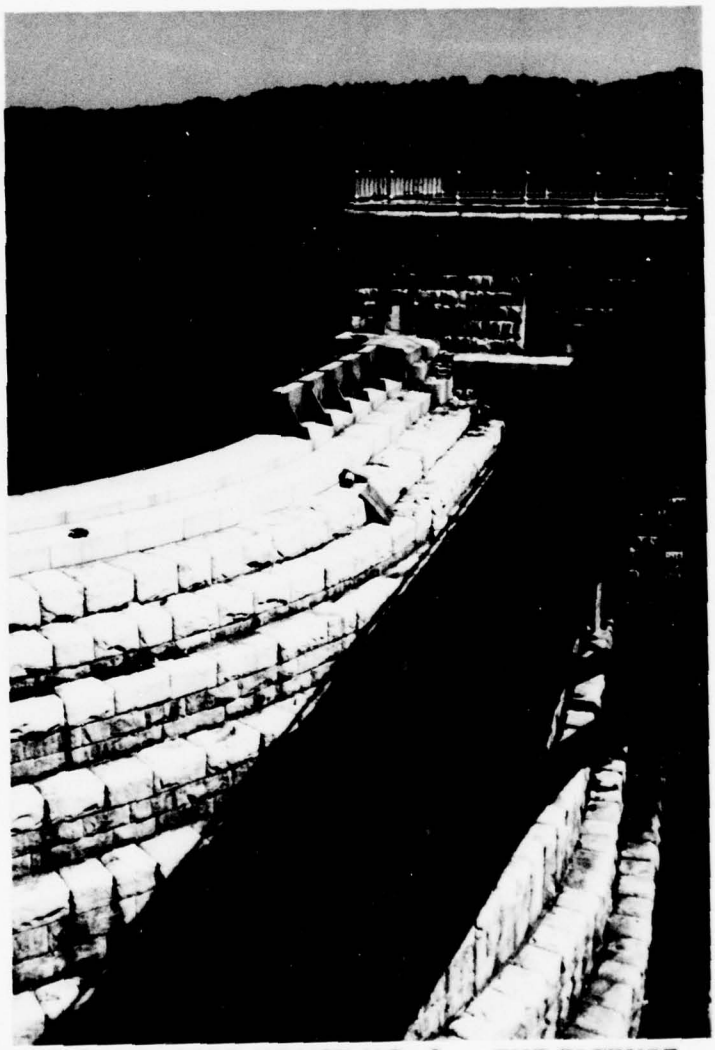
SPILLWAY AND GATE HOUSE NO. 2 (NORTH) VIEWED FROM THE SPILLWAY CHANNEL. THE WATER IN THE CHANNEL IS SEEPAGE FLOW, OBSERVATION (J).

ROAD ON THE CREST OF MASONRY DAM SHOWING CRACKS IN THE PAVEMENT, OBSERVATION (B)



DOWNSTREAM FACE OF MASONRY DAM

VIEW OF MASONRY DAM FROM THE RESERVOIR SIDE.
GATE HOUSE NO. 2 IS ON THE RIGHT.



SPILLWAY AND GATE HOUSE NO. 2. THE PICTURE ILLUSTRATES THE SEGMENTS OF LEFT IN PLACE PARAPET WALL NEXT TO THE GATE HOUSE AND ALSO SHOWS SEEPAGE FLOW, SOME DEBRIS AND VEGETATION GROWTH, OBSERVATIONS (F) AND (G).

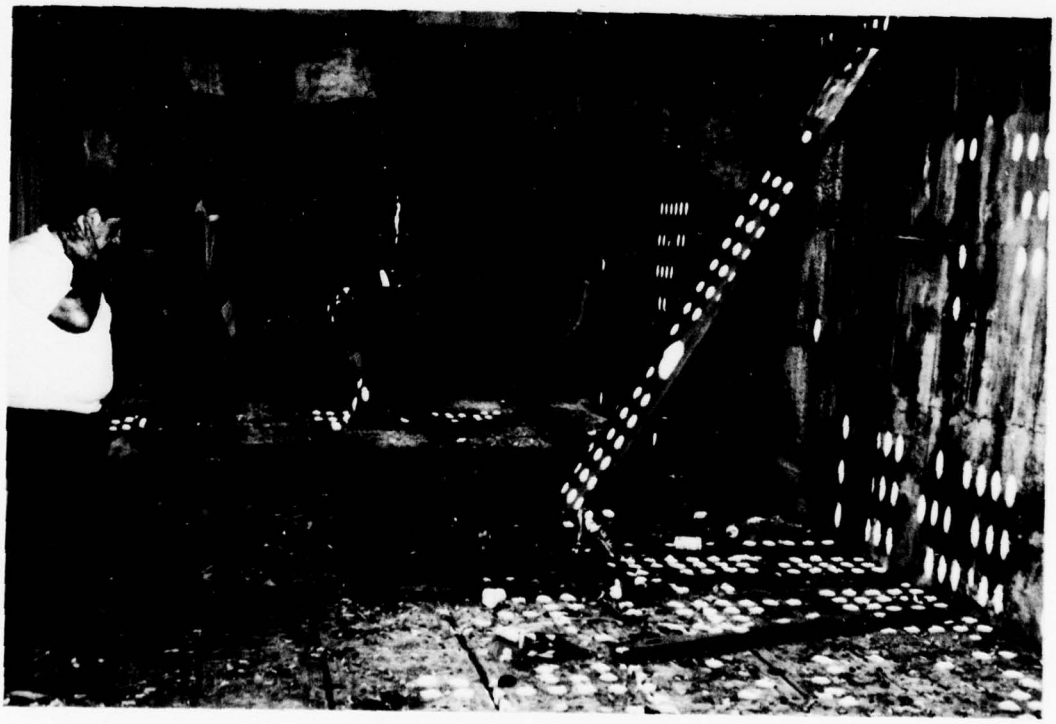
SEEPAGE FLOW ON THE DOWNSTREAM FACE OF SPILLWAY, OBSERVATION (F)

VIEW OF THE DOWNSTREAM FACE OF SPILLWAY SHOWING SEEPAGE FLOW ON THE STEPS, VEGETATION COVER AND DEBRIS ON THE EL 140 FEET PLATFORM, OBSERVATIONS (F) AND (G).

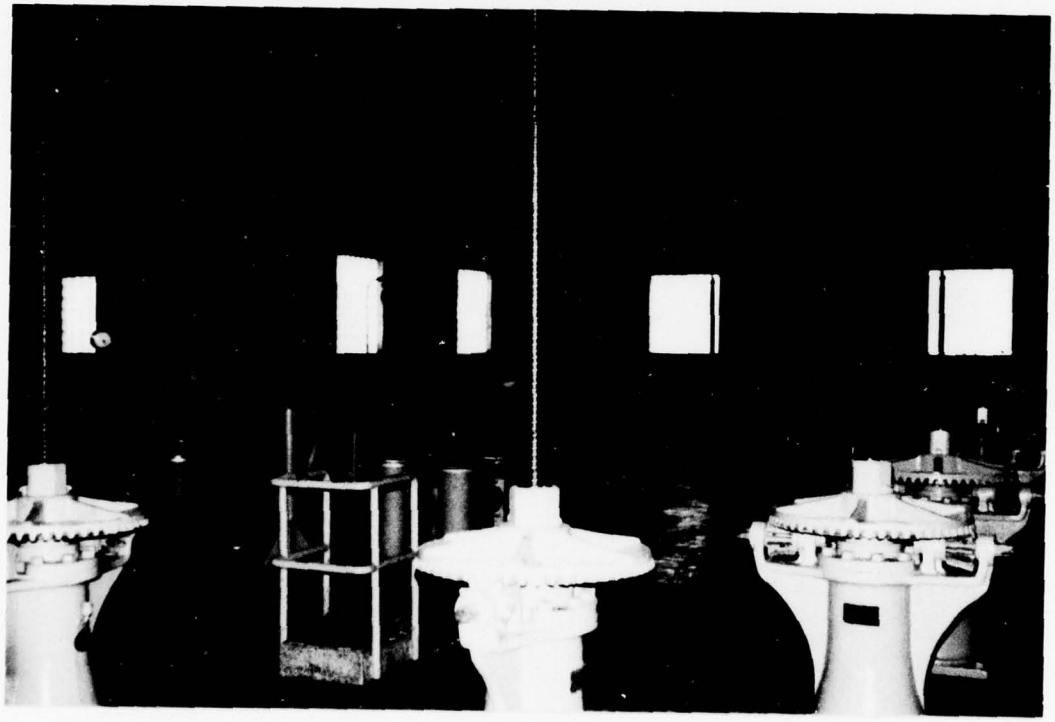
UPSTREAM END OF SPILLWAY CHANNEL. SOME DEBRIS, TREES AND SHRUBS ARE PRESENT, OBSERVATION (H).

VIEW OF DOWNSTREAM CHANNEL (CROTON RIVER) SHOWING DAMAGED CONCRETE APRON AND LOOSE ROCKS IN THE CHANNEL, OBSERVATIONS (K) AND (L). THE CURVED PORTION OF RETAINING WALL HAS BEEN DESTROYED DURING THE 1955 FLOOD AND REBUILT LATER. THE CONCRETE IN THE FRONT OF THE WALL IS BACKFILL IN AN ERODED HOLE.

GATE HOUSE NO. 1 (SOUTH) SHOWING RAISED SHIELD AT ENTRANCE TO THE OLD AQUEDUCT LEADING TO THE NEW CROTON GATE HOUSE; MISSING FLOOR PANELS, AND CONDITION OF GATE OPERATING STANDS, OBSERVATIONS (M) AND (P).



GATE HOUSE NO. 2 (NORTH) SHOWING DISMANTLED OPERATING STAND OF INTAKE SLUICE GATE, AND OPERATING STAND OF BALANCE VALVE FOR NORTH BLOWOFF PIPE, OBSERVATION (Q).



VIEW OF OPERATING FLOOR (EL 210.1) IN NEW CROTON GATE HOUSE
SHOWING GATE OPERATING STANDS FOR CHAMBERS 6, 9 AND 10

ENGINEERING DATA CHECKLIST

APPENDIX C

CHECKLIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION
PHASE I

NAME OF DAM New Croton

ID # 46

ITEM	REMARKS
AS-BUILT DRAWINGS	Plates 18, 20, 21, 22, 23, 24, 25, 26 of the Aqueduct Commissioners Report of 1895-1907 show nearly, but not entirely, as-built conditions.
REGIONAL VICINITY MAP	USGS quadrangles: Ossining, Mohegan Lake, Mount Kisco and Croton Falls - New York State.
CONSTRUCTION HISTORY	Described in the Aqueduct Commissioners Reports of 1887-95 and 1895-1907; Wegmann's book: The Design and Construction of Dams, several articles in ASCE Transactions (1900-1906) Engineering Record, Engineering News (1903-1907)
TYPICAL SECTIONS OF DAM	Aqueduct Commissioners Report of 1895-1907, Plates 18 and 22
OUTLETS-PLAN	Aqueduct Commissioners Report Plates and Dept of Water Supply gas and Electricity (DWSGE) drawings.
-DETAILS	- same sources as above -
-CONSTRAINTS	- same sources as above -
-DISCHARGE RATINGS	Spillway discharge table is available in DWSGE files
RAINFALL/RESERVOIR RECORDS	Daily record kept in DWSGE files.

ITEM	REMARKS
DESIGN REPORTS	The Aqueduct Commissioners has a report on the design of Quaker Bridge Dam which has been adopted for the New Croton Dam (1899)
GEOLOGY REPORTS	Wegmann's book and Gowen's papers (1900) and (1906) contain considerable amount of data on geology and foundation conditions. There is some information in the Aqueduct Commissioners Reports and Engineering Record Articles. (1903-1905)
DESIGN COMPUTATIONS	in Aqueduct Commissioners Reports and design studies for Quaker Bridge Dam
HYDROLOGY & HYDRAULICS	
DAM STABILITY	
SEEPAGE STUDIES	None
MATERIALS INVESTIGATIONS	core borings before and during construction. Logs can not be located any more.
BORING RECORDS	
LABORATORY	None
FIELD	—
POST-CONSTRUCTION SURVEYS OF DAM	—
BORROW SOURCES	—

ITEM	REMARKS

MONITORING SYSTEMS

Survey markers
Flow depths recorded in New Croton Gate House
USGS gaging station on Croton River d/s of dam

MODIFICATIONS

lowering crest level from 202 to 196 in 1956

HIGH POOL RECORDS

Record kept in DWSGE files

POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS

Coffin: The Slant on the Croton (1934)
Malcolm Pirnie: Report on the New Croton Dam Stability, Spillway Section (1956).
DWSGE: Repairs of Spillway Leaks (1956)

PRIOR ACCIDENTS OR FAILURE OF DAM

DESCRIPTION Cracks in spillway after Construction

REPORTS Cracks in spillway and seepage during 1955 flood. Bridge also damaged
Reports as above and ENR Jan 31 1957 article on spillway grouting

MAINTENANCE OPERATION RECORDS } Record kept in DWSGE files

ITEM	REMARKS
SPILLWAY PLAN	Plates in Aqueduct Commissioners Reports.
SECTIONS	— " —
DETAILS	— " —
OPERATING EQUIPMENT	Plates in Aqueduct Commissioners Reports and drawings in files of DWSGE.
PLANS & DETAILS	

Note: A list of references and drawings reviewed will be given in the report.

VISUAL INSPECTION CHECKLIST

APPENDIX D

VISUAL INSPECTION CHECKLIST

1. **Basic Data**

   a. **General**

   Name of Dam New Croton Hazard Category High

   County Westchester ID# 46

   Stream Name Croton River Tributary of Hudson River

   Location Westchester County Nearest Town (P.O.) Cortlandt Croton-on-Hudson

   Longitude 41° 13' 34" Latitude 73° 51' 22" Other Directions

   2 miles northeast of Croton-on-Hudson, near Route 129

   Date of Insp Jul 13, 1978 Weather Sunny Temperature 75-80 F°

   b. Inspection Personnel Kalman SZALAY

   Harold Leventhal

   John Burdick

   c. Persons Contacted Carl A Picha - Division Engineer

   City of New York, Dept of Water Resources

   John Byrnes - Section Engineer

   Donald Grassmann - Division Engineer

   Frank Cordova - New Croton Gate House-Water Plant Operator

   d. History: Date Constructed 1892 - 1906

   Present Owner City of New York

   Designed by Aqueduct Commission, A Fteley Chief Engr

   Constructed by J S Coleman, Breuchaud & Coleman

   Recent History Spillway damage, repairs and modifications in 1955-56

2. **Technical Data**

   Type of Dam Masonry Gravity Drainage Area 375 ~~Acres~~ SQ Mi

   Height 297 ft above datum / 174 ft above stream bed Length 1168 feet

   Upstream Slope Vertical above El 140 / 10:1 below El 140 Downstream Slope Varies from near vertical at crest to 10:1 at base

   Crest Width 18 ft Freeboard at Spillway Crest 20 ft

Low Level Control: (Type and Size) Three 48 in blow off pipes. Inv El 150.

Valve Condition Damaged, can not be operated at full capacity

~~Emergency~~ Spillway Type (Material) Masonry Width 950 at El 196

D/S ~~Side~~ Slope Stepped

Height (Crest to Top) 146 ft Max.

Exit Slope Varies

Exit Length N.A.

Ponded Surface Area 2260 Acres

Capacity (~~Normal~~ Spillway Crest Level) 72990 Acre Feet

~~Capacity Emergency Spillway Level Acre Feet~~

3. Embankment *

Gravity Dam

a. Crest

(1) Vertical Alignment No noticeable deformation

(2) Horizontal Alignment same

(3) Longitudinal Surface Cracks continuous crack in center of road pavement; additional longitudinal cracks in pavement

(4) Transverse Surface Cracks Some, minor. in pavement.

(5) General Condition of Road Surface Needs repairs.

(6) Miscellaneous —

* There is only a small embankment segment at the south abutment of the gravity dam. The embankment appears to be in satisfactory condition

b. Upstream ~~Slope~~ Face

(1) Undesirable Growth or Debris None

(2) Sloughing, Subsidence, or Depressions None

(3) Slope Protection N.A.

(a) Condition of Riprap N.A.

(b) Durability of ~~Individual~~ Facing Stones Durable

(c) Adequacy of Slope Protection Against Waves and Runoff N.A.

(d) Gradation of Slope Protection - Localized Areas of Fine Material N.A.

(4) Surface Cracks Minor

c. Downstream ~~Slope~~ Face

(1) Undesirable Growth or Debris None

(2) Sloughing, Subsidence, or Depressions; Abnormal Bulges or Non-Uniformity

None

(3) Surface Cracks on Face ~~of Slope~~ Minor

(4) ~~Surface Cracks or Evidence of~~ Heaving at ~~Embankment~~ Toe

None, no seepage at toe

(5) Wet of Saturated Areas or Other Evidence of Seepage on Face ~~of Slope; Evidence of "Piping" or "Boils"~~

Minor seepage and wet areas.

(6) ~~Fill~~ Embankment Contact with ~~Outlet~~ gravity Structure.

No evidence of erosion

(7) Condition of Grass Slope Protection

N.A.

d. Abutments

(1) Erosion of Contact of Embankment with Abutment from Surface Water Runoff, Upstream or Downstream

N.A

(2) Springs or Indications of Seepage Along Contact of Embankment with the Abutments

No seepage.

(3) Springs or Indications of Seepage in Areas a Short Distance Downstream of ~~Embankment — Abutment Tie-in~~ Dam

None

e. Area Downstream of ~~Embankment~~ Dam, Including Tailrace Channel

(1) Localized Subsidence, Depressions, Sinkholes, Etc.

None

(2) Evidence of "Piping" or "Boils"

None

(3) Unusual Presence of Lush Growth, such as Swamp Grass, etc.

None

(4) Unusual Muddy Water in Downstream Channel

Water is clear

(5) Sloughing or Erosion

Erosion in tailrace channel that has occurred during past floods.

(6) Surface Cracks or Evidence of Heaving Beyond ~~Embankment~~ Dam, Toe

No cracks, Concrete apron d/s of low level outlets (Gate House No 2) damaged.

(7) Stability of Tailrace Channel Sideslopes

Stable.

(8) Condition of Tailrace Channel Riprap

N.A.

(9) Adequacy of Slope Protection Against Waves, Currents and Surface Runoff

N.A.

(10) Miscellaneous some debris and large stones in tailrace channel

f. Drainage System

(1) Condition of Relief Wells, Drains and Appurtenances

No wells. There is a drainage gallery along and below crest. The gallery is cluttered with debris and sand.

(2) Unusual Increase or Decrease in Discharge from Relief Wells

N.A.

Seepage through spillway structure has decreased in recent years.

4. Instrumentation

(1) Monumentation/Surveys

Westchester County surface fix point located on top of left wall of tailrace channel

(2) Observation Wells None

(3) Weirs None in operation at present. Weirs have been used previously in spillway channel and in drainage gallery.

(4) Piezometers None

(Other) —

5. Reservoir

a. Slopes Rock slopes on north and surficial deposits on south. Slopes appear to be stable.

b. Sedimentation No indication of excessive sedimentation.

6. Spillways

a. ~~Principal~~ Spillway: Inlet Condition NA

Pipe Condition NA.

General Remarks (include information such as recently repaired, potential for debris accumulation, special items of note, etc.)

Upstream face cracked after construction and also in 1956. Cracks in spillway structure had been grouted in 1956. Crest lowered and capstones changed in 1956.

b. ~~Emergency~~ Spillway: General Condition Facing stones are in excellent condition. There are some minor cracks visible.

Tree Growth

some, particularly on platform El 140

Erosion None evident

Other Observations

Significant seepage emerges in various locations and levels on d/s face.

7. Structural (if required) See Attached Appendix

Stability calculations made by the City of New York and Malcolm Pirnie indicate stable conditions up to reservoir El 206 under static conditions.

8. Downstream Channel

a. Condition (obstructions, debris, etc.) some debris, trees and bushes.

b. Slopes Stable rock slopes.

c. Approximate No. Homes and Population 10-20 immediately d/s and several hundred in Goshen-on-Hudson 2 mi° d/s.

d. General

Kelmen Fealey
TEAM CAPTAIN

STRUCTURAL INSPECTION CHECKLIST

PHASE I DAM INSPECTION

1. Concrete Surfaces The facing stones of the dam and spillway (granite) are in good condition. There are minor cracks, mostly along joints.

2. Structural Cracking After the 1955 flood cracks were observed mostly along mortar joints in both faces of the spillway. There were also some diagonal splits through stones.

3. Movement - Horizontal and Vertical Alignment There is no noticeable change in the alignment of dam or spillway. After the storm of 1955 a displacement of 5/16 in had occurred along a horizontal crack at El 140

4. Junctions with Abutments or Embankments
No appreciable observation

5. Drains - Foundation, Joint, Face
No drains - except road drains on dam leading to a drainage gallery.

6. Water Passages, Conduits, Sluices
Three 48 in pipes in gate House No 2 (El 100) and intakes at three level to Old Croton Aqueduct in gate House No 1.

7. Seepage or Leakage
Significant leakage through the spillway structure, only minor seepage at dam

8. Monolith Joints - Construction Joints
There are no monoliths or construction joints in the dam or spillway

9. Foundation Foundation levels had been excavated to sound rock. No apparent problems

10. Abutments No unfavorable observations.

11. Control Gates Some repairs replacement or repair. All the gate Houses 1 and 2 require maintenance.

12. ~~Approach and~~ Outlet Channels Some debris and vegetation present. Surfaces very rough.

13. Stilling Basin N.A.

14. Intake Structure Part of the Gate House - No apparent structural problems.

15. Settlement No noticeable settlement of spillway or dam

16. Stability *
    a. Overturning Calculations not required for Phase I
    b. Sliding " " "
    c. Seismic Zone 1 - No analysis required.

17. Instrumentation
    a. Alignment None.
    b. Uplift
    c. Seismic

18. Miscellaneous

* In 1956 the City of New York & Malcolm Pirnie made static stability analyses using uplift forces for the spillway. These showed stable conditions up to reservoir El 206 although with some loading assumptions the resultant fell out of the ~~three~~ third.

HYDROLOGIC DATA & COMPUTATIONS

APPENDIX E

TAMS

Job No. 1487-03 Sheet ____ of ____
Project INSPECTION New Croton DAM. Date July 27
Subject Computation of Head-Discharge Relationship By ____
Ch'k. by ____

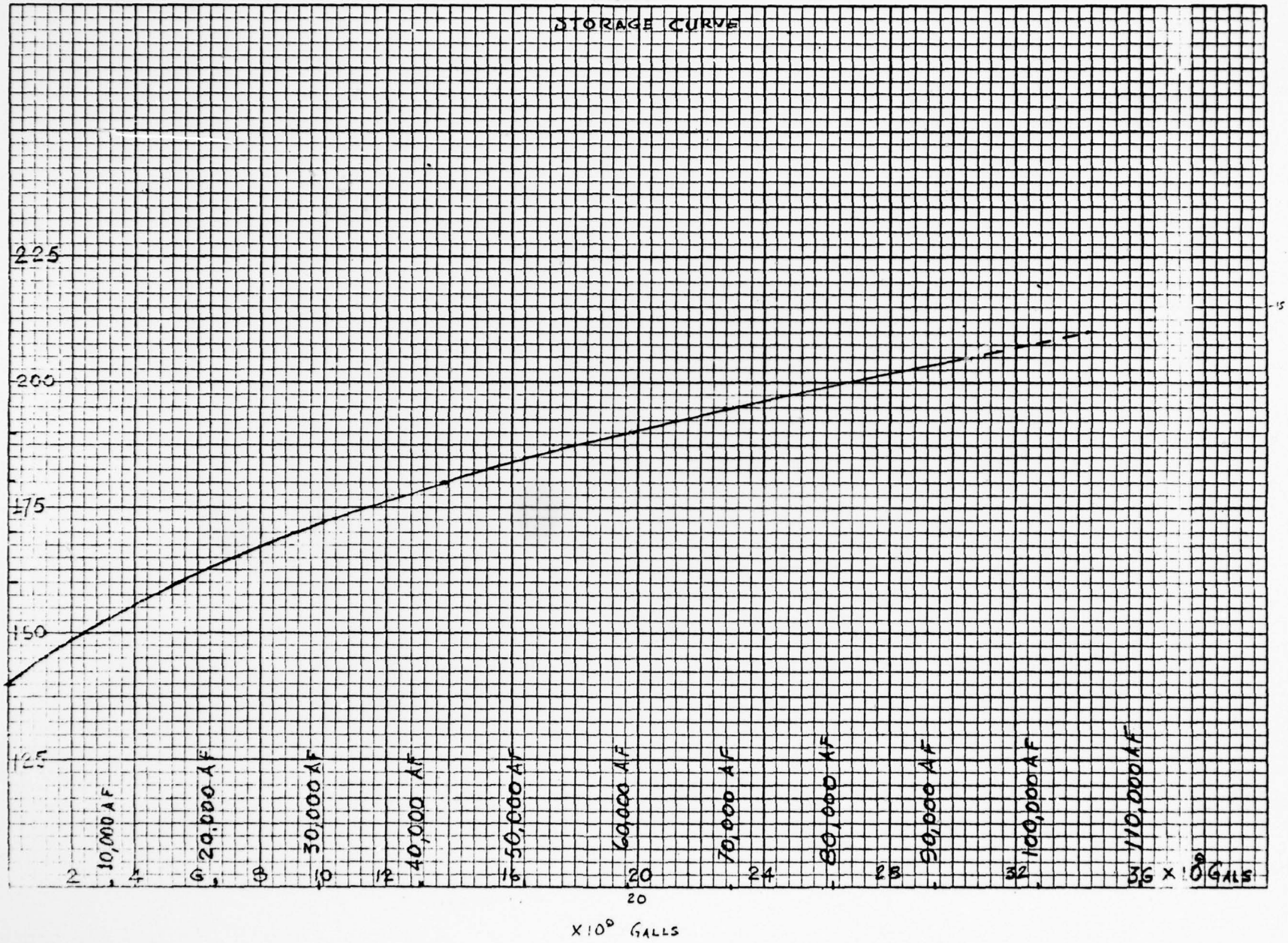
Crest length = 950.0' = L

Elev.	Head(H)	C	Q (cfs)
196.	0		0
197	1	2.64	25.10
198	2	2.64	7090
199	3	2.79	13770
200	4	2.79	21200
201	5	3.07	32610
202	6	3.34	44190
204	8	3.34	67450
206	10	3.34	93,640 (60.5 bgd)
210	14	3.34	153,560
216	20	3.34	259,410

for 'sharp-crested" weir $Q = 3.34 H^{1.47}$

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

0 3 New Croton Reservoir



LIST OF REFERENCES

APPENDIX F

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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
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7. AUTHOR(s) Eugene O'Brien, P.E.	8. CONTRACT OR GRANT NUMBER(s) DACW51-78-C-0024
9. PERFORMING ORGANIZATION NAME AND ADDRESS Tippetts-Abbett-McCarthy-Stratton 345 Park Avenue New York, New York 10022	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
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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
Westchester County
New Croton Reservoir Dam
Croton River

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.

New Croton Reservoir Dam was judged to be safe although further investigation and observation of the spillway should be made.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

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