CROTON RIVER BASIN

CARMEL DAM
(WEST BRANCH RESERVOIR)

PUTNAM COUNTY, NEW YORK
INVENTORY NO. 29

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

NEW YORK DISTRICT CORPS OF ENGINEERS
MAY 24, 1978
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.

Carmel Dam was judged to be safe, no remedial measures were required.
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Prepared by: TIPPETTS-ABBETT-McCARTHY-STRATTON

NEW YORK DISTRICT CORPS OF ENGINEERS

MAY 24, 1978
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**Croton River Basin**

**Carmel Main and Auxiliary Dams**

**Inventory No. 29**

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PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam: CARMEL MAIN AND AUXILIARY DAMS (I.D. NO. 29)
State Located: NEW YORK
County Located: PUTNAM COUNTY
Stream: WEST BRANCH, CROTON RIVER
Date of Inspection: 24 APRIL 1978

ASSESSMENT

The examination of available documents and visual inspection of Carmel Main and Auxiliary Dams and their appurtenant structures did not reveal conditions that are considered to be unsafe. Some deficiencies and inadequacies related to maintenance and operation were observed.

The total discharge capacity of the spillway and regulatory outlets at maximum pool level is approximately 37,000 cfs. This is less than the estimated probable maximum flood (PMF) of 59,000 cfs, but greater than the standard project flood (SPF) of 22,700 cfs, both as determined by the Corps of Engineers Screening criteria. The project discharge capacity is therefore adequate in accordance with the Corps of Engineers adopted general principle that structures be designed for the maximum flood reasonably characteristic of the region, which is, in practice, the Standard Project Flood.

No remedial measures are required at the present time.

The following improvements are recommended:
- Correct spillway seepage at Main Dam
- Observe and/or correct seepage at left abutment of Main Dam
- Remove vegetation from the embankments
- Clean the Auxiliary Dam drainage outlets
- Repair 36-in. gate valve at Auxiliary Dam
- Develop programs for operation and maintenance

Eugene O'Brien
New York No 29823

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

Date: 31 June 78
PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
CARMEL MAIN AND AUXILIARY DAMS
INVENTORY NO. 29
CROTON RIVER BASIN
PUTNAM COUNTY, NEW YORK

SECTION I 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 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 Main Dam
Carmel Main dam is composed of two earth embankment segments built on the sides of a masonry spillway. The upstream slope of the embankments is 1 (V): 2 (H) and the downstream slope is 1 (V): 2.36 (H). The width of the crest is 15 feet. The length of the embankment segment left of the spillway (looking downstream) is 1099.5 ft and on the right 435 ft. The maximum height of the embankment is 83 ft on the left and 86 ft on the right. Both embankments have a vertical masonry central core wall which extends through the entire length of the right embankment and a substantial distance into the left embankment. The width of the core wall is 55 ft at the base and 4 ft at the top; its maximum height is 77 ft. The downstream slope, crest and approximately a 10 ft wide top portion of the upstream slope are covered with grass; the remainder of the upstream slope is covered by hand placed cut stone slope protection.

The spillway is an ungated structure built of masonry rubble and faced with regular courses of cut stone which on the downstream slope are stepped. The width of the spillway is 260 ft and its crest at El 503.
structural height between stream bed and crest is 55 ft.

The regulating outlet system is composed of a double, parallel arrangement located in the gate house which is to the left of the spillway. The outlets are controlled by four manually operated 24-in. x 60-in. sluice gates, two on the upstream side and two on the downstream side. The intakes to the regulating outlets are located at El 456, El 476 and El 496. The high level intakes are presently closed by stop logs. The outlet has two discharge openings at El 456.

b. Description of the Auxiliary Dam

The Auxiliary dam is an earthfill structure with the following dimensions: crest width: 25 ft, upstream slope, 1 (V): 2(H): downstream slope, 1 (V): 2.5 (H). The downstream slope is grass covered except for a portion near the toe which is covered by stone protection, indicating the possible presence of a toe drain which is probably associated with the foundation drainage system described below. The crest is paved since Route 6 passes over this embankment. The upstream slope, below a 10 ft wide grass covered strip near the crest, is protected by hand placed cut stones. The length of the embankment is 749 ft and its maximum height is 65 ft. There is a masonry rubble center core wall in this embankment; the wall is 12 ft wide at the base, 5 ft wide at the top, and has a maximum height of 66 ft. A foundation drainage system, composed of several branches collects the under-seepage and the water is directed to collector vaults where it is taken away in underground conduits. The collector vaults and conduits, which are outside of the embankment, are built of cut stones and form 18 inch square sections at most places. There is a larger brick-stone enclosure for a former spring located near the left abutment contact, which also serves as one of the collector points for the system.

There is no spillway at the Auxiliary dam.

The low level outlet is a 3 ft diameter masonry conduit leading from the upstream toe to a central gate house and shaft where a 24 in. x 60-in. manually operated sluice gate controls the flow. Inside the gate house the low level conduit at El 460 joins a high level intake located at El 496. At present, the upper intake is closed by stop logs. Downstream of the gate house, the outlet consists of a 36-in. pipe inside a brick conduit which terminates in a valve vault located at the downstream toe. The downstream control for the low level releases is a 36-in. gate valve located in this vault.

Downstream of the vault, the 36-in. pipe continues underground and discharges into a circular fountain.
c. **Location**
Carmel Main Dam is located on the West Branch of the Croton River about 1.5 miles southwest of Carmel, New York. The auxiliary dam was built over a small tributary of the West Branch, and it is located about 1.2 miles southwest from the Main Dam. The portion of Route 6 between Carmel and Mahopac passes on the right abutment of the main dam and over the crest of the auxiliary embankment.

d. **Size Classification**
The main dam is 62 ft high and the auxiliary dam is 50 ft high. Both dams are therefore classified as "intermediate" size (between 40 and 100 feet).

e. **Hazard Classification**
The dams are in the "high" hazard potential category.

f. **Ownership**
The dams on the West Branch reservoir are owned and operated by the Bureau of Water Supply (BOWS) of the City of New York. The operation and maintenance is managed by the Carmel Section Office of the East-of-Hudson Division of BOWS.

g. **Purpose of Dam**
The dam provides storage for the New York City water supply system.

h. **Design and Construction History**
The main and auxiliary dams and their appurtenances were designed by the Aqueduct Commission of New York. The contract for the construction was let in 1890 to M.S. Coleman and the construction completed in 1895.

i. **Normal Operating Procedures**
Water is released through the regulating facilities of the two dams into the West Branch of the Croton River which carries the water to Croton Falls Main Reservoir. The approximate quantities released are 5 mgd at the main dam; and 2 mgd at the auxiliary dam. A much larger quantity however, approximately 180 mgd, is discharged from the reservoir into the New York City water supply system by releasing water into the Delaware Aqueduct at Shaft 10 which is located to the left and near the Auxiliary dam. Delaware Aqueduct, located near the upstream end of the reservoir, is capable of releasing water into the West Branch Reservoir; this inlet, however, is usually closed.
### 1.3 PERTINENT DATA

<table>
<thead>
<tr>
<th>Main Dam</th>
<th>Auxiliary Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a. Drainage Area - sq. mi.</strong></td>
<td>42.87</td>
</tr>
<tr>
<td><strong>b. Discharge at Dam Site - cfs</strong></td>
<td></td>
</tr>
<tr>
<td>Maximum known flood at site (Oct. 16, 1955)</td>
<td>3,600</td>
</tr>
<tr>
<td>Maximum regulatory outlets</td>
<td>700</td>
</tr>
<tr>
<td>Discharge at Shaft 10</td>
<td>285</td>
</tr>
<tr>
<td>Ungated spillway at maximum pool (El 515)</td>
<td>36,000</td>
</tr>
<tr>
<td>Total discharge capacity, at maximum pool</td>
<td>37,000±</td>
</tr>
<tr>
<td><strong>c. Elevation: feet above MSL</strong></td>
<td></td>
</tr>
<tr>
<td>Top of embankment</td>
<td>515.0</td>
</tr>
<tr>
<td>Normal Operational Pool</td>
<td>502.0</td>
</tr>
<tr>
<td>Maximum design pool (top of slope protection)</td>
<td></td>
</tr>
<tr>
<td>Spillway crest</td>
<td>503.0</td>
</tr>
<tr>
<td>Stream bed downstream of dam</td>
<td>450.0</td>
</tr>
<tr>
<td><strong>d. Reservoir</strong></td>
<td></td>
</tr>
<tr>
<td>Length of maximum pool, miles</td>
<td>3.0</td>
</tr>
<tr>
<td>Length of shoreline at spillway crest level, miles</td>
<td>15.6</td>
</tr>
<tr>
<td>Surface area at spillway crest level, acres</td>
<td>1082.8</td>
</tr>
<tr>
<td><strong>e. Storage acre-feet</strong></td>
<td></td>
</tr>
<tr>
<td>Top of spillway crest, El.503</td>
<td>30,900</td>
</tr>
<tr>
<td>Maximum design pool - top of slope protection El.510</td>
<td>38,200</td>
</tr>
<tr>
<td>Maximum pool - top of dam, El.515</td>
<td>42,300</td>
</tr>
<tr>
<td><strong>f. Dams</strong></td>
<td></td>
</tr>
<tr>
<td>Type: Earthfill embankment with masonry Rubble Core Wall</td>
<td></td>
</tr>
<tr>
<td>Length, ft.</td>
<td>1534.5</td>
</tr>
<tr>
<td>Upstream Slope</td>
<td>1(V): 2(H)</td>
</tr>
<tr>
<td>Downstream Slope</td>
<td>1(V): 2.5(H)</td>
</tr>
<tr>
<td>Width of Crest, ft.</td>
<td>15</td>
</tr>
</tbody>
</table>
Main Dam       Auxiliary Dam

Impervious Core: Rubble Masonry
  Bottom Width, ft.  55           12
  Top Width, ft.    4             5
  Maximum Height, ft.  86           65

g. Spillway
  Type: Ungated - stepped downstream face
  Length, ft:  260

Upstream Channel: None
Downstream Channel: 435 ft long; 60 ft wide to Rt. 6.

h. Regulatory Outlets
  At Main Dam: Intakes on three-levels controlled by two 24-in. x 60-in. sluice gates. Double outlet conduits controlled by two 24-in. x 60-in. sluice gates.
  At Auxiliary Dam: Two-level inlet controlled by 24-in. x 60-in. sluice gate. 36-in. downstream discharge pipe controlled by 36-in. diameter gate valve.
  At Shaft 10: Six 4 ft x 12 ft sluice gates discharging into Delaware Aqueduct.
SECTION 2 - ENGINEERING DATA

2.1 DESIGN

a. Geology and Foundation Conditions

There is no information on site geology or foundation conditions in the files of the Bureau of Water Supply. The report to the Aqueduct Commissioner (Reference 9) which contains the as-built drawings, also has a number of photographs taken during construction. These photographs give some indication of the foundation condition. The project drawings included in the report to the Aqueduct Commissioner indicate that the spillway and part of the central core wall adjacent to the spillway are resting on bedrock but the embankment and the rest of the core wall may be founded probably on surficial glacial deposits. There is no record of a foundation investigation program made prior to construction and there are no data on exploratory borings.

The geology of the region has been studied in detail in the past and data concerning the general geological conditions of the area can be found in the literature (References 8 and 9).

The site of West Branch Dam and Reservoir is underlain by a series of Precambrian formations, primarily granitic gneisses and paragneisses. These formations are considered to be excellent foundation materials for water retaining or other engineering structures. In most parts of the area, there is only a shallow surficial deposit over the rock. A minor fault is indicated in the area of the reservoir, it passes near the left abutment of the main dam. The fault, which is thought to be inactive, strikes in the NW-SE direction.

b. Embankments and Appurtenant Structures

The two dams and their appurtenant structures located on the West Branch Reservoir were designed in 1890 by the Aqueduct Commission of New York. The original contract drawings differ from the as-built conditions, in many respects. Another set of drawings is included in the Aqueduct Commission's report, 1887-1895 (Reference 9); these drawings more accurately reflect the as-built structures. In addition, a drawing was located at the BOWS offices which shows the layout of the foundation drainage system at the Auxiliary Dam. The list of drawings examined during this investigation is given in the Appendix. The general approach employed in the design of these dams is described in E. Wegmann's book (Reference 1).

2.2 CONSTRUCTION RECORDS

There is little information available on the construction; the Aqueduct
Commission Report 1887-1895 (Reference 9) contains data on the bidding process, the contract award and cost. It also contains a short description of the construction work which is illustrated in construction photographs (Plates 18-23, Reference 9).

2.3 OPERATION RECORD

BOWS records the pool elevations and rainfall daily and also keeps records of repair and maintenance work orders. No operation and maintenance manuals exist and there is no written record of inspections.

2.4 EVALUATION OF DATA

The data reviewed is considered adequate for this Phase I investigation. The data has been made available by the BOWS' New York City Office, the Katonah Office and the Carmel Section Office. Verbal descriptions of the procedures, and information on the operation and maintenance were also received from the District Engineer, Section Engineer and Foreman, who cooperated with the inspection team in all respects.
SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General
The visual inspection of Carmel Main and Auxiliary Dams was made on April 24, 1978. The weather was sunny to partially cloudy; the inspection was made 5 days after the last rainfall. The reservoir level at the time of inspection was 1 ft below spillway crest, El.502.

b. Main Embankment and Abutments
The embankment is generally well maintained; there are no visible signs of major slides, sloughing, erosion, cracks or other distress. There are no signs of unusual conditions on the abutments which would adversely effect the functioning of the dam. The following minor irregularities or deficiencies are noted: (The locations of these observations corresponding to the capital letters in parenthesis are marked on the sketches in the Appendix).

(A) Trees are growing near and at the upstream toe of the left embankment.

(B) Seepage emerges from the lower portion of the abutment contact of the left embankment. The water appears near the old paved collector ditch and flows in and near the ditch. The surface of the embankment and abutment in the area of seepage is wet and soggy. The embankment surface shows minor irregularities which are thought to be made by the maintenance tractor in the wet ground. Because of the soggy surface the vegetation was not cut in the area.

(C) Wet, soggy ground exists but no seepage water appears at the lower part of the abutment contact of the right embankment. Surface irregularities similar to those found at the left abutment were also noted here.

(D) Some bushes are growing on the downstream slope of the right embankment near the spillway wall.

(E) There are some animal burrows (approximately 8-in. in diameter) on the left abutment near the embankment contact.

(F) Minor damage has been noted in the stone slope protection at the far right end of the right embankment.
(G) The upstream stone slope protection has developed a depression and a bulge to the right of the spillway. In this area there is a crack in the slope protection which is associated with the slight downward movement of the stones.

c. Auxiliary Embankment and Abutments
The auxiliary embankment is well maintained and it is in good condition. There are no signs of problems or adverse conditions on the two abutments. This embankment has a foundation drainage system which is apparently still functioning. The following minor irregularities and deficiencies are noted:

(H) The access vaults and manholes of the drain system are partially clogged with debris, sand and leaves. The seepage measuring weirs of the system are not operational.

(I) There is minor erosion made by surface runoff from the highway on the downstream slope near the left abutment contact.

(J) The stone protection on the upstream slope has developed some minor damage on both sides of the gate house.

(K) Some saplings and bushes are growing on the upstream slope.

d. Spillway
The spillway structure appears to be sound and in acceptable operating condition. There are no significant cracks or signs of major deformations or movements. Some of the facing stones are slightly weathered but in satisfactory condition. The top two rows of facing stones were replaced in the early 1950's.

The following deficiencies are noted:

(L) Although the inspection was made at a time when the reservoir level was below spillway crest, considerable amounts of water were cascading on the downstream face of the spillway. The water emerged from between the joints of stones facing the spillway at all levels but the heaviest flow came from the joints of the top 2 or 3 layers.

(M) The top two layers of surface stones have been dislocated from their original position and pushed (probably by ice) downstream. The alignment of these two rows of stones has a downstream curvature.

e. Regulating Outlets
The operating gates of the main and auxiliary dams appear to be in working order, except:
(N) The 36-in. gate valve at the auxiliary dam is broken and stuck in a partially open position.

The brick conduit that surrounds the 36-in. outlet pipe inside the downstream portion of the embankment is in good condition and shows no signs of structural damage or distress.

There is no regular inspection schedule and maintenance program in effect.

The outlet facilities at Shaft 10 were constructed in 1949, much later than those at the two embankments. The facilities at Shaft 10 are regularly inspected, maintained and repaired.

f. Downstream Channel
   At the main dam the downstream channel appears to be in good condition with no signs of erosion or slope failure.

(O) The stream bed and its banks downstream of the auxiliary dam are cluttered with debris and are overgrown with vegetation.

g. Reservoir
   There are no noticeable sloughing, landslides or other signs of instability in the reservoir area adjacent to the dam.

3.2 EVALUATION OF OBSERVATIONS

The Phase I inspection did not reveal any condition which would significantly affect the safety of the dam or would require either immediate investigation or remedial measures. The irregularities and deficiencies described above require regular observations, some improvement and maintenance work.

The seepage through the spillway structure appears to enter the structure through the joints of the two top rows of dislocated surface stones. The water either surfaces downstream of these two rows of stones or continues downward behind the facing stones and exits through the joints at lower levels. While this condition does not appear to represent imminent danger, if left unattended, may lead to further damage to the structure, particularly when subjected to freezing and thawing cycles.

The quality of the upstream slope protection is excellent and its condition is good. There are minor damages located on the slope near structures, such as gate houses, and spillway walls. The presence of these structures probably contributes to the disturbing effect of the waves.

The remedial measures for improving the conditions are given in Paragraph 7.2.
4.1 PROCEDURES

The Carmel Reservoir discharges approximately 180 mgd into the Delaware Aqueduct of the New York City water supply system through Shaft No. 10, which is located near the auxiliary embankment.

Smaller discharges of 5 mgd and 2 mgd respectively, are released through the regulating outlets of the Main and Auxiliary Dams into the Croton Falls Main Reservoir, which also is a component of the New York City Water Supply System.

The water level is normally kept 1 or 2 feet below spillway crest (El 503). In summer months the reservoir level may drop as much as 15 feet below spillway crest.

4.2 MAINTENANCE OF DAM

There is no formally established program of inspection by BOWS personnel and there is no operation and maintenance manual for the project. The reservoir is visited frequently by the personnel of the Carmel Section Office but they do not necessarily examine the dam or other project features.

The grass surfaces of the main and auxiliary dams are mowed periodically but no regular maintenance procedures are in effect for the masonry structures and spillway. A system of drains and drain outlets located at the downstream slope of the auxiliary dam were found to be partially clogged with leaves and transported sand. Because these drains control the foundation seepage, it is mandatory that they be inspected and cleaned regularly. The seepage discharge should be monitored and recorded on a systematic basis.

4.3 MAINTENANCE OF OPERATING FACILITIES

The regulating gates appeared to be in operational condition. The 36-in. diameter gate valve on the auxiliary dam discharge line, however, is not in working order. The valve stem is damaged and the valve is jammed in a partially open position. The regulating gates are opened and closed about every six months to check their functioning.

4.4 WARNING SYSTEMS IN EFFECT

There are no warning systems in effect or in preparation.
4.5 EVALUATION

The maintenance of the Carmel Dam is considered adequate except in the following areas:

a. Disrepair of the 36-inch gate valve at the auxiliary dam.

b. Seepage at the top two rows of stones at the spillway sill.

c. Maintenance of the drainage system at the auxiliary dam is less than adequate.

d. There is some vegetation on the surfaces of the embankments.
SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 DRAINAGE AREA CHARACTERISTICS

The drainage area contributing to the West Branch Reservoir is 42.87 square miles and consists of steep hills, interspersed with swamp and natural lakes typical of a glaciated region. These lakes and swamps are believed to provide a substantial storage, capable of modifying the peak flood runoffs.

5.2 SPILLWAY CAPACITY

The spillway is uncontrolled, with a flat crest 260 feet long and approximately 3.0 feet wide, followed by a stepped downstream face. A spillway discharge rating, up to a head of 1.5 feet was obtained from the Department of Water Supply, but it was necessary to extend this table to a head of 12.0 feet corresponding to the top of the dam. It was assumed that the spillway would act as a broad-crested weir up to a depth of 5.0 feet, and as a "sharp-crested" weir above this depth. The computed spillway capacity at a head of 12.0 feet is 36,000 cfs (839.5 cfs per sq. mi.).

5.3 RESERVOIR CAPACITY

The total reservoir capacity at the spillway crest is 10,070 million gals (30,900 acre-feet). The storage capacity curve, based on a table furnished by the Department of Water Supply is shown on Figure 2. The capacity curve has been extrapolated to an elevation corresponding to the top of the dam (Elevation 515.0), and indicates a surcharge storage of 11,400 acre-feet, which is equivalent to a runoff depth of 5.00 inches over the drainage basin. This surcharge storage is an important factor in considering the adequacy of the spillway’s capacity to pass the design floods.

a. Floods of Record

Historic data of known floods in the Croton River Basin indicates that the largest floods were those of August and October, 1955. Daily readings of the head on the spillway crest gave the following data on these floods:

<table>
<thead>
<tr>
<th>Date</th>
<th>Elevation in feet</th>
<th>Head in feet</th>
<th>Discharge cfs</th>
<th>Discharge cfs/sq. mi.</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 21, 1955</td>
<td>504.85</td>
<td>1.85</td>
<td>1800</td>
<td>42</td>
</tr>
<tr>
<td>October 16, 1955</td>
<td>505.83</td>
<td>2.83</td>
<td>3600</td>
<td>84</td>
</tr>
</tbody>
</table>
The records of precipitation at the dams indicates that, in the August storm, 6.83 inches of rain fell from the eleventh to the thirteenth inclusive, followed by 7.17 inches on the 17th and 18th, a total of 14 inches in eight days. The October storm was 9.9 inches, occurring in three days, 14-16 inclusive, and was of greater intensity, 6.77 inches falling on October 15. However, the spillway discharge was relatively low due to the storage available in the reservoir prior to the storms, on August 11th and October 14 when the water surface was 8.78 feet and 1.98 feet below spillway crest, respectively.

b. Overflow Potential

The maximum spillway discharge of 36,000 cfs, given in Paragraph 5.2 above, has been compared with the generalized design flood criteria as explained below. The Probable Maximum Flood for the 42.87 square mile drainage area has been extrapolated from Maps of Probable Maximum Flood Potential for selected sizes of drainage area (Reference 11). The smallest drainage area for which floods have been plotted was 100 square miles. The extrapolation to 42.87 square miles must be considered approximate, but indicates a PMF peak inflow of about 59,000 cfs or about 1.6 times the spillway discharge capacity.

A second criteria for evaluating a design flood is the Standard Project Flood (SPF) which is usually about one half of the PMF. Derivations of the SPF in the Lower Hudson River Basin are available in a report made for the Corps of Engineers (Reference 12). Data in this report permitted interpolation of the SPF for an area of 42.87 square miles and indicated a flood potential of 22,700 cfs or 63% of the spillway capacity.

5.5 EVALUATION

The estimated Probable Maximum Flood inflow of 59,000 cfs, and the Standard Project Flood inflow of 22,700 cfs must be considered as representing potential inflow to a reservoir from a drainage area that has little natural or artificial storage. The Carmel Main Dam drainage area has substantial natural storage, and to properly evaluate the relation between its spillway capacity and the probable outflow from these design floods, it would be necessary to develop complete hydrographs and route them through the substantial surcharge storage. A greater refinement would require development of sub-area hydrographs which would be routed through the natural storage in each sub-area. Without these detailed analyses, it is not possible to say whether or not the spillway capacity is adequate relative to the runoff from a Probable Maximum Flood, but the capacity is obviously adequate to pass the Standard Project Flood.
SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations

Visual observations did not indicate significant problems or major deficiencies which would represent an imminent danger to the project.

The seepage noted at left abutment contact of the main dam is not detrimental to project safety unless it increases in quantity or the water turns muddy.

The pronounced curvature of the top masonry courses near the middle of the spillway is assumed to be caused by ice pressure. During the winter of 1977-78 there was as much as 26 inches of ice in the reservoir. The curvature might have been greater if steel rods had not been installed to anchor these top courses. The movement of the top masonry courses probably crushed any mortar in the joints resulting in some leakage through the joints. This is not considered a hazardous condition.

b. Design and Construction Data

No design computations or other data regarding the structural stability of the spillway or earth embankment are available.

On the basis of the performance experience of the spillway and earth embankment, as well as engineering judgement, these structures are not considered to be unstable.

Although there are no design computations available, it is likely that the spillway was designed in accordance with E. Wegmann's Text "Design and Construction of Dams". Mr. Wegmann, at the time the dam was put in service, was an Engineer for Construction, assigned the duty of making the theoretical studies and calculations for the Aqueduct Commission. It is assumed the spillway was designed accordingly and that its stability is sufficient. It should be noted that flashboards had been previously installed on top of the spillway without adverse effects.

Some photographs taken during construction for both the main and auxiliary dams are included in the Report to the Aqueduct Commissioner, 1887-1895 (Reference 9).

c. Operating Records

Records of gate operation and repairs are available in the BOWS' Section Engineer's office at the dam site. No major operational problems which
would affect the stability of the dam were reported.

d. Post Construction Changes
Prior to 1950 water was regularly discharged over the spillway but after the Aqueduct system was enlarged there was no regular release over the spillway.

The top courses of stone were probably in poor condition when they were replaced about 1951.

Before the floods of 1955, flashboards were regularly used on the spillways of the Croton System. The flashboards have since been removed and are no longer used. Holes are clearly visible on the top courses where the flashboards had been installed.

e. Seismic Stability
The dam is located in Seismic Zone No. 1 (Reference 13) therefore no seismic analyses are warranted.
SECTION 7 - ASSESSMENT/RECOMMENDED MEASURES

7.1 ASSESSMENT

a. Safety

The Phase I investigation of the Carmel Main and Auxiliary Dams on the West Branch Reservoir did not reveal any unsafe conditions. The irregularities and deficiencies described in Paragraph 3.1 do not constitute hazard to human life and property. Recommendations are given, however, in Paragraph 7.2 for improving the conditions related to these irregularities and deficiencies.

The total discharge capacity of the spillway and regulating gates without overtopping of the dam is approximately 36,000 cfs. This is less than the estimated probable maximum flood (PMF) of 59,000 cfs but greater than the standard project flood of 22,700 cfs, both as determined using the Corps of Engineer’s screening criteria. The project discharge capacity is therefore adequate in accordance with the Corps of Engineers adopted general principle that structures be designed for the maximum flood reasonably characteristic of the region, which is, in practice, the standard project flood.

b. Adequacy of Information

The information available is adequate for performing this investigation. In addition to the existing information and data, however, the following items would be required for the proper operation and maintenance of the project:

(1) Up-to-date drawings of the Auxiliary Dam,
(2) Operation and maintenance manuals,
(3) Ratings for release facilities,
(4) Systematic schedule of inspection and record of inspection,
(5) Monitoring of seepage and record of the measurements, and
(6) Schedule and record of maintenance.

c. Urgency

No immediate action is required.

d. Additional Investigations

Additional investigations to assess the safety of the dams and appurtenant structures do not appear to be warranted at the present time.

7.2 RECOMMENDED MEASURES

No remedial measures are required at the present time.
Certain measures are recommended, however, for improving the conditions at locations noted in Paragraph 3.1.

a. The stonework, serving as spillway facing needs to be repaired in order to correct the seepage condition noted at locations (L) and (M).

b. The seepage and wet conditions noted at locations (B) and (C) should be systematically observed and possibly corrected by trench drains or protected by filter blankets.

c. The drain system of the Auxiliary Dam should be cleaned and new seepage measuring devices installed (Location (H)).

d. The 36-in. gate valve at Auxiliary Dam should be repaired (Location (N)).

e. The following measures can be carried out as part of the maintenance work: Removing trees and bushes, repairing minor damage and erosion of slope protection, clearing debris, and treating animal burrows. (Locations (A), (D), (E), (G), (I) and (K)).

f. Some of the observations, such as the minor upstream slope protection damages at locations (F) and (J) do not require any action at present, however periodic observations are recommended to detect potential further deterioration in the future.

g. For monitoring the performance of the embankment it would be desirable to reactivate the existing piezometers.
APPENDIX A

List of Drawings Reviewed in Connection
with Phase I Investigation of Carmel Main and Auxiliary Dams

DRAWINGS

From Report to the New York Aqueduct Commission 1887-1895 (As-Built Conditions) -
   Sheet 18 - Contour Plan of Main Dam *
   19 - Elevation and Section of Main Dam *
   20 - Elevations and Sections of Auxiliary Dam *

Plan and Sections of Auxiliary Dam Drainage System -
   Sections of Auxiliary Dam (BOWS Reference No. 3916-X)

Contract Drawings: (Different from as-built conditions) (1890)
   Sheet 2 - Plan of Auxiliary Dam
   3 - Plan of Main Dam and Spillway
   4 - Plan of Spillway
   6 - Sections of Main Dam
   9 - Section of Auxiliary Dam

*Drawings reproduced in this report - see Item b in this Appendix
This drawing is reproduced from Reports on the New Croton Aqueduct Reservoirs and Dams to the City of New York Aqueduct Commission. (1887-1895)
THE AQUEDUCT COMMISSIONERS

CONTOUR PLAN

OF

MAIN DAM

RESERVOIR D

CARMEL N.Y.

Scale

[Map of the area with various labeled sections such as Old Road, Old Channel, New Channel, Branches of Relief, Old Bridge, Croton Rly., and an Office building.]
This drawing is reproduced from Reports on the New Croton Aqueduct Reservoirs and Dams to the City of New York Aqueduct Commission. (1887-1895)
AQUEDUCT COMMISSIONERS
ELEVATION & SECTION
OF
MAIN DAM
RESERVOIR "D"
CARMEL
PUTNAM COUNTY
N.Y.

SCALE

A. Filer
CHIEF ENGINEER
GENERAL MAP
(SKETCH)

C.G. GUSTAFSON, DEL.
ELEVATION.

THE AQUEDUCT COMMISSIONERS
ELEVATION AND SECTIONS
OF
AUXILIARY EARTH DAM
RESERVOIR "D"
CARMEL
PUTNAM COUNTY N.Y.

SCALE

A. PARKER
ENGINEER IN CHARGE

3
This drawing is from Reports on the New Aqueduct Reservoirs for the City of New York Commission. (1856)

SECTION.

AVATION ON CENTER LINE.

EARTH ROLLED IN 6" LAYERS

SLOPE 2.36:1
This drawing is reproduced from Reports on the New Croton Aqueduct Reservoirs and Dams to the City of New York Aqueduct Commission. (1887-1895)
PLAN
AUXILIARY DAM
RESERVOIR D.
SHOWING
SECTIONS AND
DRAINAGE TRENCHES
The letters in parenthesis indicate the locations of observations listed in Chapter 3.1.
DOWNSTREAM SLOPE AND GATEHOUSE
(CARMEL MAIN DAM)

LEFT EMBANKMENT PORTION
(CARMEL MAIN DAM)
VIEW OF EMBANKMENT, SPILLWAY AND GATEHOUSE FROM THE UPSTREAM DIRECTION
(CARMEL MAIN DAM)

DISCHARGE CONDUIT AND TAILRACE CHANNEL
(CARMEL MAIN DAM)
DOWNSTREAM SLOPE OF SPILLWAY SHOWING SEEPAGE FLOW [OBSERVATION (L)] (CARMEL MAIN DAM)

UPSTREAM SLOPE PROTECTION. SOME VEGETATION GROWTH IS SHOWN. [OBSERVATION (A)] (CARMEL MAIN DAM)
DAMAGE TO UPSTREAM SLOPE PROTECTION
LEFT OF SPILLWAY WALL [OBSERVATION (G)]
(CARMEL MAIN DAM)

SEEPAGE FLOW AT ABUTMENT CONTACT
OF LEFT EMBANKMENT [OBSERVATION (B)]
(CARMEL MAIN DAM)
SPI LLWAY CREST, DISLOCATED STONES OF THE UPPER TWO COURSES AND SEEPAGE FLOW ARE SHOWN [OBSERVATIONS (M) AND (L)]
(CARMEL MAIN DAM)
GENERAL VIEW OF AUXILIARY DAM AND OUTLET FOUNTAIN
VIEW OF EMBANKMENT AND GATEHOUSE FOR THE UPSTREAM DIRECTION
(AUXILIARY DAM)

VIEW OF EMBANKMENT, GATEHOUSE AND SHAFT 10
FROM THE UPSTREAM DIRECTION
(AUXILIARY DAM)
ENGINEERING DATA CHECKLIST

APPENDIX C
### CHECKLIST

**ENGINEERING DATA**

**DESIGN, CONSTRUCTION, OPERATION**

**PHASE I**

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#### NAME OF DAM

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#### ID # |

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#### AS-BUILT DRAWINGS

- *see Drawing List*

#### REGIONAL VICINITY MAP

- USGS maps: Lake Carmel, Greenwood Lake, Poughkeepsie, and Hopewell Junction quadrangles - 7.5 minute series 1:24,000

#### CONSTRUCTION HISTORY

- Some materials together with construction photographs is included in the Agreemant Commission Report 1887-95.

#### TYPICAL SECTIONS OF DAM

- *shown in the available drawings*

#### OUTLETS-PLAN

- *details*

#### CONSTRAINTS

- *details*

#### DISCHARGE RATING

- 3 pages out of 6 of the spillway rating have been found.

#### RAINFALL/RESERVOIR RECORDS

- Daily record is available in the Hudson District Office of Bows
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<td>MATERIALS INVESTIGATIONS</td>
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<td>BORING RECORDS</td>
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<td>MONITORING SYSTEMS</td>
<td>3 piezometers in the main dam and 3 in auxiliary dam. They had been placed in the early 1920s. The piezometers are not in use.</td>
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<td>MODIFICATIONS</td>
<td>The top two rings of stones at the spillway crest have been replaced.</td>
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<td>--------------------------------</td>
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<td>PLANS &amp; DETAILS</td>
<td>available drawings</td>
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</table>
VISUAL INSPECTION CHECKLIST

APPENDIX D
VISUAL INSPECTION CHECKLIST

1. Basic Data
   a. General
      Name of Dam ___________ Hazard Category ___________
      County ___________ ID# ___________
      Stream Name ___________ Tributary of ___________
      Location ___________ County Nearest Town (P.O.) ___________
      Longitude ___________ Latitude ___________ Other Directions ___________
      Date of Insp ___________ Weather ___________ Temperature ___________

   b. Inspection Personnel
      ___________

   c. Persons Contacted
      ___________

   d. History:
      Date Constructed ___________
      Present Owner ___________
      Designed by ___________
      Constructed by ___________

2. Technical Data
   Type of Dam ___________
   Drainage Area ___________
   Height ___________
   Length ___________
   Upstream Slope ___________
   Downstream Slope ___________
   Crest Width ___________
   Freeboard at Spillway Crest ___________
Low Level Control: (Type and Size) Approx. 15 foot 6 ft by 12 ft
Valve Condition
Emergency Spillway Type (Material) Wearing surface, Width 260 ft
Side Slopes As shown on drawings
Height (Crest to Top)
Exit Slope
Exit Length
Ponded Surface Area Acres
Capacity (Normal Level) Acre Feet
Capacity Emergency Spillway Level Acre Feet

3. Embankment

a. Crest

(1) Vertical Alignment No noticeable deviation

(2) Horizontal Alignment

(3) Longitudinal Surface Cracks None evident

(4) Transverse Surface Cracks

(5) General Condition of Surface General up to maintenance

(6) Miscellaneous

1955 flood.
b. Upstream Slope

Undesirable Growth or Debris

Some at a few locations

(2) Sloughing, Subsidence, or Depressions

Depression in the riprap on both slopes adjacent to spillway outlets

(3) Slope Protection

Head surface of stone in excellent condition except at noted

(a) Condition of Riprap

(b) Durability of Individual Stones

Highly durable

mostly medium grade

(c) Adequacy of Slope Protection Against Waves and Runoff

Satisfactory

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

Smaller stones only occasionally - one such area main damage at that

(4) Surface Cracks

ue heard inside brick in main alignment slope protection

Right of spillway, 50 ft.

c. Downstream Slope

(1) Undesirable Growth or Debris

Well maintained area - some small

small areas of additional growth in main
dam
(2) Sloughing, Subsidence, or Depressions; Abnormal Bulges or Non-Uniformity

Some irregularities near toe of main dam where the material is wet--on both right and left sides.

(3) Surface Cracks on Face of Slope

None evident

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

None except the minor irregularities mentioned in (2)

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

Wet areas at the lower abutment portion of main dam--right and left side. Water seepage on the left side.

(6) Fill Contact with Outlet Structure

No problems evident

(7) Condition of Grass Slope Protection

Generally well maintained.

d. Abutments

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

Minor erosion at left mile, downstream slope of abutment dam.

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

Spring and seepage at left abutment main dam. Spring enclosed in a brick vault at right abutment seepage dam. This vault is part of the foundation drainage system at outer edge dam.
(3) Springs or Indications of Seepage in Areas a Short Distance Downstream of Embankment - Abutment Tie-in

Some wet areas at both dams - no springs or seepage. Water in flowing out from the foundation drains may flow to auxiliary drain.

e. Area Downstream of Embankment, Including Tailrace Channel

Well established stream bed at main dam, heavy vegetation growth downstream of auxiliary dam.

(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.

No unusual vegetation

(4) Unusual Mu'dy Water in Downstream Channel

No

(5) Sloughing or Erosion

No major areas

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

None
(7) Stability of Tailrace Channel Sideslopes
   No major concerns or stability problems noted.

(8) Condition of Tailrace Channel Riprap
   No riprap.

(9) Adequacy of Slope Protection Against Waves, Currents and Surface Runoff
   Adequate for normal discharges.

(10) Miscellaneous
     Some debris on the stream downstream of the dam.

f. Drainage System
    Drainage system appears to be in good condition.

(1) Condition of Relief Wells, Drains and Appurtenances
    The drainage system requires cleaning and removal of sand and debris.

(2) Unusual Increase or Decrease in Discharge from Relief Wells
    No relief wells.

4. Instrumentation

(1) Monumentation/Surveys
   No periodic surveys.
(2) Observation Wells

None

(3) Weirs

None

The existing drainage system had

premises but these are not in

operational condition now.

(4) Piezometers

3 on main dam and 3

on auxiliary dam. These standpipe

piezometers have been placed in

1920-5. The piezometers are not in use.

(Other)

5. Reservoir

a. Slopes

16 ft 8 in. of 18.25%
b. Sedimentation

No indication of excessive sedimentation.

6. Spillways

a. Principal Spillway: Inlet Condition

Pipe Condition

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

After 1950 water was no longer discharged over the spillway because the conduit system was enlarged and became possible to rerun and replace the two masonry courses which were probably in fair shape after 35 years of service.

b. Emergency Spillway: General Condition

The stepped downstream surface of the spillway appeared in satisfactory condition despite pronounced downstream curvature of the top masonry course near the middle and some leakage from the joints of these top courses. Water flowing down the stepped surface was difficult to determine whether there was any additional leakage from the joints of the lower courses.

Holes for flashboards were visible but are no longer used. 1/2" steel rods are also visible on the top stones at irregular intervals. They are probably used as anchors tying the new masonry course to those below. No drawings or details of rods are available.

7. Structural (if required) See Attached Appendix

Stability calculations are not required for Phase I Dam Inspection.
8. Downstream Channel

a. Condition (obstructions, debris, etc.) The downstream channel of the main dam is mostly clear and appears in good condition. There was no accumulation of debris in the channel. Water was being discharged into the channel to supply the local water requirements.

b. Slopes

c. Approximate No. Homes and Population

d. General

Katman Szalay
TEAM CAPTAIN
STRUCTURAL INSPECTION CHECKLIST

PHASE I DAM INSPECTION

1. Concrete Surfaces
   - Earth fill with center masonry core. There are no exposed concrete surfaces. The spillway walls and downstream face are lined with masonry blocks. The stream bed below the spillway is merely protected by heavy paving. The masonry facing appears in good condition.

2. Structural Cracking
   - No structural cracking is visible.

3. Movement - Horizontal and Vertical Alignment
   - There is no apparent change in either the horizontal or vertical alignment of the spillway except for the top masonry courses which have curved slightly downstream because of ice pressure.

4. Junctions with Abutments or Embankments
   - There is a cut through both upstream and downstream recession at the junction of the spillway and the main embankment.

5. Drains - Foundation, Joint, Face
   - No drains under the spillway structure are visible or indicated on the drawings.

6. Water Passages, Conduits, Sluices
   - In addition to the sluice taking thru the joints of the uppermost masonry courses, water is discharged from the Gate House into the channel which leads into the West Branch of the Grotto River.

7. Seepage or Leakage
   - There is some leakage from the joints of the top masonry courses especially near the middle of the spillway.

8. Monolith Joints - Construction Joints
   - There are no concrete structures - no monolith joints or construction joints.

9. Foundation
   - No apparent problem. Stone facing at downstream base of spillway is sound and shows no sign of movement or cracking.
10. Abutments  
There are no structural (concrete) abutments.

11. Control Gates  
There are no structural control gates on the spillway.  
There is a gate house on the left side of the spillway, which has  
both upstream and downstream regulation (see fig.)

12. Approach and Outlet Channels  
Water leaking thru the spillway falls on heavy stone steps contained between curved wingwalls. The  
streambed directly downstream is protected by heavy paving.

13. Stilling Basin  
- There is no stilling basin.

14. Intake Structure  
There is no intake structure. The gate house  
has upstream regulation (two 24” x 60” manually  
operated sluice gates.

15. Settlement  
No apparent or significant settlement  
of the spillway structure.

16. Stability  
No stability computations are available  
for the spillway structure.

   a. Overturning  
   b. Sliding  
   c. Seismic  
   After 80 years of operation - none

17. Instrumentation  
Seem necessary.

   a. Alignment  
   b. Uplift  
   c. Seismic

18. Miscellaneous  
Check lower portion of downstream  
spillway face for leaks at masonry joints when reservoir  
level is much below the crest.

   Existing leakage should be observed regularly to see  
whether flow is increasing.
HYDROLOGIC DATA AND COMPUTATIONS

APPENDIX E
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**Spillway Rating - Length = 260'**

**Water Supply**

C. From King's Harbor

**Flows of Record**

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<td>Oct 16, 1953</td>
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**Note:**

This page is best quality practicably from copy furnished to E&DQ.
APPENDIX F

REFERENCES

1. Edward Wegmann: The Design and Construction of Dams, John Wiley and Sons (1918)


4. R. C. Haven - Saturation of Existing Earth Dams, USBR Technical Memorandum 389, Pages 94-103 (1934)


7. C. P. Berkey: Geology of the New York City (Catskill) Aqueduct New York State Museum Bulletin 146, Page 283 (1911)


