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NATIONAL DAM SAFETY PROGRAM. MIDDLESEX RESERVOIR DAM (NJ-00377)--ETC(U)
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1 OF 2
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RAHWAY RIVER BASIN

ROBINSONS BRANCH, SUSSEX COUNTY

NEW JERSEY

MIDDLESEX RESERVOIR DAM

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

LEVEL II

NJ 00377

DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
CUSTOM HOUSE - 2D & CHESTNUT STREETS
PHILADELPHIA, PENNSYLVANIA 19106

AUGUST 1978

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

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Middlesex Reservoir Dam
Sussex County, N.J.

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Box 280
Beaver, Pa. 15009

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18. SUPPLEMENTARY NOTES

Copies are obtainable from National Technical Information Service, Springfield, Virginia, 22151.

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

This report cites results of a technical investigation as to the dam's adequacy. The inspection and evaluation of the dam is as prescribed by the National Dam Inspection Act, Public Law 92-367. The technical investigation includes visual inspection, review of available design and construction records, and preliminary structural and hydraulic and hydrologic calculations, as applicable. An assessment of the dam's general condition is included in the report.

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DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
CUSTOM HOUSE—2D & CHESTNUT STREETS
PHILADELPHIA, PENNSYLVANIA 19106

IN REPLY REFER TO

NAPEN-D

Honorable Brendan T. Byrne
Governor of New Jersey
Trenton, New Jersey 08621

19 SEP 1978

Dear Governor Byrne:

Inclosed is the Phase I Inspection Report for Middlesex Reservoir Dam in Sussex County, New Jersey which has been prepared under authorization of the Dam Inspection Act, Public Law 92-367. A brief assessment of the dam's condition is given on the first four pages of the report.

Based on visual inspection, available records, calculations and past operational performance, Middlesex Reservoir Dam, a high hazard potential structure, is judged to be in fair overall condition. However, the dam's spillway is considered inadequate since 42 percent of the Probable Maximum Flood (PMF) would overtop the dam. To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. The spillway's adequacy should be determined by a qualified professional consultant, engaged by the owner, using more sophisticated methods, procedures and studies initiated within one month and completed within six months from the date of approval of this report. The effects of and on the Garden State Parkway structures should be included in the analysis. Any remedial measures necessary to insure the adequacy of the spillway and to prevent overtopping should be initiated within calendar year 1979. In the interim, detailed emergency operation, drawdown and evacuation plans and a warning system, should be promptly developed. Also, during periods of unusually heavy precipitation, around-the-clock surveillance should be provided.

b. Within one year from the date of approval of this report, the owner should thoroughly examine the dam and abutment areas for evidence of any seepage that may occur during normal and high reservoir levels. Should the owner detect any seepage, it is recommended that he engage a qualified engineer to examine and evaluate the significance of the seepage. Any remedial measures found necessary should be initiated within calendar year 1979.

c. Within six months from the date of approval of this report, the following actions should be taken.

(1) Repairs must be made to the spalled, cracked and deteriorated gunite, and concrete surfaces of the spillway weir, downstream spillway face, spillway wing walls, concrete outlet apron and spillway upstream approach slab.

(2) A portion of the deteriorated concrete grouted stone paving on the upstream side of the spillway should be removed and replaced, and the undermined area of the two feet wide spillway approach slab should be repaired.

(3) The slight undermining of the right wall of the discharge channel should be backfilled with concrete or cement grout.

(4) Low areas of the embankment crest and eroded spots must be filled in and revegetated.

(5) The badly deteriorated and failed slope paving on the embankment upstream slope should be replaced or covered with rip-rap, or an alternate means of protection should be developed to protect the embankment slope. The corrective solution for this problem should be engineered.

(6) All wood, debris and trash which is present in the spillway apron area and outlet channel should be promptly removed and properly disposed of.

d. Within one year from the date of approval of this report, the following actions should be taken.

(1) In the spillway discharge channel, placement of additional large rip-rap in scoured areas is recommended.

(2) The left side slope of the discharge channel should be graded to a flatter slope to prevent erosion and sloughage, and the slope toe should be protected with properly engineered rip-rap.

(3) The right eroded discharge channel bank should be graded and revegetated or alternately protected with rip-rap.

(4) Bare eroding areas near the outlet pipe outfall and left abutment reservoir slope should be treated and seeded.

(5) Brush and trees on the embankment and adjacent to the abutments should be removed, and all resultant bare spots should be revegetated.

(6) A groundhog hole in the embankment should be filled.

NAPEN-D
Honorable Brendan T. Byrne

e. It is strongly recommended that the level of maintenance of the dam and appurtenances be upgraded, and that formal periodic inspections be implemented.

A copy of the report is being furnished to Mr. Dirk C. Hofman, New Jersey Department of Environmental Protection, the designated State Office contact for this program. Within five days of the date of this letter, a copy will also be sent to Congressman Matthew Rinaldo of the Twelfth District. Under the provisions of the Freedom of Information Act, the inspection report will be subject to release by this office, upon request, five days after the date of this letter.

Additional copies of this report may be obtained from the National Technical Information Services (NTIS), Springfield, Virginia, 22161 at a reasonable cost. Please allow four to six weeks from the date of this letter for NTIS to have copies of the report available.

An important aspect of the Dam Safety Program will be the implementation of the recommendations made as a result of the inspection. We accordingly request that we be advised of proposed actions taken by the State to implement our recommendations.

Sincerely yours

1 Incl
As stated

JOEL T. CALLAHAN
Lieutenant Colonel, Corps of Engineers
Acting District Engineer

Cy furn:
Mr. Dirk C. Hofman, P.E., Deputy Director
Division of Water Resources
N. J. Dept. of Environmental Protection
P.O. Box 2809
Trenton, NJ 08625

MIDDLESEX RESERVOIR DAM (NJ00377)

CORPS OF ENGINEERS ASSESSMENT OF GENERAL CONDITIONS

This dam was inspected on 21 June 1978 by Michael Baker, Jr., Inc. Consulting Engineers under contract to the U. S. Army Engineer District, Philadelphia, in accordance with the National Dam Inspection Act, Public Law 92-367.

The Middlesex Reservoir Dam, a high hazard potential structure, is judged to be in fair overall condition. However, the dam's spillway is considered inadequate since 42 percent of the Probable Maximum Flood (PMF) would overtop the dam. To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. The spillway's adequacy should be determined by a qualified professional consultant, engaged by the owner, using more sophisticated methods, procedures and studies initiated within one month and completed within six months from the date of approval of this report. The effects of and on the Garden State Parkway structures should be included in the analysis. Any remedial measures necessary to insure the adequacy of the spillway and to prevent overtopping should be initiated within calendar year 1979. In the interim, detailed emergency operation, drawdown and evacuation plans and a warning system, should be promptly developed. Also, during periods of unusually heavy precipitation, around-the-clock surveillance should be provided.

b. Within one year from the date of approval of this report, the owner should thoroughly examine the dam and abutment areas for evidence of any seepage that may occur during normal and high reservoir levels. Should the owner detect any seepage, it is recommended that he engage a qualified engineer to examine and evaluate the significance of the seepage. Any remedial measures found necessary should be initiated within calendar year 1979.

c. Within six months from the date of approval of this report, the following actions should be taken.

(1) Repairs must be made to the spalled, cracked and deteriorated gunite, and concrete surfaces of the spillway weir, downstream spillway face, spillway wing walls, concrete outlet apron and spillway upstream approach slab.

(2) A portion of the deteriorated concrete grouted stone paving on the upstream side of the spillway should be removed and replaced, and the undermined area of the two feet wide spillway approach slab should be repaired.

(3) The slight undermining of the right wall of the discharge channel should be backfilled with concrete or cement grout.

(4) Low areas of the embankment crest and eroded spots must be filled in and revegetated.

(5) The badly deteriorated and failed slope paving on the embankment upstream slope should be replaced or covered with rip-rap, or an alternate means of protection should be developed to protect the embankment slope. The corrective solution for this problem should be engineered.

(6) All wood, debris and trash which is present in the spillway apron area and outlet channel should be promptly removed and properly disposed of.

d. Within one year from the date of approval of this report, the following actions should be taken.

(1) In the spillway discharge channel, placement of additional large rip-rap in scoured areas is recommended.

(2) The left side slope of the discharge channel should be graded to a flatter slope to prevent erosion and sloughage, and the slope toe should be protected with properly engineered rip-rap.

(3) The right eroded discharge channel bank should be graded and revegetated or alternately protected with rip-rap.

(4) Bare eroding areas near the outlet pipe outfall and left abutment reservoir slope should be treated and seeded.

(5) Brush and trees on the embankment and adjacent to the abutments should be removed, and all resultant bare spots should be revegetated.

(6) A groundhog hole in the embankment should be filled.

e. It is strongly recommended that the level of maintenance of the dam and appurtenances be upgraded, and that formal periodic inspections be implemented.

APPROVED: Joel T. Callahan

JOEL T. CALLAHAN
Lieutenant Colonel, Corps of Engineers
Acting District Engineer

DATE: 19 September 1978

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam - Middlesex Reservoir Dam, Union County, New Jersey
Stream - Robinsons Branch of the Rahway River
Date of Inspection - 21 June 1978

ASSESSMENT OF GENERAL CONDITIONS

Middlesex Reservoir Dam consists of a 400 feet long earth embankment, a 149.3 feet long concrete ogee spillway, and a gate house with outlet works. It is owned and maintained by the Middlesex Water Company for use as an emergency or supplemental public water supply.

The visual inspection and review of engineering data, made during June to August 1978, indicate that deficiencies exist in the dam to a degree warranting prompt action; although emergency attention is not required. In general, the dam is evaluated as being in fair condition. It is recommended, that the following repairs or work items be performed promptly by the owner. Repairs must be made to the spalled, cracked and deteriorated gunite, and concrete surfaces of the spillway weir, downstream spillway face, spillway wing walls, concrete outlet apron and spillway upstream approach slab. A portion of the deteriorated concrete grouted stone paving on the upstream side of the spillway should be removed and replaced, and the undermined area of the two feet wide spillway approach slab should be repaired. The slight undermining of the right wall of the discharge channel should be backfilled with concrete or cement grout. Low areas of the embankment crest and eroded spots must be filled in and revegetated. The badly deteriorated and failed slope paving on the embankment upstream slope should be replaced or covered with riprap, or an alternate means of protection should be developed to protect the embankment slope. The corrective solution for this problem should be engineered.

Additional work items or repairs are recommended, as follows, and should be accomplished by the owner in the near future. In the spillway discharge channel, placement of additional large riprap in scoured areas is recommended. The left side slope of the discharge channel should be graded to a flatter slope to prevent erosion and sloughage, and the slope toe should be protected with properly engineered riprap. The right eroded discharge channel bank should be graded and revegetated or alternately protected with riprap. Bare eroding areas near the outlet pipe outfall and left abutment reservoir slope should be treated and seeded. Brush and

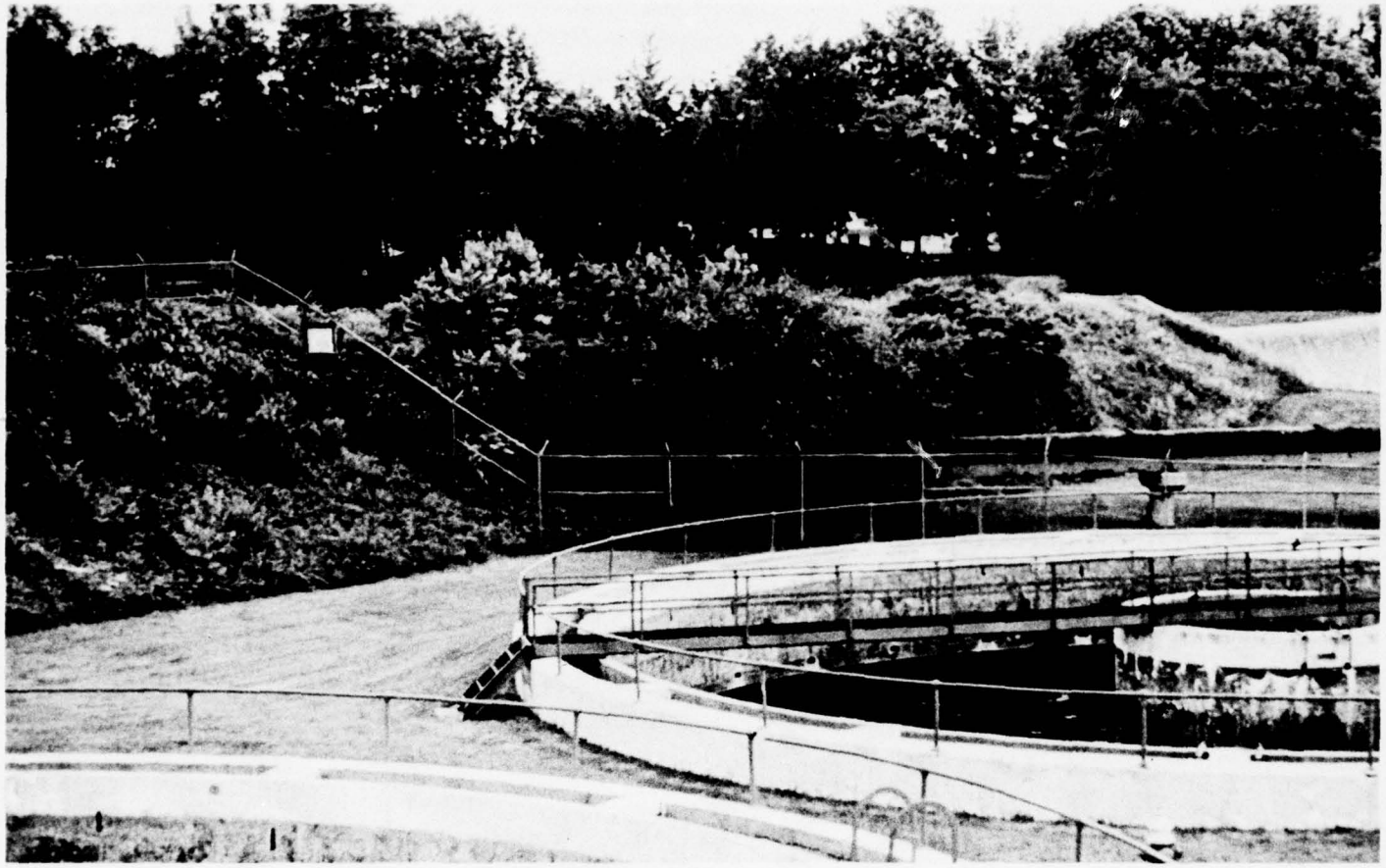
trees on the embankment and adjacent to the abutments should be removed, and all resultant bare spots should be revegetated. A groundhog hole in the embankment should be filled. It is strongly recommended that the level of maintenance of the dam and appurtenances be upgraded, and that formal periodic inspections be implemented. Inspections of the dam and abutment areas for any evidence of seepage should be done in the near future when normal and high reservoir levels are present.

The hydraulic/hydrologic evaluations performed in accordance with established Corps of Engineers procedures for Phase I Inspection Reports revealed that the spillway will not pass the Probable Maximum Flood without overtopping the dam. The analysis did not take into account the flood attenuation effects of the Garden State Parkway embankment and bridge across the reservoir, upstream from the dam. However, the flood attenuation effect of the parkway is considered to be significant; and therefore, the owner should immediately undertake an engineering investigation of this. If the investigation shows that the parkway will not prevent overtopping, it is recommended that the owner have further engineering investiation performed immediately to develop remedial measures to reduce the overtopping potential of the dam. It is further recommended that the owner immediately start work on developing emergency operation and, in cooperation with local authorities, evacuation procedures.

MICHAEL BAKER, JR., INC.

Michael Baker, III, P.E.
Chairman of the Board and
Chief Executive Officer
Registration Number 13385

NAME OF DAM: MIDDLESEX RESERVOIR DAM



OVERALL VIEW OF DAM

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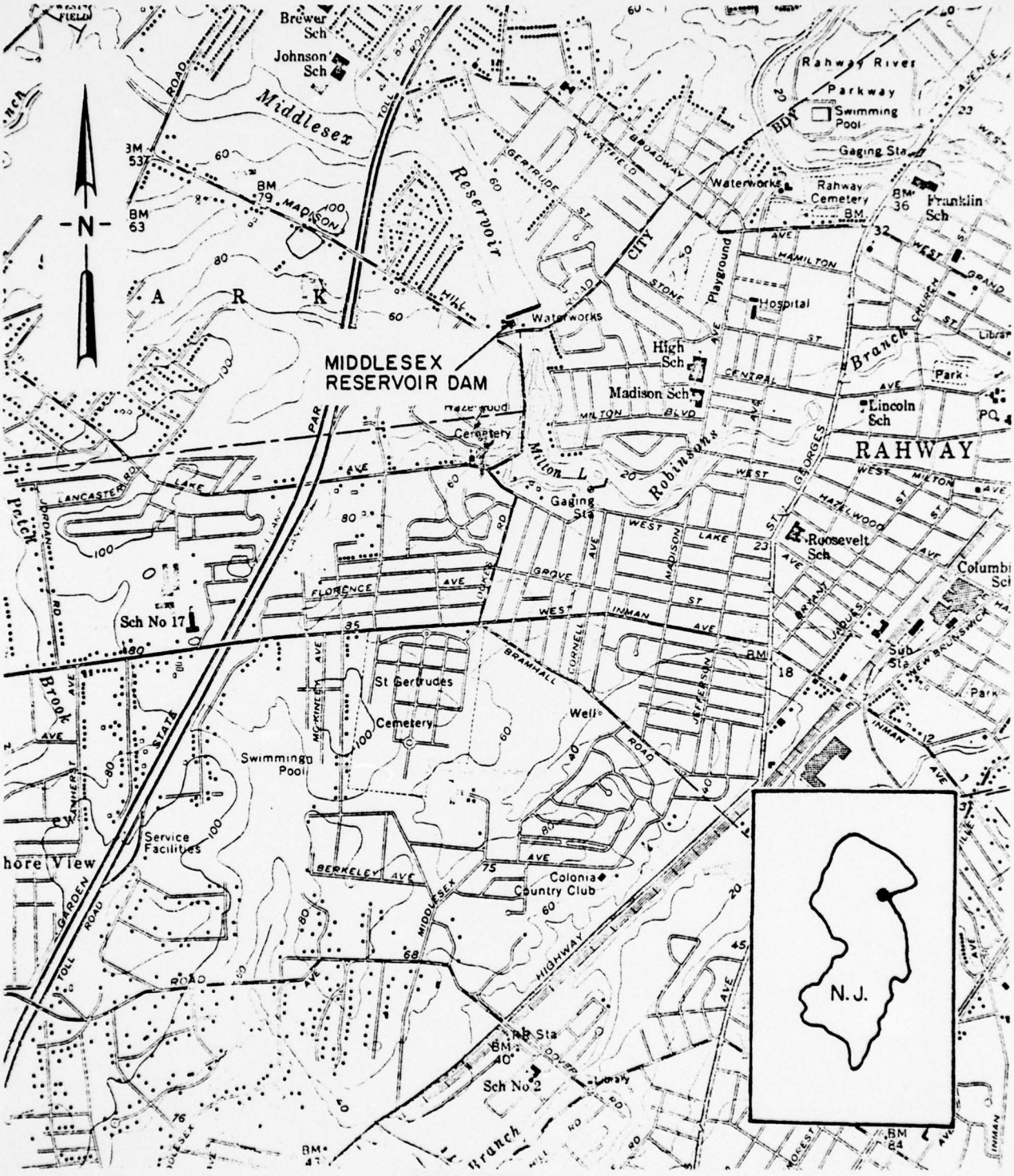


LOCATION PLAN

MIDDLESEX RESERVOIR DAM

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
NAME OF DAM: MIDDLESEX RESERVOIR DAM, ID# NJ 00377

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority - This report is authorized by the National Dam Inspection Act, Public Law 92-367, 92nd Congress, H.R. 15951 enacted 8 August 1972 and has been prepared in accordance with Contract No. DACW61-78-C-0141 between Michael Baker, Jr., Inc., and the U.S. Army Corps of Engineers, Philadelphia District.

b. Purpose of Inspection - The purpose of this inspection is to evaluate the general condition of Middlesex Reservoir Dam with respect to safety of the facility based upon available data and visual inspection.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances - The Middlesex Reservoir Dam, constructed in 1907 and 1908, consists of a homogeneous earth embankment with a concrete ogee spillway. The dam with crest El. 50.0 feet has a maximum height of 27 feet and a length of 595 feet. However, due to the placement of an extensive nearly level fill to approximately El. 34.0 feet between the dam and Madison Hill Road (see Plate 1) the exposed height of the embankment on the downstream side is now only about 16 feet. The upstream and downstream embankment slopes are approximately two horizontal to one vertical (2:1). Seepage control is provided by a concrete core wall extending down to top of bedrock beneath both the earth embankment and concrete spillway according to the drawings provided to Michael Baker, Jr., Inc. by the owner's representative. These drawings are presented as Plates 1 through 4. An ogee type spillway with a crest elevation of 44 feet, or six feet lower than top of dam, is located at the left end of the dam. The spillway was measured to have a crest length of 149.3 feet. Outlet works consisting of a 24 inch diameter reinforced concrete pipe extends from the gate house at the right abutment to the discharge channel immediately north of the Madison Hill Road bridge. A total of six additional gates are located in the gate house (see Plate 3) which were provided to convey water to the public water supply treatment plant constructed immediately south of the earth dam.

b. Location - The Middlesex Reservoir Dam is located on Robinsons Branch of the Rahway River approximately two miles upstream from its confluence with the Rahway River, in Clark Township, Union County, New Jersey.

c. Size Classification - The maximum height of the dam is 27 feet and the reservoir volume to the top of the dam is 2090 acre-feet. Therefore, the dam is in the "Intermediate" size category as defined by the "Recommended Guidelines for Safety Inspection of Dams."

d. Hazard Classification - Due to the proximity of the town of Rahway, New Jersey with a population of about 29,000, many lives could be lost in the event of failure of the dam. Therefore, this dam is considered in the "High" risk category as defined by the "Recommended Guidelines for Safety Inspection of Dams."

e. Ownership - The dam is owned by the Middlesex Water Company, One Woodbridge Center, Woodbridge, New Jersey 07095.

f. Purpose of Dam - The dam is presently used as a standby emergency or supplemental public water supply.

g. Design and Construction History - The existing facility was designed for the prior owner, Consumers Aquaduct Company, by Earlet Harrison Engineers. The dam was built during the period 1907-1908. The area between the dam and Madison Hill Road was later filled in to allow construction of the water treatment plant which was in more or less continuous operation until 1969.

h. Normal Operational Procedures - Since 1969, the normal operating procedure has been to keep the reservoir full as a standby public water supply, and no attempts are made to regulate the pool elevation by opening the sluice gates. During August 1971, however, the reservoir was used to supply Elizabethtown, New Jersey, with four million gallons of water over a one week period when their water treatment plant was flooded as a result of Hurricane Doria. Sporadically, the reservoir is drawn down to perform limited maintenance.

1.3 PERTINENT DATA

a. Drainage Area - The drainage area of Robinsons Branch of the Rahway River upstream from the dam is 19.1 square miles.

b. Discharge at Damsite - The maximum known flow at the damsite is unknown.

c. Elevation [feet above Mean Sea Level (M.S.L.)] -

Design Top of Dam (Spillway Capacity) - 50.0 (8966 c.f.s.)
Normal Pool - 44.0
Streambed at Centerline of Dam - 23 (as shown on Plate 2)
Maximum Tailwater - Not available

d. Reservoir (miles) -

Length of Maximum Pool - Could not be determined with available information.
Length of Normal Pool - 2.31

e. Storage (acre-feet) -

Top of Dam (El. 50.0) - 2090
At Spillway Crest (El. 44.0) - 1470

f. Reservoir Surface (acres) -

Top of Dam - Approximately 114
Spillway Crest - Approximately 92

g. Dam -

Type - Homogeneous earthfill with concrete core wall extended down to bedrock
Total Length - 590 feet
Maximum Height - 27 feet
Top Width - 10 feet
Side Slopes - Upstream - 2:1
Downstream - 2:1
Impervious Core - Concrete core wall
Cutoff - Core wall extends down to shale bedrock

h. Diversion and Regulating Tunnel - None

i. Spillway -

Type - Concrete ogee
Length of Weir - 149.3 feet
Crest Elevation - 44.0 feet (M.S.L.)
Gates - None
Downstream Channel - Riprap protection

j. Regulating Outlet - 24 inch concrete pipe from gate chamber discharges into the downstream channel; flow regulated by manually operating sluice gate from gate chamber.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

The design data available for review consisted of the drawings of the dam and appurtenances presented as Plates 1, 2 and 3, and borings made in the vicinity of the dam presented on Plate 4. These plates were reproduced from prints of drawings provided by the owner. Correspondence from the owner's files and from the New Jersey Department of Environmental Protection (N.J.D.E.P.) files was also reviewed. However, no design data was available from N.J.D.E.P., nor from the owner, except for the plates included in this report and the reference data in Appendix C.

2.2 CONSTRUCTION

The Middlesex Reservoir Dam and appurtenances were constructed during 1907 to 1908. No record of any problems that might have occurred during their construction was available for this investigation. After construction of the dam, the extensive area between the dam and Madison Hill Road was filled in and regraded. The water treatment facilities (visible in the Overall View of Dam) were then constructed on the fill, which is nearly level. Settling basins were constructed in this area after World War I, and a new pump station was built in the early 1960's.

2.3 POST-CONSTRUCTION INSPECTION AND ENGINEERING

Because of the application of gunite to the concrete spillway and wing walls in 1939, it is believed that an inspection of the concrete surfaces at that time must have revealed some deterioration.

An inspection of the dam was also performed by the N.J.D.E.P. on 16 December 1971. The very brief inspection report, provided by the owner, stated, "The dam appeared to be in good condition and no seepage was found." No other inspection reports or engineering data were available for this Phase I investigation, except for a copy of a 1924 New Jersey, Reference Data card obtained from the owner and reproduced as Appendix C.

2.4 OPERATION

As owner of the dam, Middlesex Water Company is responsible for the operation and maintenance of the dam and appurtenances. There were no records available pertaining to operations, maintenance, lake levels or discharges. However, flows have been recorded since about 1974 at the U.S.G.S. gaging station at Milton Lake Dam located one-half mile downstream.

2.5 EVALUATION

Little design information was available for review and evaluation. Although it would be desirable to have more information for review, the information available is believed to be adequate for this Phase I investigation, especially since the facility has functioned in a satisfactory manner for the past 70 years.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General - The dam and its appurtenant structures were found to be in fair overall condition at the time of inspection. The problems noted during the visual inspection are considered significant and do require remedial treatment without undue delay. Noteworthy deficiencies observed are described briefly in the following paragraphs. The complete visual inspection check list is given in Appendix A.

b. Dam - Erosion and possibly a small amount of settlement of the embankment has occurred behind the spillway right wing wall causing the top of dam to be 0.7 foot lower than constructed. The erosion, up to two feet deep, continues down the upstream slope adjacent to the wing wall. The embankment adjacent to the right abutment wall at the gate house also appeared to be low by approximately one-half foot. The concrete slope paving on the upstream side of the embankment is badly deteriorated. Many sections of concrete are broken up and have settled due, probably, to erosion from wave action.

Disintegration and settlement of the concrete slope protection is especially severe 50 feet from the spillway, as shown in Photo 9. Near the right abutment a groundhog burrow was observed that extended under the concrete pavement. Numerous small trees and brush are present on the embankment crest and slopes.

During the visual inspection the reservoir had been drawn down to approximately El. 36.7 so that the owner could perform maintenance on the dam, including the cutting of small trees and brush and removal of debris. During this inspection no seepage or evidence of prior seepage was observed. However, some seepage may occur when the reservoir is at normal pool or higher elevations.

c. Appurtenant Structures - The gate house (which contains sluice gates for diverting water to the water treatment plant and a gate for draining the reservoir) appeared to be functioning normally during the visual inspection. Some minor cracking and spalling of the gate house concrete walls and right abutment wing wall were observed.

The spillway located at the left abutment was observed to be in fair overall condition. However, numerous deficiencies were observed. The approach slope to the spillway (upstream side) which appears to be concrete grouted stone paving has been eroded away at midspan exposing the underlying soil. Between this slope and the weir crest, there exists a two feet wide concrete approach slab which was cracked and slightly settled. At midspan of the spillway this slab was undermined by erosion. The spillway, which was gunited in 1939, showed several areas where the gunite coating has spalled off. One of the minor spalled areas was at the weir crest near the right spillway wall. The spillway face and downstream apron showed several spalled areas of gunite, one as large as three feet wide by seven feet long by one and one-half inches deep. Several cracks, approximately one-sixteenth of an inch wide were also observed in the gunite spillway face and downstream apron. Several spalled areas and cracks were noted to be linear and parallel to the direction of flow, and they may reflect construction or monolithic joints in the original concrete. Hairline fractures were noted throughout the spillway gunite.

The left and right spillway walls were noted to have hairline fractures throughout the gunited surfaces. Some leaching of calcite was observed from the gunite on the left spillway wall. However, the right spillway wall showed other defects including a one-half inch wide crack across the top of the wall which has apparently been caused by differential settlement. Substantial spalling of the gunite has also occurred on this wing wall.

Immediately downstream from the spillway apron there is located a small concrete wall on the right side of the discharge channel. The wall was observed to be slightly out of alignment, probably due to earth pressure. This wall also appeared to be slightly undermined by scour up to four inches over a length of 20 feet.

Examination of the outlet structure near Madison Hill Road, which consists of a 24 inch concrete pipe outfall and concrete head wall with wings, revealed no obvious problems, except that a small section of the adjacent upstream bank was barren of any vegetation and eroding.

d. Reservoir Area - The reservoir area including the side slopes was examined during the visual inspection. No significant sedimentation of the reservoir could be seen, even though the reservoir had been drawn down seven feet in order for the owner to perform maintenance. Most of the side slopes are moderately to slightly sloping, and a good vegetative cover consisting of trees and grass is established. One eroded bank as steep as 1.5:1 was noted, however, immediately upstream from the left abutment spillway wall.

e. Spillway Discharge Channel - The spillway discharge channel was observed to be lined with large riprap, but some of it has been scoured out immediately downstream from the concrete apron and at approximately 150 feet downstream from the spillway. A considerable amount of wood and trash was present on the apron and immediately downstream in the discharge channel.

Some erosion of the discharge channel left side slope was observed. This slope, approximately 100 feet downstream from the spillway, is a maximum of about 26 feet high with a slope ration of 1:1. Because of the steepness of the slope, sloughage is occurring. Erosion of the approximately four feet high bank on the right side of the discharge channel is also occurring.

3.2 EVALUATION

a. Dam - The erosion and possible settlement adjacent to the right spillway wall and near the gate house pose a threat to overtopping during large flood flows. If the condition at the spillway right wing wall were left uncorrected, it could worsen to the point where early overtopping could occur.

The severe deteriorated condition of the upstream embankment slope paving, likewise, does not at present create a serious threat to the stability of the dam; but this condition must be corrected to prevent further erosion of the embankment slope which could become serious in time.

Removal of trees and brush, and repair of all bare areas should be performed to prevent possible future leakage through decayed root systems and to prevent erosion of the dam.

Since the reservoir was drawn down during the visual inspection, it is not possible to conclude with certainty that some seepage would not occur during high reservoir levels. Therefore, further inspection of the dam is considered necessary to determine if seepage does occur at normal or high pool levels.

b. Appurtenant Structures - The cracks and local spalling of the concrete surfaces of the gate house are not evaluated as requiring repair work at this time since they are not considered serious enough to endanger the integrity of the dam. However, the cracks and spalled areas will likely become more significant in time and should be periodically examined.

With regard to the spillway and adjacent walls, discharge apron, and upstream paving; the prompt repair of all deficiencies noted in paragraph 3.1.c. and the visual inspection check list are considered necessary to prevent further deterioration, except for repair of hairline fractures. Work considered necessary includes the repair of spalled gunite, cracks, undermined areas and replacement of badly deteriorated concrete sections. Repair and revegetation of bare and eroded areas adjacent to appurtenant structures is also necessary to prevent the serious consequences of overtopping and to insure that they function as intended.

c. Reservoir Area - The erosion of the reservoir bank near the left abutment was not considered a serious condition endangering the dam; but this erosion should be checked to prevent development of a more serious problem in the future.

d. Spillway Discharge Channel - To insure that further scour of the channel bottom does not occur, the placement of additional larger riprap in the scour areas is considered necessary. Grading of the left channel slope to a flatter slope ratio and protecting the lower portion of this slope with riprap, or by other means, is considered necessary to stabilize the bank and help prevent possible landslides into the channel which might otherwise occur from future erosion of the channel side slope. Although the erosion of the right outlet channel side slope is not a serious problem, prevention of further erosion is desirable.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

Presently, the normal operating procedure is to keep the reservoir full as a standby or emergency water supply source. No attempts are made to regulate the reservoir level since, according to the owner, the dam is for water supply purposes and not for flood control.

There is no formal written procedure for emergency downstream evacuation in the event of impending catastrophy; however, local civil defense and police authorities would be notified if such a failure was determined to be imminent. It is considered necessary that a formal emergency procedure be prepared and prominently displayed, and furnished to appropriate personnel, particularly to the owner's watchman who visits the dam daily.

4.2 MAINTENANCE OF DAM

Maintenance of the dam is the responsibility of the owner, the Middlesex Water Company. It is apparent that structural maintenance has not been performed for many years. However, the owner had performed some maintenance just before the Phase I visual inspection which included removal of some debris and the cutting of brush and trees on a portion of the embankment.

4.3 MAINTENANCE OF OPERATING FACILITIES

According to the owner, the facilities in the gate house and pump station are maintained as necessary so that the reservoir can serve as an emergency or supplemental public water supply if needed.

4.4 EVALUATION

As a result of the visual Phase I inspection, the current ongoing maintenance practice for the dam is concluded to be inadequate, and should be upgraded and improved.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data - There were no design data available for review and evaluation.

b. Experience Data - There were no experience data available for review and evaluation. However, according to the owner's representative, the dam has never been overtopped to their knowledge.

c. Visual Observations - A significant amount of debris had collected in the outlet channel below the spillway apron. Also, considerable erosion had taken place in this area. It appeared that the spillway would function properly, but repair and maintenance work should be performed to minimize further deterioration. The drawdown facility appeared to operate properly. The reservoir was being drained at time of inspection in order for the Middlesex Water Company to perform maintenance. No evidence of overtopping flood flow damage was noted during the visual inspection.

d. Overtopping Potential - The Middlesex Reservoir Dam is classified as a "High" hazard-"Intermediate" size dam requiring evaluation for a spillway design flood equal to the Probable Maximum Flood (P.M.F.). The spillway consists of an ogee type shaped overfall 149.3 feet wide at El. 44.0. The spillway rating curve was developed in accordance with the procedures in Design of Small Dams, a U.S. Bureau of Reclamation publication. The rating, as developed, shows the maximum discharge at top of dam El. 50.0 to be 8966 c.f.s. Design plans and field measurements were used for spillway dimensions. However, the calculations were based on the assumption that the low spots of the embankment crest will be filled in to the top of dam design El. 50.0 feet.

The hydrologic analysis of the Middlesex Reservoir Dam was completed using the procedures outlined in Design of Small Dams, for rainfall-runoff characteristics, EM-1110-2-163, for rainfall-time distribution patterns, and the HEC-1 Flood Hydrograph Package, for unit hydrograph determination by Clark's Method. Coefficients for Clark's Method were obtained from the "Hydraulic and Hydrologic Simulation of the Rahway River Basin" by the U.S.

Army Corps of Engineers. The hydrologic analysis contained herein does not include an evaluation of the flood peak attenuation effects of the Garden State Parkway which crosses the reservoir 0.6 mile upstream. The hydrologic analysis indicates a peak discharge flow of 22,800 c.f.s. for the peak discharge of the P.M.F.

Using the routing option of HEC-1, the P.M.F. was routed through the dam and found to overtop the embankment. The spillway therefore, according to the criteria specified in "Recommended Guidelines for Safety Inspections of Dams" and this preliminary analysis, is considered to be inadequate. In order to access the degree of inadequacy, a flood of magnitude equal to one-half P.M.F. was routed and was also found to overtop the dam. Based upon these routings, it was estimated the dam will pass approximately 41 percent of the P.M.F. if the Garden State Parkway is not considered, but assuming that the low spots of the embankment crest will be filled in to the top of dam design El. 50.0 feet. However, it is believed that the parkway will cause storage of additional water in the upper portion of the reservoir and result in a significant reduction of the calculated one-half P.M.F. peak flow at the dam. For this reason, Michael Baker, Jr., Inc. concludes that the spillway should not be considered "seriously inadequate."

e. Emergency Drawdown - A 24 inch reinforced concrete pipe has been provided to draw down the reservoir. Sluice gates in the gate chamber are operated from the gate house to release this flow. With the reservoir filled to top of dam, the peak discharge through the outlet pipe, if opened, is estimated to be 57 c.f.s. and approximately 36 days would be required to drain the reservoir assuming no stream inflow. If the reservoir level is at elevation 44 feet, the maximum flow rate through the outlet pipe would be about 50 c.f.s. and approximately 30 days would be required to drain the reservoir.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations - The low area of the embankment adjacent to the right abutment could develop into a stability problem by eroding the embankment during a major flood, if remedial measures are not performed. Additionally, further deterioration of the concrete spillway, as a result of continuous flow over the weir and natural weathering effects, could eventually cause a failure if repairs are not made.

b. Design and Construction Data - The limited data available for review indicates that there should be no cause for concern for the structural stability of the earth embankment, spillway and appurtenances.

c. Operating Records - Since no operating records are available, an evaluation in this area could not be made.

d. Post-Construction Changes - The placement of the extensive nearly level fill between the dam and Madison Hill Road should have had the effect of increasing dam stability. The gunite coating applied to the spillway and wing walls in 1939 has helped reduce deterioration of the underlying concrete. The construction of the 24 inch sanitary sewer across the downstream face of the embankment is not considered to have significantly affected the stability of the dam.

e. Seismic Stability - Middlesex Reservoir Dam is located in Seismic Zone 1 according to the "Seismic Zone Map of the Continguous United States" given in Figure 1, page D-30, "Recommended Guidelines for Safety Inspection of Dams." This is a zone of very low seismic activity. Experience indicates that dams in Seismic Zone 1 will have adequate stability under seismic loading conditions if they have adequate stability under static loading conditions. As indicated in paragraph 6.1.b., Middlesex Reservoir Dam is considered to have adequate static stability; consequently, further consideration of seismic stability is not considered necessary for this Phase I Inspection Report.

SECTION 7 - ASSESSMENT, RECOMMENDATIONS/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety - The deficiencies noted in paragraph 3.1. and their evaluation in paragraph 3.2. reveal that the Middlesex Reservoir Dam is in need of a substantial amount of repair work and maintenance.

The dam which is in the "High" hazard-"Intermediate" size category requires a spillway capacity equal to the P.M.F. in accordance with the "Recommended Guidelines for Safety Inspection of Dams." As presented in paragraph 5.1.d., the spillway will pass only approximately 41 percent of the P.M.F. and is therefore considered to be inadequate. However, this analysis did not take into account the flood attenuation effects that would occur from impoundment of water against the Garden State Parkway bridge and embankments across the reservoir. It is not known how much reduction there would be in the peak P.M.F. discharge at the dam because of the parkway, but the reduction is believed to be substantial.

As a result of this Phase I investigation, it is believed that the dam is not in imminent danger of failure. However, it is concluded that the ability of the spillway to carry very large flood flows can be questioned, and therefore the safety of the dam during major floods is in doubt.

b. Adequacy of Information - In general, the information available for this Phase I investigation, although limited, is considered adequate, except that more detailed hydraulic and hydrologic data is needed to assess more accurately the spillway capacity and peak P.M.F. flow at the dam.

c. Urgency - The repair and maintenance work as well as other recommendations contained in paragraph 7.2 should be implemented without delay. The priorities for performing the recommended items of work are also indicated.

d. Necessity for Further Investigation - Further hydrologic investigation of this dam by the owner is considered necessary. The investigation should be directed initially toward the flood attenuation effects of the Garden State Parkway bridge and

embankment to determine if they would prevent overtopping of the dam, and toward more accurately determining the spillway capacity using more detailed hydraulic and hydrologic data.

7.2 RECOMMENDATIONS/REMEDIAL MEASURES

The visual inspection, review of available information and hydraulic/hydrologic analyses performed reveal that the following studies and repairs should be implemented by the owner. These recommendations are as follows:

1) It is recommended that the owner immediately engage a qualified engineer with experience in dams, bridges and hydraulics/hydrology to promptly perform the following additional investigations:

   a) Determine the flood attenuation effects of the Garden State Parkway bridge and embankments, and determine if the attenuation effects will prevent overtopping of the Middlesex Reservoir Dam. This investigation should include a detailed analysis of hydraulic and hydrologic factors using more precise and sophisticated methods of analysis.

   b) If appropriate, evaluate the structural ability of the bridge and embankments to resist lateral flood pressures, and the ability of the highway embankments to resist erosion during peak P.M.F. flow conditions.

   c) If it is determined that the Garden State Parkway will not significantly reduce the peak P.M.F. flow at the dam, or if the stability of the Parkway bridge or embankments can not be relied upon; further engineering study will be necessary to develop recommendations for the dam for remedial action. It should be noted that modifications to the spillway or dam, if required, may aggravate upstream or downstream flooding during high flows. This should be taken into account in the investigation.

2) It is recommended that formal emergency procedures be promptly prepared, and prominently displayed and furnished to all appropriate personnel. Work on developing the emergency procedures should begin immediately. The formal emergency procedures should include the following:

   a) Procedures for rapid drawdown of the reservoir under emergency conditions.

   b) Who to notify, including public officials, in case evacuation from the downstream area is necessary.

   c) The owner should assist public officials in developing an emergency evacuation plan for areas which will be affected in the event of a dam failure.

3) It is recommended that extensive repairs be made promptly to all spalled, cracked and deteriorated gunite and exposed concrete surfaces on the spillway weir, downstream face of the spillway, spillway wing walls, concrete outlet apron, and spillway upstream approach slab. (Repair of hairline fractures on the gunite surfaces is not considered necessary at this time.) In addition, it is recommended that a section of the concrete grouted stone paving on the upstream side of the spillway--where the underlying earth is exposed--should be promptly removed and replaced. The central portion of the two feet wide spillway approach slab which is undermined by scour should be promptly backfilled with concrete and all cracks repaired. The slightly undermined section of discharge channel right concrete wall (just downstream from the spillway right wing wall) should also be promptly backfilled with concrete or cement grout. All repair work included in this Recommendation No. 3 should be accomplished by a contractor experienced in such repairs.

4) It is recommended that all low and eroded areas of the embankment be promptly filled in, graded, treated, and seeded with an appropriate seeding mixture to prevent further erosion. Particular attention should be

given to filling in the low areas adjacent to the right spillway wall and at the crest adjacent to the gate house so as to minimize the overtopping potential. These low areas should be filled in to the top of dam design elevation and verified by instrument surveying.

5) The severely deteriorated and failed concrete slope paving on the upstream embankment slope should be promptly replaced or covered with riprap. Alternately, some other effective means of protecting the embankment slope may be devised and implemented. Regardless of which corrective measure is taken, the solution to this problem must be properly engineered.

6) All wood, debris and trash which is present in the spillway apron area and outlet channel should be promptly removed and properly disposed of.

The inspection of the dam also revealed other items of work which should be performed by the owner in the near future. These are recommended below as follows:

1) Several items of work are recommended for the spillway discharge channel. Specifically, low areas in the channel bottom where riprap has been scoured out should be filled in with large riprap. The steep, eroding left channel side slope with sloughage should be regraded to a flatter slope followed by proper soil treatment and seeding to prevent erosion. The toe of the left channel side slope should be stabilized to prevent scour by placing properly engineered riprap. The relatively minor bank erosion of the right channel slope should be graded, treated and seeded with an appropriate seeding mixture to prevent further erosion. Alternately, properly designed riprap may be placed for protection.

2) Other areas which are bare and eroding such as the left reservoir bank near the spillway wing wall and the slope adjacent to the pipe outlet structure should be properly treated and seeded to prevent erosion.

3) It is recommended that the owner thoroughly examine the dam and abutment areas for evidence of any seepage that may occur during normal and high reservoir levels. Should the owner

detect any seepage, it is recommended that he engage a qualified engineer to examine and evaluate the significance of the seepage. Appropriate engineered corrective measures should be taken to control or prevent seepage if this is found to be necessary.

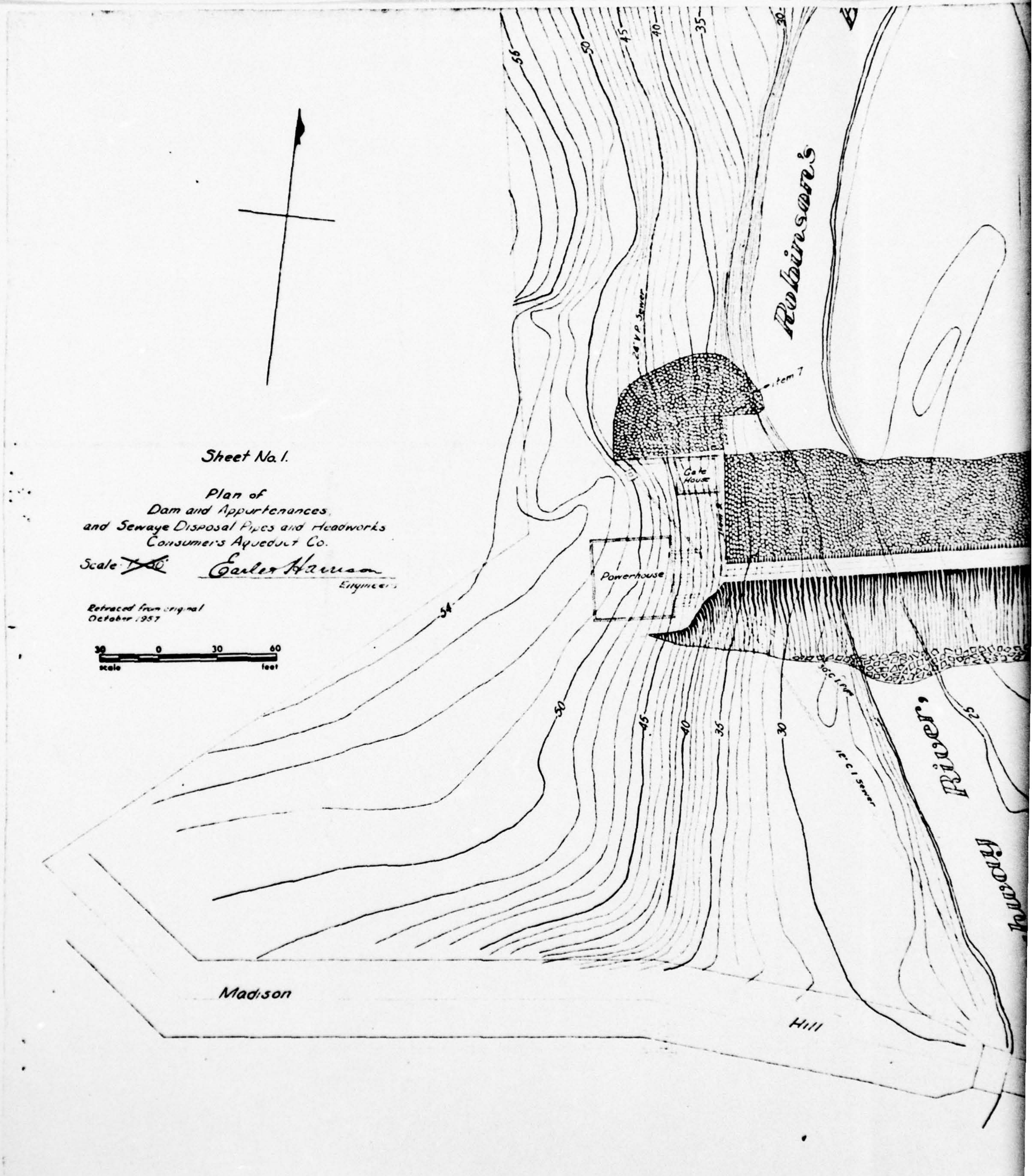
4) All brush and trees on the embankment and adjacent to the abutments should be removed, and any bare areas that may result from this work should be properly treated and seeded to prevent erosion. Periodic mowing of the grass should be performed.

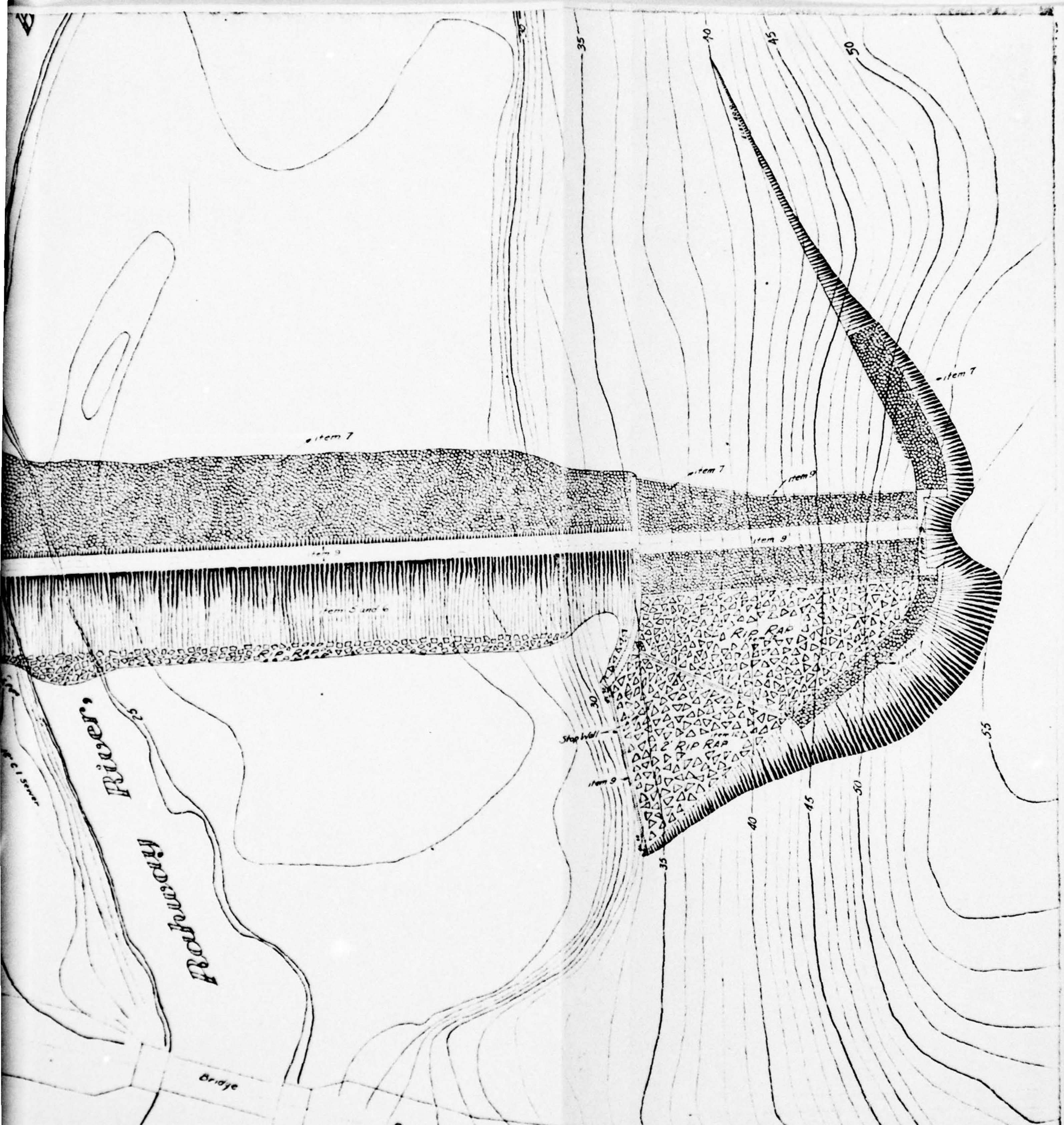
5) The groundhog burrow extending under the slope paving near the gate house should be filled in with compacted earth.

Finally, it is strongly recommended that the general level of maintenance of the dam and appurtenances be upgraded and that formal periodic inspections be conducted by the owner.

PLATES

Note: The following plates were reproduced from drawings provided by the Middlesex Water Company.

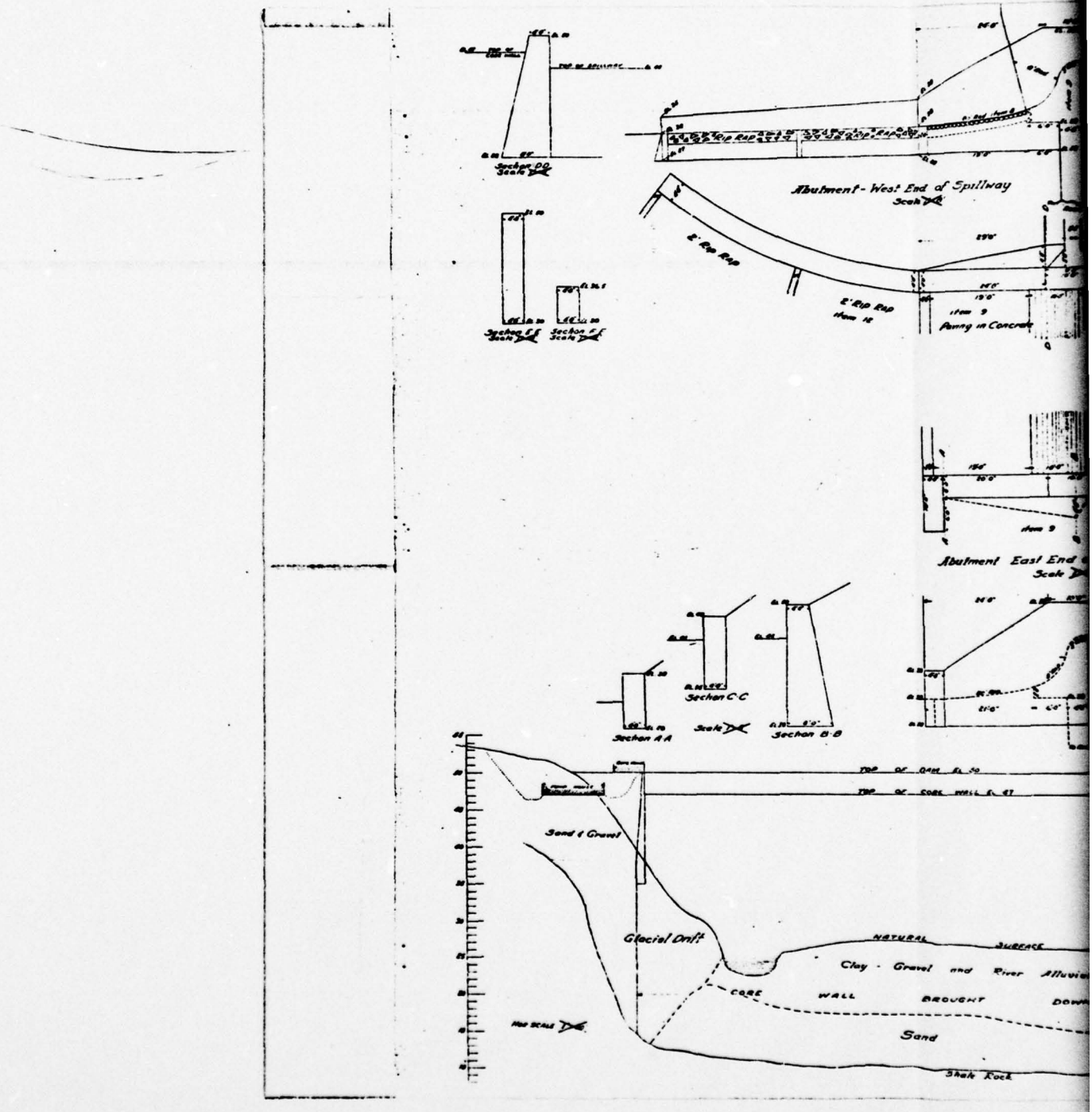

Sheet No. 1.
Plan of
Dam and Appurtenances,
and Sewage Disposal Pipes and Headworks
Consumers Aqueduct Co.
Scale
Earle Harrison
Engineers
Retraced from original
October 1957
30 0 30 60
scale feet
Robinson's
River,
Madison
Hill
Gate House
Powerhouse
Item 7
24" V.P. Sewer
12" C.I. Sewer
55
50
45
40
35
30
54
25

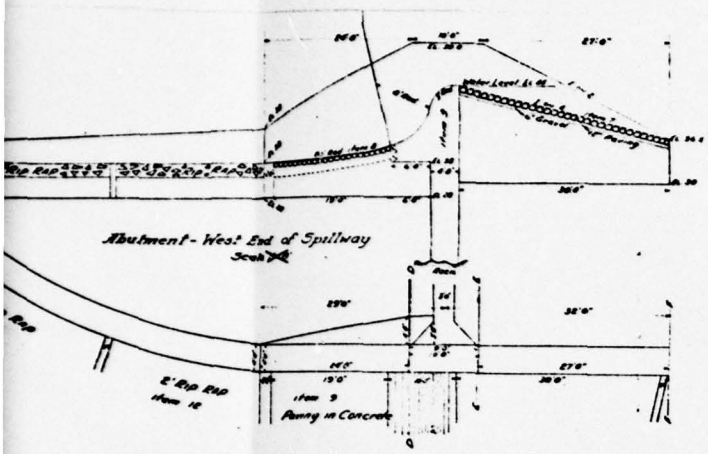


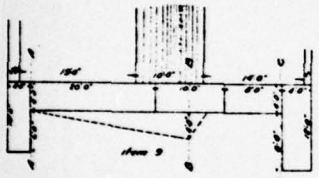
MIDDLESEX RESERVOIR DAM

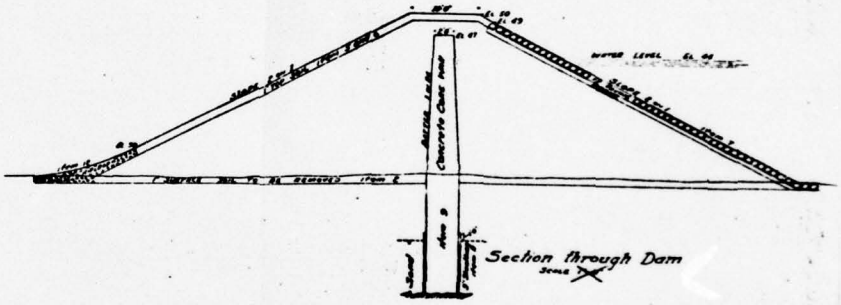
PLATE 1

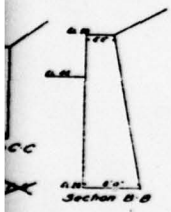
2

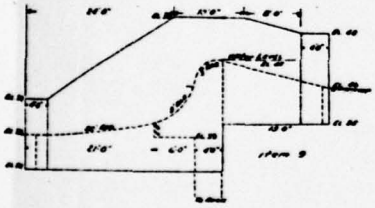

Section DD
Scale
Section EE
Scale
Section FF
Scale
Abutment - West End of Spillway
Scale
2' Rip Rap
2' Rip Rap
Item 12
Item 9
Paving in Concrete
Item 9
Abutment East End
Scale
Section CC
Section AA
Scale
Section BB
TOP OF DAM EL 50
TOP OF CORE WALL EL 47
Sand & Gravel
Glacial Drift
NATURAL SURFACE
Clay - Gravel and River Alluvi
CORE WALL BROUGHT DOWN
Sand
Shale Rock
Hor SCALE

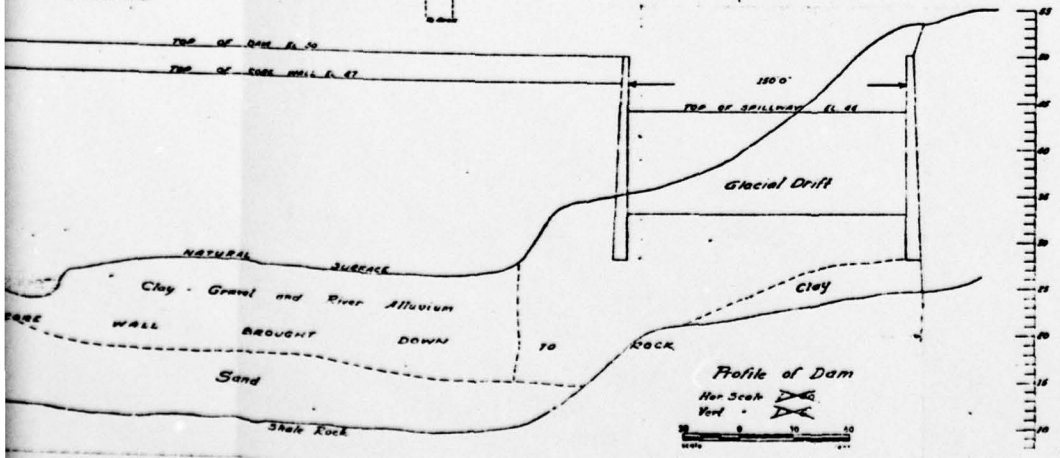












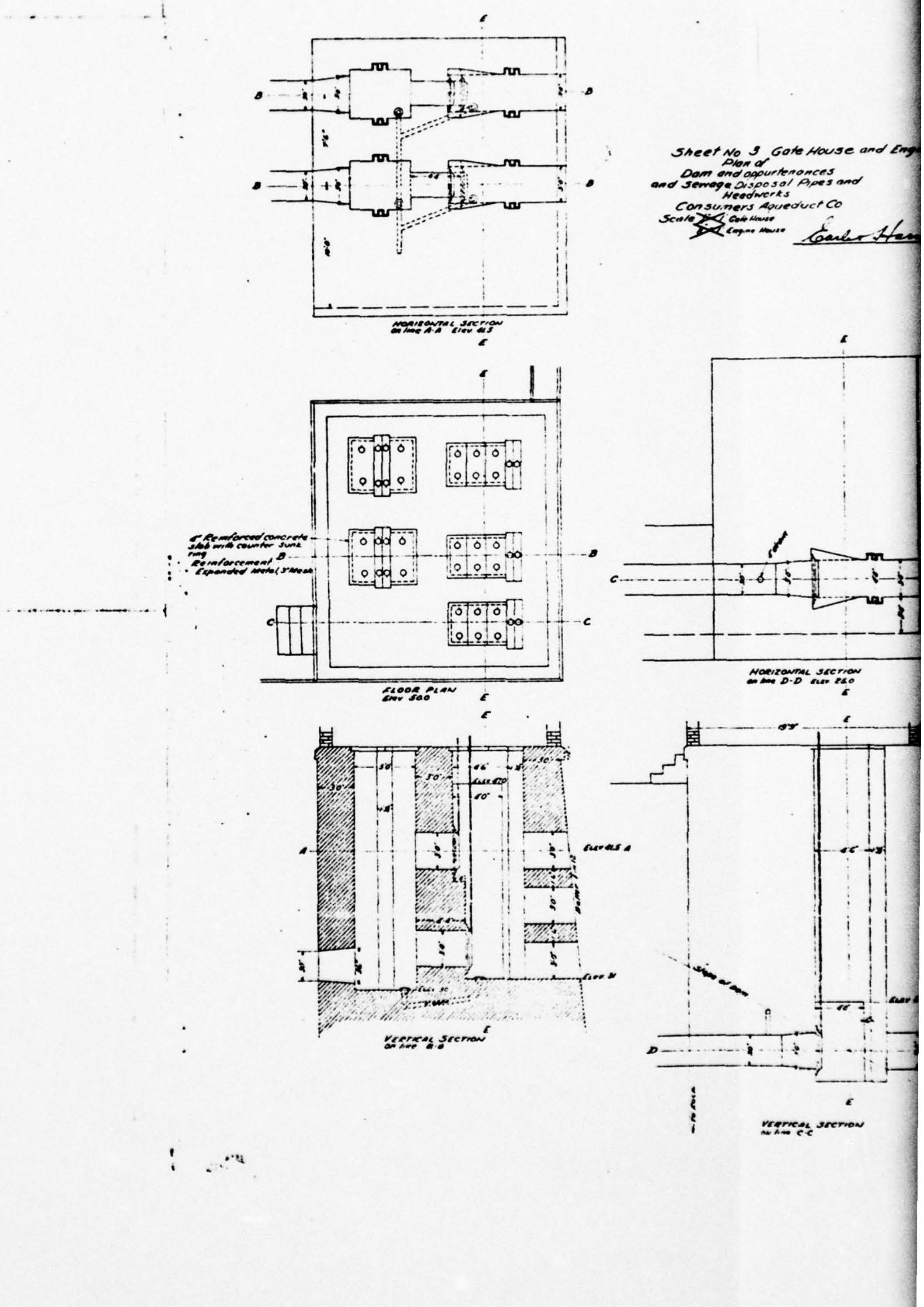
Sheet No 2
Details of Dam & Spillway
Plan of
Dam and Appurtenances
and Sewage Disposal Pipes and Headworks
Consumers Aqueduct Co.

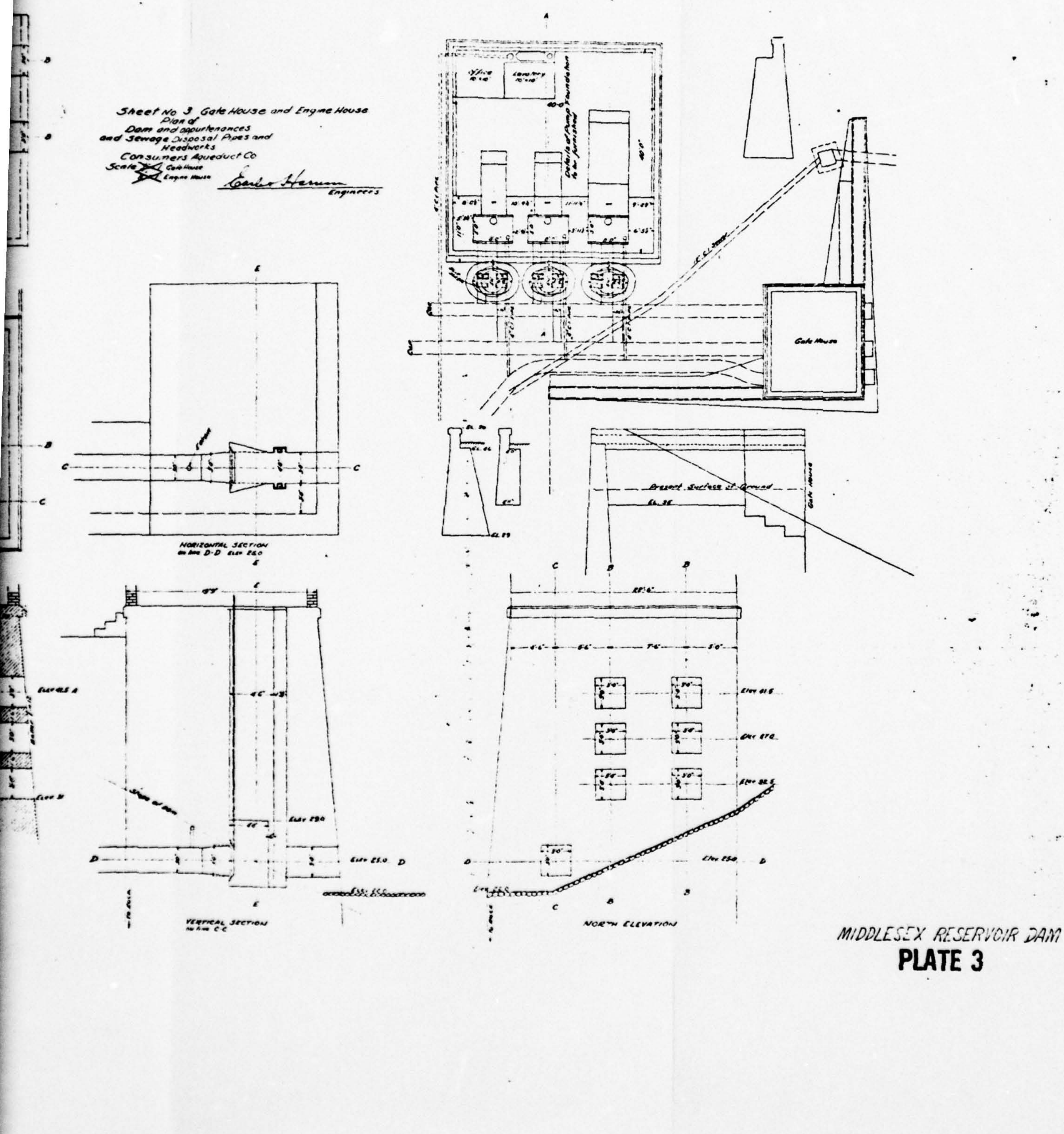
Engineer

MIDDLESEX RESERVOIR DAM

PLATE 2

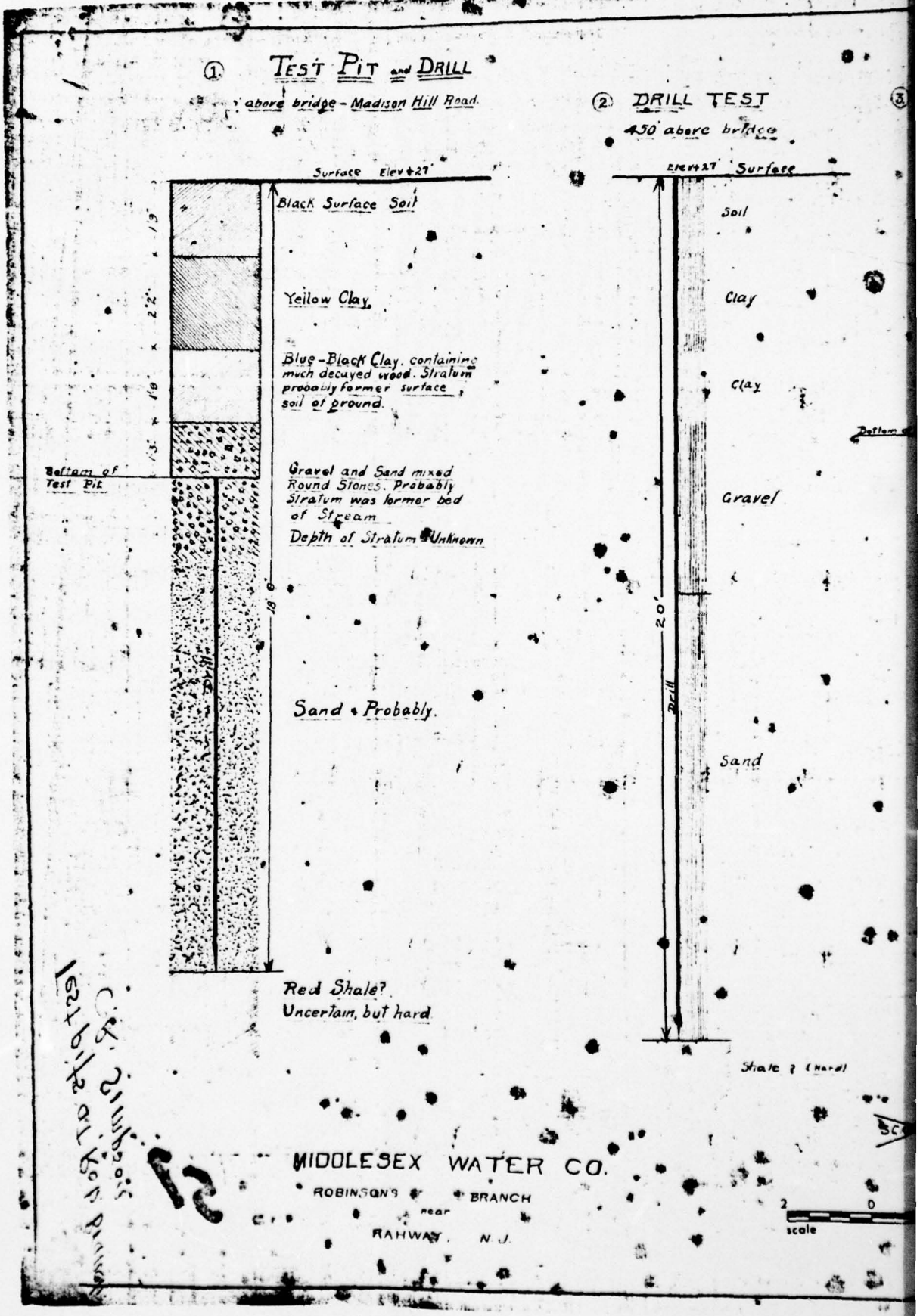
2

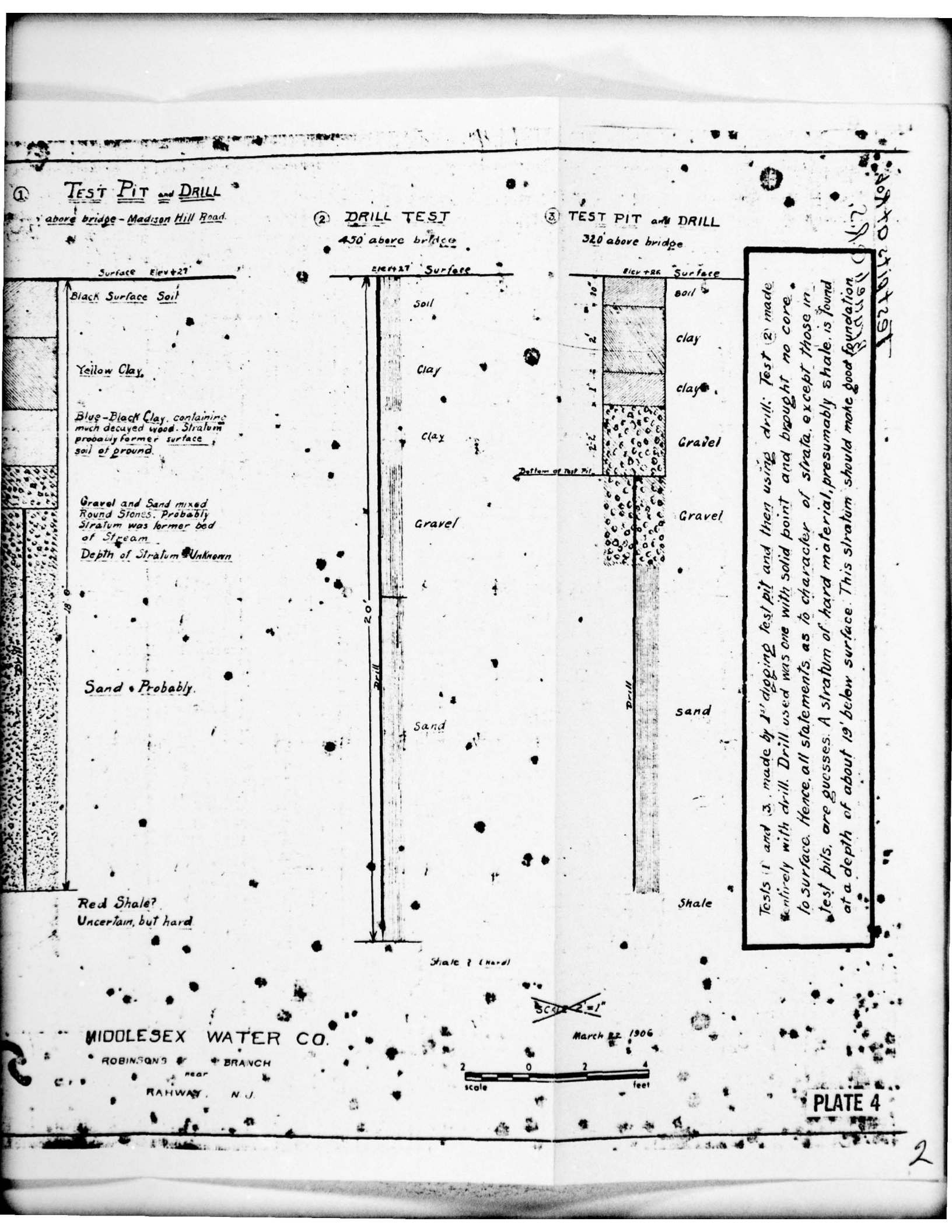

Sheet No 3 Gate House and Eng
Plan of
Dam and appurtenances
and Sewage Disposal Pipes and
Headworks
Consumers Aqueduct Co
Scale
Gate House
Engine House
HORIZONTAL SECTION
on line A-A Elev 61.5
6" Reinforced concrete
slab with counter sunk
ring
Reinforcement
Expanded Metal (3" Mesh
FLOOR PLAN
Elev 50.0
HORIZONTAL SECTION
on line D-D Elev 26.0
VERTICAL SECTION
on line B-B
VERTICAL SECTION
on line C-C



MIDDLESEX RESERVOIR DAM
PLATE 3

2


① TEST PIT and DRILL
' above bridge - Madison Hill Road.
Surface Elev +27'
Black Surface Soil
Yellow Clay.
Blue-Black Clay, containing much decayed wood. Stratum probably former surface soil of ground.
Bottom of Test Pit
Gravel and Sand mixed Round Stones. Probably Stratum was former bed of Stream.
Depth of Stratum Unknown
18'6"
Sand, Probably.
Red Shale?
Uncertain, but hard
② DRILL TEST
450' above bridge
Elev +27' Surface
Soil
Clay
Clay
Bottom
Gravel
20'
Drill
Sand
Shale ? (Hard)
MIDDLESEX WATER CO.
ROBINSON'S BRANCH
near
RAHWAY, N.J.
2 0
scale


① TEST PIT and DRILL
abore bridge - Madison Hill Road.
Surface Elev +27'
Black Surface Soil
Yellow Clay.
Blue-Black Clay, containing much decayed wood. Stratum probably former surface soil of ground.
Gravel and Sand mixed Round Stones. Probably Stratum was former bed of Stream
Depth of Stratum Unknown
18'
Sand. Probably.
Red Shale?
Uncertain, but hard
② DRILL TEST
450' above bridge
Elev +27' Surface
Soil
Clay
Clay
Gravel
20'
Drill
Sand
Shale ? (Hard)
③ TEST PIT and DRILL
320' above bridge
Elev +26 Surface
Soil
clay
clay
Gravel
Bottom of Test Pit
Gravel
Drill
sand
Shale
Tests 1 and 3, made by 1st digging test pit and then using drill. Test (2) made entirely with drill. Drill used was one with solid point and brought no core to surface. Hence, all statements as to character of strata, except those in test pits, are guesses. A stratum of hard material, presumably shale, is found at a depth of about 19' below surface. This stratum should make good foundation.
Scale 1"=1'
March 22, 1906
MIDDLESEX WATER CO.
ROBINSONS BRANCH
near
RAHWAY, N.J.
2 0 2 4
scale feet
PLATE 4

PHOTOGRAPHS

DETAILED PHOTOGRAPH DESCRIPTIONS

Overall View of Dam - Looking Toward Northeast at Embankment and Spillway at Far Right (Water Treatment Tanks Are in Foreground; Note Sanitary Sewer Supported on Small Bridge at Right) - 21 June 1978.

Photo 1 - View of Concrete Overflow Spillway and Riprap in Foreground - 21 June 1978.

Photo 2 - Picture of Spillway Concrete Approach Slab on Upstream Side (Top) and Deteriorated Concrete Grouted Stone Paving Spillway Approach Slope (Foreground) Which Has Eroded Out Causing Underming of Concrete Approach Slab - 21 June 1978.

Photo 3 - Spalled Area on Spillway Concrete Apron Near Right Wing Wall - 21 June 1978.

Photo 4 - View of Right Wing Wall Showing Gunite Repair and Deteriorated Concrete Below Gunite (Note Eroded Surface of Upstream Embankment Slope and Remains of Concrete Slope Paving on Embankment Slope) - 21 June 1978.

Photo 5 - Picture of Spillway Right Wing Wall With Spalling of Gunite and Concrete Apron in Foreground (Debris Is Located at Edge of Concrete Apron) - 21 June 1978.

Photo 6 - Downstream Embankment Slope Partially Covered With Brush and Small Trees (View Is Toward East or Toward Spillway Not Visible in Picture) - 21 June 1978.

Photo 7 - Looking West Across Crest of Embankment Toward Gate House at Right AButment (Note Small Trees and Brush on Embankment) - 21 June 1978.

Photo 8 - Picture of Deteriorated Concrete Slope Paving on Upstream Side of Embankment (View Is Toward East or Toward Spillway) - 21 June 1978.

Photo 9 - Failed Section of Embankment Concrete Slope Paving Within 50 Feet of Spillway Right Wing Wall - 21 June 1978.

Photo 10 - Overall View of Outlet Channel Showing Debris in Foreground and Sanitary Sewer Bridging Stream Channel - 21 June 1978.

Photo 11 - Close-Up of Riprap and Debris Immediately Downstream From Concrete Apron - 21 June 1978.

Photo 12 - View of Steep (1:1) Outlet Channel Slope With Sloughage (Note Corner of Left Wing Wall and Debris in Foreground) - 21 June 1978.

Photo 13 - Steep Outlet Channel Slope (1:1) With Sloughage (Slope Is Approximately 25 Feet High) - 21 June 1978.

Photo 14 - Picture of Lower Portion of Outlet Channel With Dumped Concrete Rubble Slope Protection) - June 21, 1978.

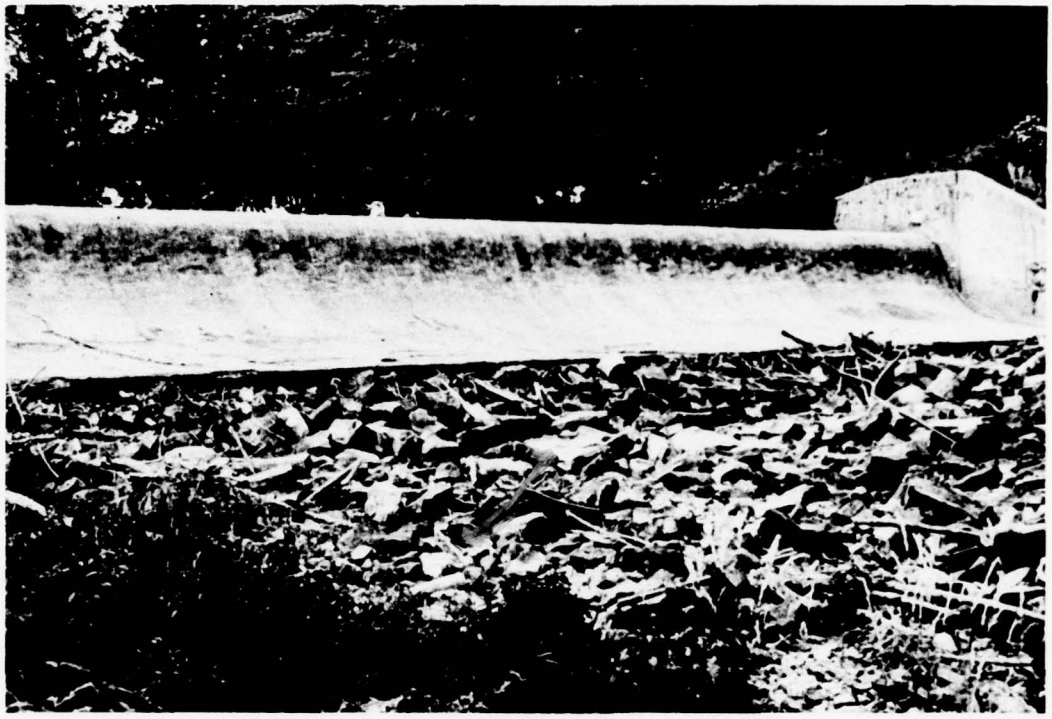


PHOTO 1

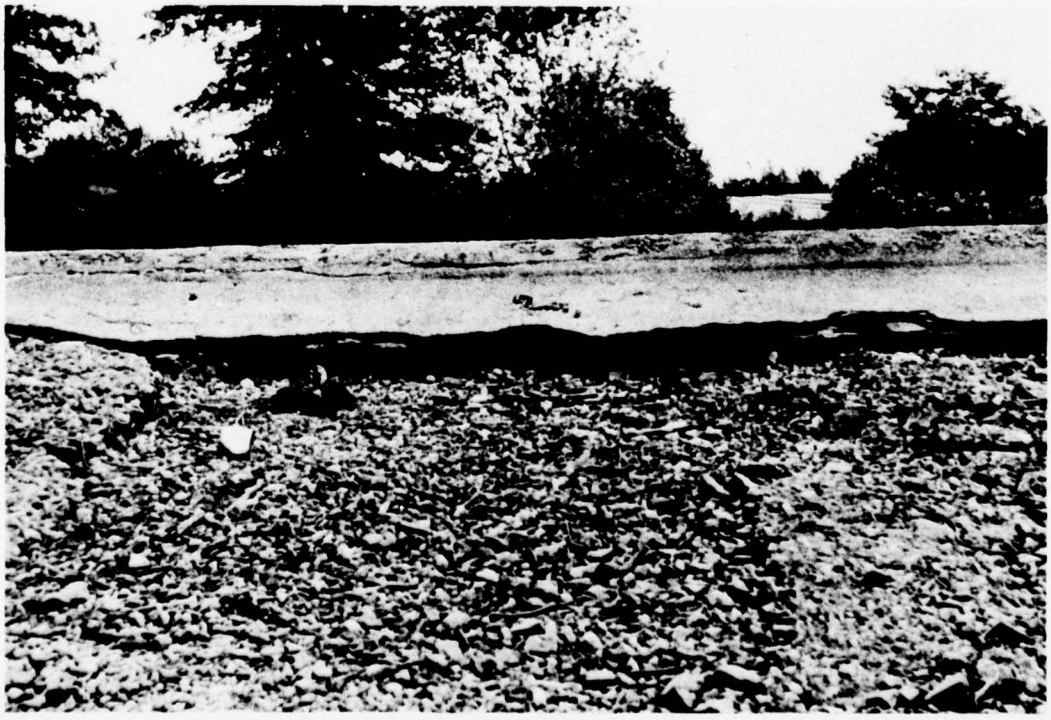
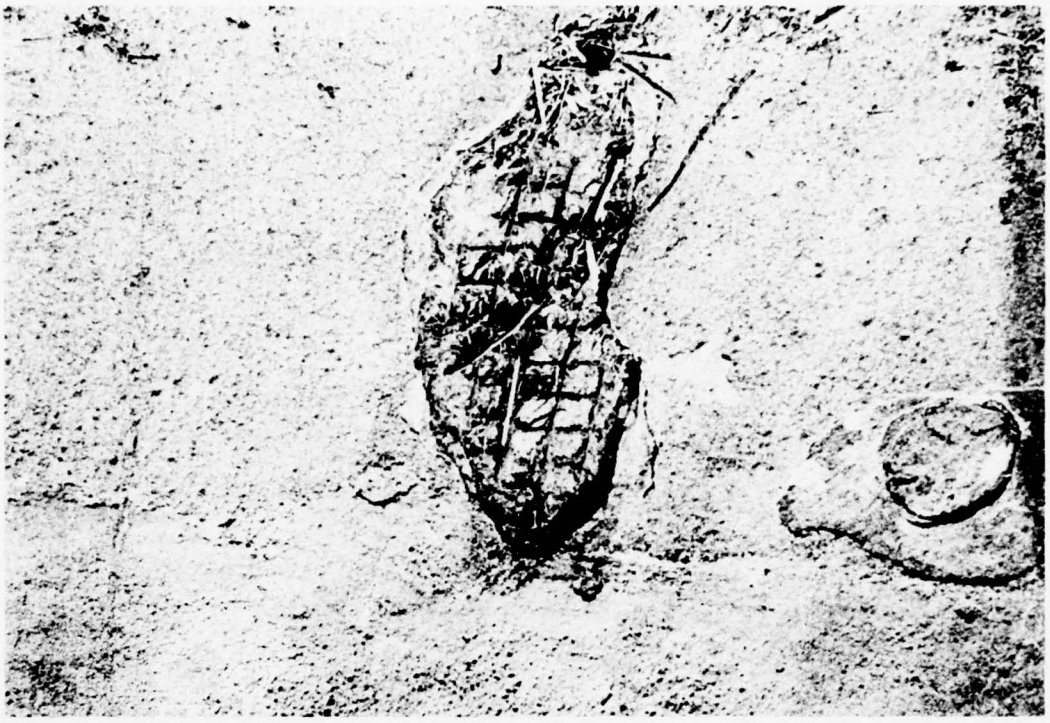


PHOTO 2



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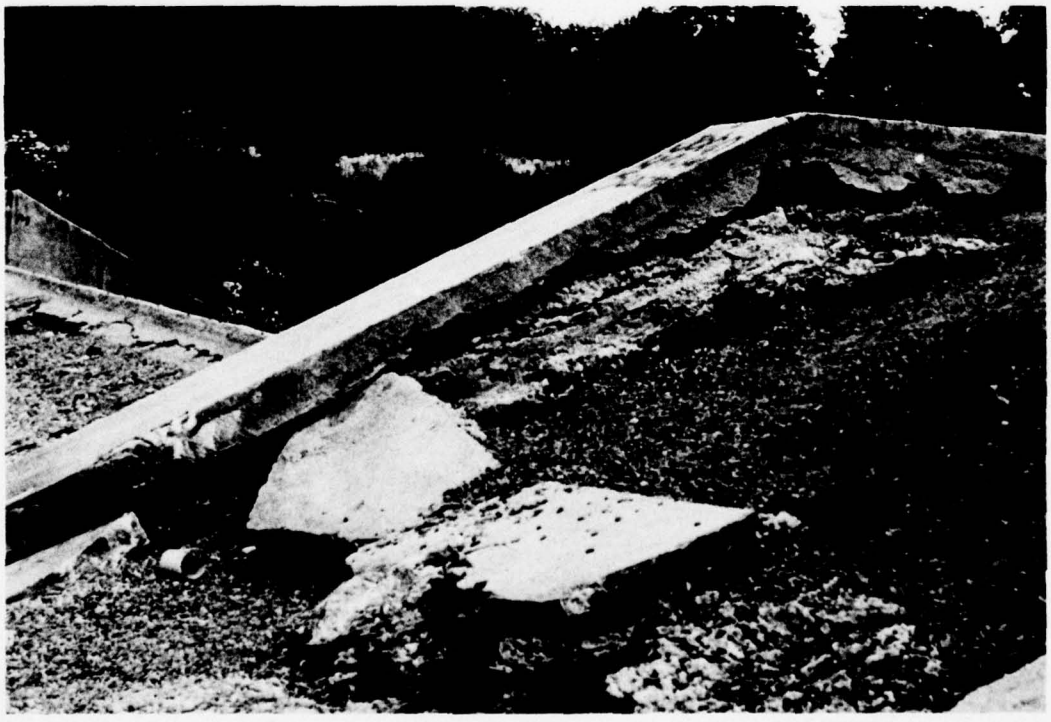

PHOTO 4

PHOTO 5

PHOTO 6

PHOTO 7

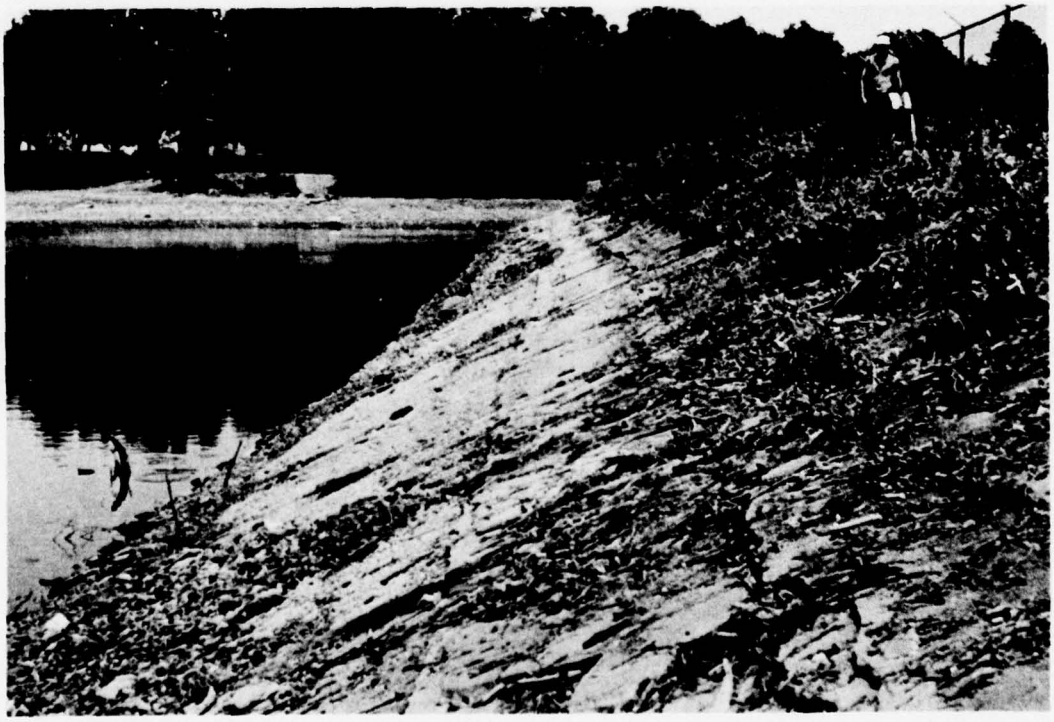

PHOTO 8

PHOTO 9

PHOTO 10

PHOTO 11

PHOTO 12

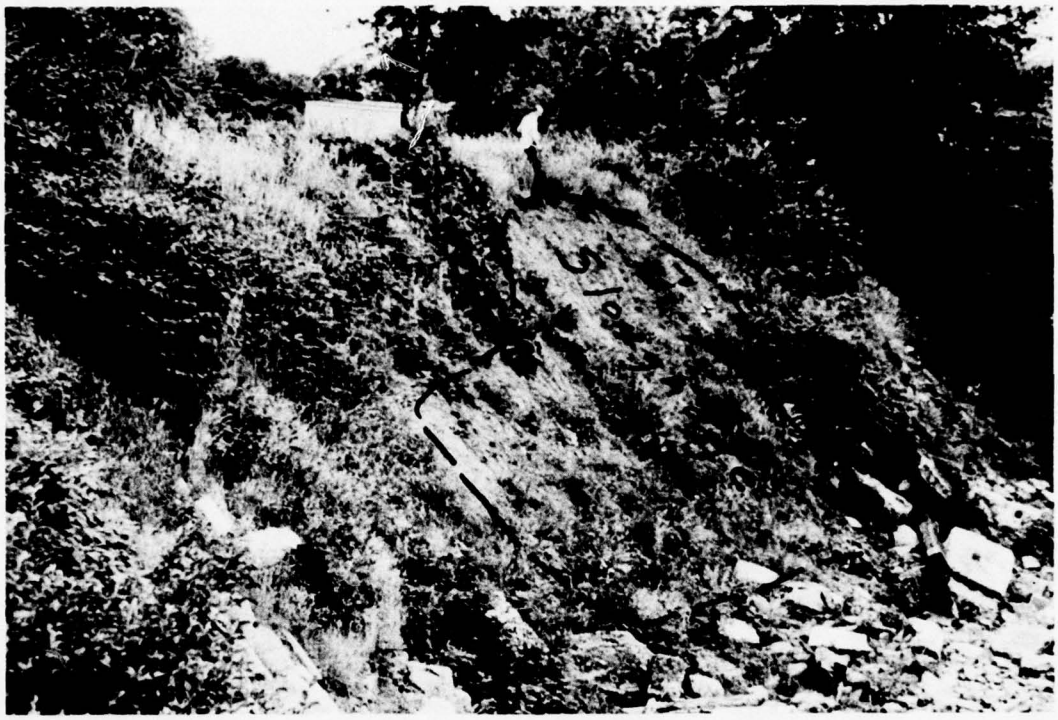

PHOTO 13

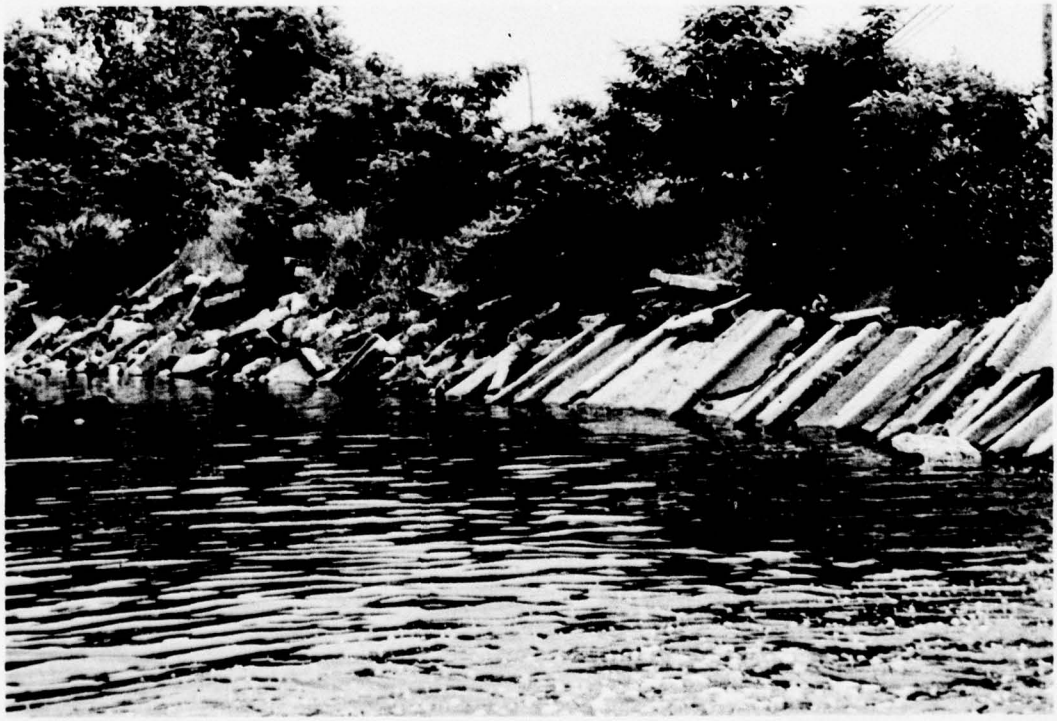

PHOTO 14

APPENDIX A

CHECK LIST - VISUAL INSPECTION

Check List
Visual Inspection
Phase 1

Name Dam Middlesex Reservoir Dam County Union State New Jersey Coordinates Lat. N 40° 36.8' Long. W 74° 18.2'

Date Inspection 21 June 1978 Weather partly sunny Temperature 80° - 85° F. ±

Pool Elevation at Time of Inspection 36.7 M.S.L. Tailwater at Time of Inspection - No flow present

Inspection Personnel:

MICHAEL BKAER, JR., INC.:

E. U. Gingrich
T. J. Dougan
J. R. Rapp

J. R. Rapp Recorder

CONCRETE/MASONRY DAMS

MIDDLESEX RESERVOIR DAM

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
LEAKAGE	Not Applicable	
STRUCTURE TO ABUTMENT/EMBANKMENT JUNCTIONS	Not Applicable	
DRAINS	Not Applicable	
WATER PASSAGES	Not Applicable	
FOUNDATION	Not Applicable	

CONCRETE/MASONRY DAMS

MIDDLESEX RESERVOIR DAM

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS CONCRETE SURFACES	Not Applicable	
STRUCTURAL CRACKING	Not Applicable	
VERTICAL AND HORIZONTAL ALIGNMENT	Not Applicable	
MONOLITH JOINTS	Not Applicable	
CONSTRUCTION JOINTS	Not Applicable	

MIDDLESEX RESERVOIR DAM

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS	None were observed.	
UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE	None were observed.	
SLOUGHING OR EROSION OF EMBANKMENT AND ABUTMENT SLOPES	No sloughage of the embankment slopes was observed. Erosion of the embankment (and possibly some settlement) has occurred adjacent to the spillway right wing wall resulting in the embankment being low by 0.7 foot. The erosion contines down the upstream slope adjacent to the wing wall reaching a depth of two feet.	This area should be filled in, graded, and seeded with an appropriate seeding mixture to stabilize the soil.
VERTICAL AND HORIZONTAL ALIGNMENT OF THE CREST	No deflections in the horizontal alignment were observed. As noted above, the embankment is low adjacent to the spillway right wing wall due to erosion and possibly some settlement. The embankment crest appears to have settled one-half foot immediately adjacent to the right abutment wall at the gate house.	All low areas of the embankment should be filled in and graded to the design top of dam elevation. These areas should then be treated and seeded with an appropriate seeding mixture to prevent erosion.
CONCRETE SLOPE PAVING	Concrete slope paving was provided for the full length of the embankment on the upstream side. The paving is badly deteriorated, cracked and spalled. Erosion from wave action, and frost and ice effects, have resulted in collapse and/or tilting of the broken concrete slabs at numerous locations along the dam. This condition is most severe along a 100 ± feet length of the embankment adjacent to the spillway right wing wall.	The concrete slope paving should be replaced, covered with riprap or alternately some other method devised to protect the embankment. the corrective solution to this problem must be properly engineered.

EMBANKMENT

MIDDLESEX RESERVOIR DAM

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
VEGETATION	Portions of the embankment were covered with brush and small trees. Some of the brush and small trees had been recently cut down near the spillway.	All brush and trees on the embankment should be removed. Any resulting bare spots should be treated and seeded with an appropriate seeding mixture to prevent erosion.
JUNCTION OF EMBANKMENT AND ABUTMENT, SPILLWAY AND DAM	Spillway left wing wall (left abutment) - small trees were noted to be present in the abutment area.	The trees should be removed and the resulting bare areas should be treated, seeded with an appropriate seeding mixture to prevent erosion.
	Spillway right wing wall and right abutment - see observations and recommendations presented under "EMBANKMENT - VERTICAL AND HORIZONTAL ALIGNMENT OF CREST".	
ANY NOTICEABLE SEEPAGE	No seepage, or any evidence of previous seepage, was observed. However, at the time of the Phase I visual inspection the reservoir was partially drained down, and seepage which might occur when the reservoir is full would not, therefore, be evident.	It is recommended that the owner thoroughly examine the dam and abutment areas for seepage when the reservoir is at normal and high water levels. If any seepage is detected, it is recommended that the owner engage an engineer experienced in dams to evaluate the significance of the seepage and to recommend appropriate corrective measures if determined to be necessary.
STAFF GAGE AND RECORDER	There are none.	

EMBANKMENT

MIDDLESEX RESERVOIR DAM

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
DRAINS	No embankment drains are present.	
OTHER	A groundhog burrow was noted extending under the slope paving about 50 feet from the right abutment gate house.	The burrow should be backfilled with compacted earth.

OUTLET WORKS

MIDDLESEX RESERVOIR DAM

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CRACKING AND SPALLING OF CONCRETE SURFACES IN OUTLET CONDUIT	The outlet conduit which extends from the gate house to near the Madison Hill Road Bridge could not be observed.	
INTAKE STRUCTURE	The intake structure consists of a gate house located at the right abutment. Six gates are provided for flow to the water treatment plant. A seventh lower gate for draining the reservoir was open during the visual inspection. The intake structure, or gate house, appeared to be functioning normally.	
OUTLET STRUCTURE	The outlet structure consists of a 24 inch diameter outlet pipe and concrete head wall with wing. The 24 inch pipe was flowing half full. The outlet structure appeared to be in good condition. The upstream bank (four feet high) adjacent to the outlet structure was bare of vegetation for a distance of 20 feet.	The bare area should be treated and seeded with an appropriate seeding mixture to prevent erosion.
OUTLET CHANNEL	The 24 inch outlet pipe discharges directly into the stream channel of Robinsons Branch. No other outlet "channel" for this pipe is needed.	
EMERGENCY GATE	There is none.	

OUTLET WORKS

MIDDLESEX RESERVOIR DAM

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
OTHER	Some minor cracks and spalled areas of the gate house concrete walls and right abutment wing wall were observed.	Repair of the spalled and cracked concrete surfaces is not considered necessary at this time, but the need for repairs should be evaluated periodically.

UNGATED SPILLWAY

MIDDLESEX RESERVOIR DAM

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE WEIR	1) The upstream approach slope to the spillway crest appears to be a rough concrete grouted stone paving. At about midspan, earth beneath the paving is exposed where the paving has deteriorated.	1) A section of the grouted paving at midspan, where the underlying earth is exposed, should be removed and replaced.
	2) Immediately upstream from the weir crest there is a two feet wide concrete approach slab which is cracked and slightly settled from the right spillway wall to about midspan. At midspan, this slab is undermined by scour. The portion of the slab from this point to the left spillway wall shows only minor evidence of deterioration.	2) The upstream concrete slab adjacent to the spillway crest should have all cracks repaired and undermined portions backfilled with concrete.
	3) Minor spalling of the gunite on the weir crest was present five feet from the right spillway wall. Several large (up to 3' x 7' x 1-1/2") spalled areas of the gunite are present on the weir face and downstream apron, exposing wire mesh, the original concrete and large rocks in the original concrete near the left end of the apron. Some of the spalled areas and small cracks (1/16 inch) on the apron gunite are linear (parallel with the direction of flow) and are spaced at 15 to 20 feet intervals. These may reflect monolithic or construction joints in the original concrete. Hairline cracks were present throughout the gunite surfaces.	3) All spalled areas and cracks (larger than hairline cracks) on the spillway crest, face and apron should be repaired. This work should be done by a contractor experienced in this type of repair work.
SPILLWAY WALLS	1) The left spillway wall which is covered with gunite shows hairline cracks, throughout, and some leaching of calcite. No other problems were noted.	1) The cracks in the gunite of the left spillway wall are not considered serious enough at this time to require repairs, but the condition of this wall should be monitored periodically and repaired as necessary.

(Continued on next page)

UNGATED SPILLWAY

MIDDLESEX RESERVOIR DAM

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SPILLWAY WALLS (Continued)	2) The right spillway wall shows hairline cracks throughout. A 1/2 inch wide settlement crack is located across the top of the wall adajacent to the spillway. Considerable spalling of the gunited surfaces was observed.	2) The settlement crack should be repaired. See item 1 remarks for hairline cracks in gunite. All spalled areas should be repaired.
	3) A low wall on the right side of the spillway is located downstream from the apron. This wall shows a slight misalignment probably due to earth pressure. The wall appeared to be undermined four inches by scour for a length of 20 feet.	3) The misalignment is not considered serious enough to warrant correction. The undermined section should be corrected by backfilling with concrete or cement grout.
APPROACH CHANNEL	There is none.	
DISCHARGE CHANNEL	1) The bottom of the spillway discharge channel is protected with large riprap, but low spots have formed adjacent to the apron and 150 feet downstream where the riprap has washed away.	1) Low areas should be filled in with large riprap.
	2) Considerable wood debris and trash was located in the channel immediately downstream from the spillway apron, as well as on the apron.	2) All debris and trash should be removed and properly disposed.
	3) The left spillway discharge channel slope was noted to have some erosion where the slope is as steep as 1:1, 100± feet downstream from the spillway. The outlet channel slope is highest (26 feet) in this area, and sloughage of soil on the slope is occurring. No major landsliding is present.	3) The slope should be regraded to a flatter slope ratio. The toe of the slope should be protected with large riprap. Soil above the riprap should be treated and seeded with an appropriate seeding mixture to prevent erosion.

(Continued on next page)

UNGATED SPILLWAY

MIDDLESEX RESERVOIR DAM

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
DISCHARGE CHANNEL (Continued)	4) The right spillway discharge channel slope was observed to have minor bank erosion.	4) The right slope should be graded, treated and seeded with an appropriate mixture, or alternately riprap should be placed to prevent erosion.
BRIDGE AND PIERS	A 24 inch diameter iron or steel sanitary sewer line bridges over the discharge channel about 200 feet downstream from the spillway. No problems with this bridge or its piers were observed.	

GATED SPILLWAY

MIDDLESEX RESERVOIR DAM

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE SILL	Not Applicable	
APPROACH CHANNEL	Not Applicable	
DISCHARGE CHANNEL	Not Applicable	
BRIDGE AND PIERS	Not Applicable	
GATES AND OPERATION EQUIPMENT	Not Applicable	

INSTRUMENTATION

MIDDLESEX RESERVOIR DAM

VISUAL EXAMINATION	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
MONUMENTATION/SURVEYS	No monumentation was noted.	
OBSERVATION WELLS	There are none.	
WEIRS	There are none.	
PIEZOMETERS	There are none.	
OTHER		

RESERVOIR

MIDDLESEX RESERVOIR DAM

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	Most reservoir slopes are moderately to slightly sloping and are well vegetated with grass and trees. However, the reservoir bank, approximately 50 feet from the left abutment, is as steep as 1.5:1 with minor erosion exposing a red clayey silt soil with rock fragments.	The eroded bank should be graded, treated and seeded with an appropriate seeding mixture to prevent erosion.
SEDIMENTATION	No sedimentation problems were observed.	

DOWNSTREAM CHANNEL

MIDDLESEX RESERVOIR DAM

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONDITION (OBSTRUCTIONS, DEBRIS, ETC.)	No obstructions, significant accumulations of debris, or other problems were observed.	
SLOPES	No problems were noted in the downstream channel at the Madison Hill bridge or further downstream, where the side slopes are mostly gentle and well vegetated.	
APPROXIMATE NO. OF HOMES AND POPULATION	The town of Rahway with a population of 29,114 is located immediately downstream from the Middlesex Reservoir Dam. The sections of Rahway which are adjacent to Robinsons Branch of the Rahway River are highly urbanized.	

APPENDIX B

CHECK LIST - ENGINEERING DATA

CHECK LIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION

MIDDLESEX RESERVOIR DAM

ITEM	REMARKS
PLAN OF DAM	A plan of the dam is included as Plate 1. This plan does not show the fill that was placed between the dam and Madison Hill Road, nor the water treatment plant facilities. Cross sections, a profile and details of the dam and gate house are shown on Plates 2 and 3. (Note: All plates in this report were reproduced from drawings provided by the Middlesex Water Company.)
REGIONAL VICINITY MAP	See Location Plan included in this report.
CONSTRUCTION HISTORY	The dam was constructed in 1907 and 1908 for the Consumers Aqueduct Company. No construction reports, photographs or information about problems that may have been encountered were available.
TYPICAL SECTIONS OF DAM	Typical sections at the dam are shown on Plate 2. The typical section of the earth embankment does not reflect the fill placed between the dam and Madison Hill Road.
HYDROLOGIC/HYDRAULIC DATA	None were available for this investigation.
OUTLETS - PLAN	See Plate 1.
- DETAILS	Details of the dam are shown on Plates 2 and 3.
- CONSTRAINTS	There are none.
- DISCHARGE RATINGS	None were available for this investigation.
RAINFALL/RESERVOIR RECORDS	None are available.

MIDDLESEX RESERVOIR DAM

ITEM	REMARKS
DESIGN REPORTS	None are available.
GEOLOGY REPORTS	None are available. However, logs of test pits and borings drilled in the vicinity of the dam was included in this report as Plate 4. Subsurface information is also shown on the profile of the dam on Plate 2.
DESIGN COMPUTATIONS HYDROLOGY & HYDRAULICS DAM STABILITY SEEPAGE STUDIES	None were available for this investigation.
MATERIALS INVESTIGATIONS BORING RECORDS LABORATORY FIELD	The only data available were the test pit and boring records shown on Plate 4.
POST-CONSTRUCTION SURVEYS OF DAM	None are available.
BORROW SOURCES	Borrow sources are not known.

MIDDLESEX RESERVOIR DAM

ITEM	REMARKS
MONITORING SYSTEMS	None were installed.
MODIFICATIONS	1) Concrete surfaces of spillway and wing walls were covered with gunite in 1939. 2) A 24 inch diameter steel or iron sanitary sewer line was constructed across the downstream face of the embankment from the right abutment to the middle of the dam. Date of construction was not available. 3) Flashboards were installed in early 1960's across spillway to raise the reservoir pool elevation by 1.6 feet to increase storage. Flashboards were removed about 1969. 4) A narrow (two ± feet wide) concrete approach apron to the spillway crest has been constructed. The date of this construction was not available.
HIGH POOL RECORDS	None are available but according to the owner's representation, Mr. Edward Bastian, the dam is not known to have ever been overtopped.
POST-CONSTRUCTION ENGINEERING STUDIES AND REPORTS	None have been performed.
PRIOR ACCIDENTS OR FAILURE OF DAM DESCRIPTION REPORTS	There are none.
MAINTENANCE OPERATION RECORDS	None were available for the Phase I Investigation.

MIDDLESEX RESERVOIR DAM

ITEM	REMARKS
SPILLWAY PLAN	A plan showing the spillway is included in this report as Plate 1.
SECTIONS	
DETAILS	Cross sections and details of the spillway are shown on Plate 2.
OPERATING EQUIPMENT PLANS & DETAILS	Available information for the gate house located at the right abutment is shown on Plate 3.

CHECK LIST
HYDROLOGIC AND HYDRAULIC DATA
ENGINEERING DATA

DRAINAGE AREA CHARACTERISTICS: 19.1 square miles (based on 7.5 minute U.S.G.S. topographic maps) of nearly level glaciated terrain which is mostly urbanized

ELEVATION TOP NORMAL POOL (STORAGE CAPACITY): 44.0 (1470 acre-feet)

ELEVATION TOP FLOOD CONTROL POOL (STORAGE CAPACITY): Not Applicable

ELEVATION MAXIMUM DESIGN POOL: Not Applicable

ELEVATION TOP DAM: 50.0

CREST:

a. Elevation 44.0
b. Type Concrete ogee
c. Width 30 feet sloping approach channel
d. Length 149.3 feet
e. Location Spillover Left abutment
f. Number and Type of Gates None

OUTLET WORKS:

a. Type Six (6) 36 inches square openings to gate chamber at three levels (originally constructed).
b. Location Gate chamber at right abutment
c. Entrance inverts El.'s 31.0, 35.5 and 40.0
d. Exit inverts El. 30.8 for water supply purpose
e. Emergency draindown facilities 24 inch concrete pipe from gate chamber to downstream channel

HYDROMETEOROLOGICAL GAGES: None

a. Type
b. Location
c. Records

MAXIMUM NON-DAMAGING DISCHARGE Not available

NAME OF DAM: MIDDLESEX RESERVOIR DAM

APPENDIX C

DAMS IN NEW JERSEY - REFERENCE DATA

ROBINSONS BRANCH

DAMS IN NEW JERSEY—REFERENCE DATA NO. 26-23

Name of Owner **Middlesex Water Co.** Address *Woodbridge, N.J.*

Name of Dam Robinsons Branch County Union Location 26.31.1.6.9

CONSTRUCTION: Date 1907 By whom Middlesex Water Company

Stream Robinsons Branch Tributary to Rahway River

DRAINAGE BASIN: Area 22.0 sq. mi. Description Rolling, cultivated

Description of valley below dam, Rolling, partly wooded, inhabited.

DAMAGE FROM FAILURE: Probable None

Previous (date) None

Purpose Water supply Type Earth - concrete wings.

Foundation (?)

Length 590 ft. Max. height 20. ft. Max. width of base 90 ft.

Upstream slope 2:1 Downstream slope 2:1 Volume Cu. yds.

SPILLWAY: Type Concrete ogee Length 155 ft.

Depth below top of dam 6.0 ft. Capacity 290 c. f. s. per sq. mi.

RESERVOIR: Capacity mill. gals. Area acres. Length ft.

Outlets 3 - 12" pipes in tunnel to pumps

Remarks Spillway at left. Concrete, well and brick gate house at Right end.

Sources of data: **Men at pumping station and inspection J.N.B.** **Date: 11/17/24**

(OVER)

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APPENDIX D

HYDRAULIC/HYDROLOGIC CALCULATIONS

MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

Subject MILLER RESERVOIR S.O. No. _____
H&H APPENDIX Sheet No. _____ of _____
Drawing No. _____
Computed by _____ Checked by _____ Date _____

TABLE OF CONTENTS

MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

Subject WATERSHED TIME - AREA RELATIONSHIP COMPUTATIONS — S.O. No. ____
MIDDLESEX RESERVOIR — Sheet No. 1 of 11 — Drawing No. ____
Computed by ALB — Checked by ____ — Date 07/19/78

TRAVEL TIME FROM 5 TO DAM FACE IS 5 HRS FOR 6.86 MI

MAP AREA NUMBER	INCREMENTAL UNIT	ACCUMULATED UNIT	ACCUMULATED AREA MI²	TRAVEL TIME IN PERCENT
1.	6.09	6.09	0.85	20
2.	14.27	20.36	2.85	40
3.	29.19	49.55	6.94	60
4.	38.82	88.37	12.37	80
5.	48.00	136.37	19.09	100
TOTAL	136.37			

Unit Hydrograph Data obtained from U.S. Army Corps - Philadelphia District

Clark's Coefficients $T_c = 5.0$, $R = 4.9$

from Special Projects Memo. No. 469
"Hydrologic - Hydraulic Simulation of the Rahway River Basin" - November 1976

MICHAEL BAKER, JR., INC.
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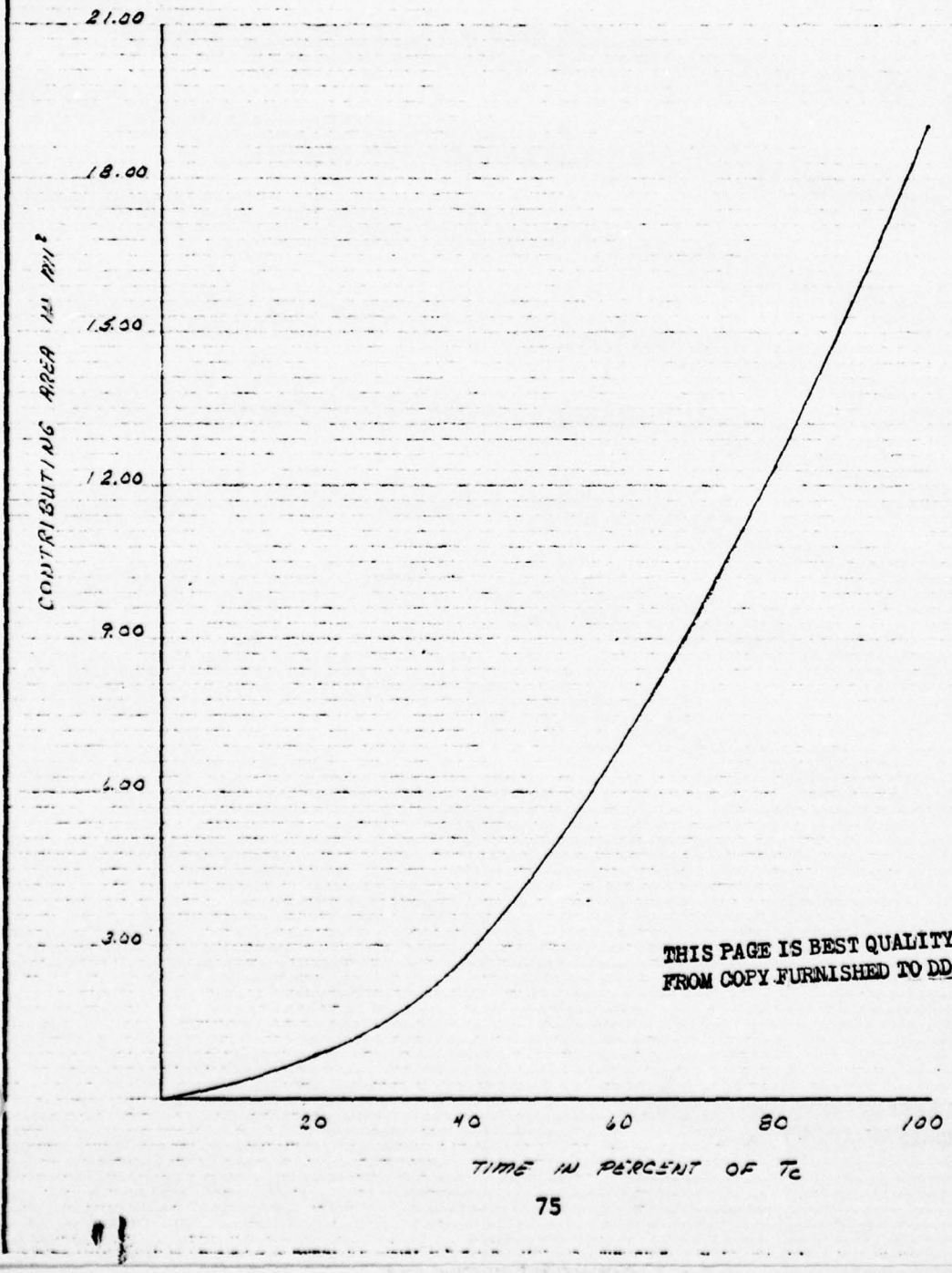
Subject WATERSHED TIME - AREA RELATIONSHIP. MIDDLESEX RESERVOIR

S.O. No. _____
Sheet No. 2 of 17
Drawing No. _____
Computed by ALB Checked by _____ Date 02/19/28



MICHAEL BAKER, JR., INC.
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Subject: N.J. Dam Inspections — S.O. No. ______
Middlesex Reservoir — Sheet No. 3 of 17
PMF - Rainfall Estimate — Drawing No. ______
Computed by: D.J.G. — Checked by: ______ — Date: 7/21/78

$T_c = 5.0$ DA = 19.1 mi²

Duration = 1 hour ∴ Use 1 hour Rainfall Increments

CN = 74 Rainfall PMP = 25.7

Fig. 16 D.S.D. pg 48 (Fig. 15) Zone 6 ⇒

% Adj. 6 hr. 95% Corr Adj. @ 19 mi² = 18.9% Reduction
12 hr. 105%
24 hr. 112%

$S = \frac{1000}{CN} - 10 = \frac{1000}{74} - 10 = 3.51$

P.M.P. = 25.7 × 81.1% = 20.8 inches

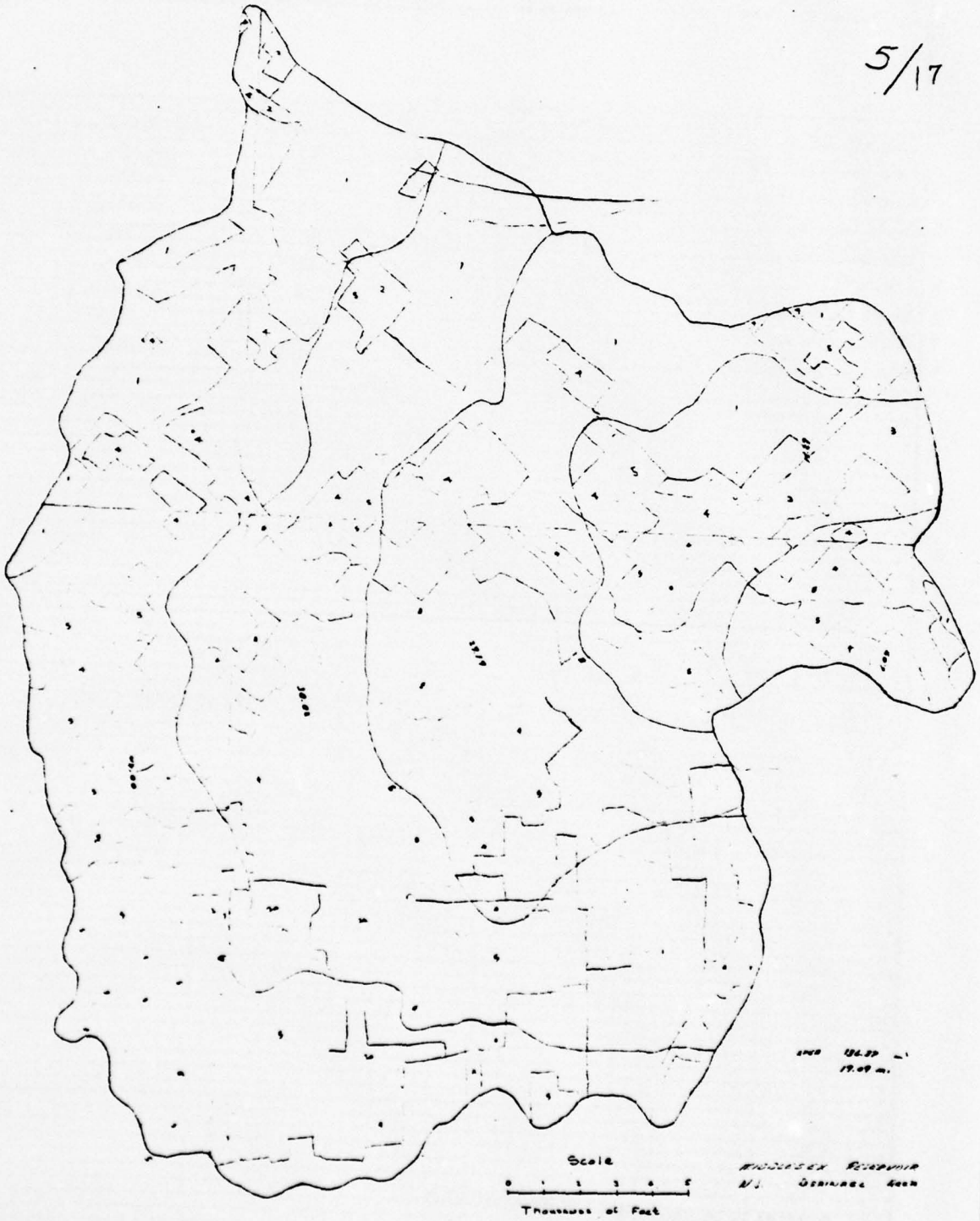
6 Hr Adj. 20.8 × 0.95 = 19.8 inches

$Q = \frac{[P - 0.2(3.51)]^2}{P + 0.8(3.51)}$ = (pg 54)

Time	Inc Rain	Cum Rainfall	Cum Excess	Δ Excess	Inc Loss	Min Loss Rate 0.24	Excess Adj.
0	0	0	0				
1	2.0	2.0	0.35	0.35	1.65		0.35
2	2.2	4.4	1.90	1.55	0.65		1.55
3	2.9	7.3	4.30	2.40	0.50		2.40
4	7.6	14.9	11.38	7.08	0.52		7.08
5	2.7	17.6	13.99	2.61	0.09	0.24	2.46
6	2.2	19.8	16.13	2.14	0.06	0.24	1.96

use ∑
15.08 inches

5/17



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Subject MIDDLESEX RESERVOIR S.O. No.
RUNOFF CURVE NO. COMPS Sheet No. 4 of 17
Drawing No.
Computed by J. Sawyer Checked by Date

	LAND USE	#	SOIL CLASS	%	CURVE #	PRODUCT
1	RESIDENTIAL 1/8	24.58	B	18.0	85	1530.
	" 1/2	46.09		33.6	72	2419.2
	" 1/2	5.67	B	4.2	70	294.
3	COMMERCIAL	3.62	B	2.7	92	248.4
4	OPEN SPACES	25.98	B	19.0	61	1159.
5	WOODS	16.86	B	12.4	60	744.
6	ROADS (PAVED)	3.30	B	2.6	98	254.8
7	ROADS (HARD)	.05	B	0.1	84	8.4
8	WATER & SWAMPS	10.07	B	7.4	100	740.
		136.37		100%		7397.8 CN-74

SPILLWAY ACCESSMENT

19.1 mi² RAFWAY BASIN

FROM GENERALIZED CURVE PMF = 31,000 cfs

Spillway Capacity at Top of Dam 10,157

= Spillway Inadequate Proceed with

Detailed analysis & Routing

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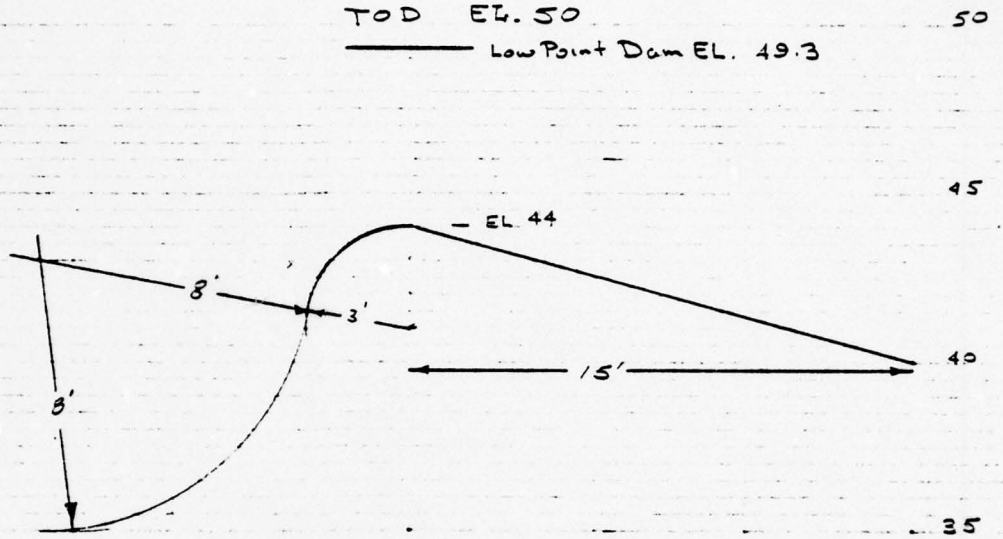
Subject N.J Dam Inspections S.O. No.
Proctor Dam Sheet No. 6 of 17
Spillway Setting Drawing No.
Computed by D.T.G. Checked by Date 7/22/-3



CREST CURVE FITTING BY D. OF S.D.

H_o	① X	① Y	② x	② Y	③ X	③ Y
4'	0.87	0.12	2.33	0.75	4.92	2.94
(2)	0.43	0.06	1.16	0.37	2.46	1.47
(3)	0.65	0.09	1.75	0.56	3.69	2.20

See Fitting Next Page

Use H_o in D. of S.D = 3' & P = 4'

$\frac{P}{H_o} = \frac{4}{3} = 1.33$

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Subject N.J. Dam Inspections S.O. No. _____
Middlesex Dam Sheet No. 7 of 17
Spillway Rating Drawing No. _____
Computed by D.J.G. Checked by _____ Date 7/22/73

MICHAEL BAKER, JR., INC.
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Subject Middlesex Dam
Spillway Rating
S.O. No.
Sheet No. 8 of 17
Drawing No.
Computed by EEK Checked by Date 7/22/73

$Q = CLH^{3/2}$

where: H = total head on crest
L = Crest length (feet)
Q = Discharge
C = Crest coefficient

Point	$H^{3/2}$	L	C_o	C/C_o	$\frac{C_{WE}}{C_{WEE}}$	Q
7	18.52	149.3	3.91	1.13	0.95	11,606
1	1.00	149.3	3.91	0.886	0.95	491
3	2.85	149.3	3.91	0.967	0.95	1517
5	5.20	149.3	3.91	1.00	0.95	2882
4	8.00	149.3	3.91	1.040	0.95	4614
5	11.16	149.3	3.91	1.080	0.95	6696
6	14.70	149.3	3.91	1.10	0.95	8,966
8	22.63	149.3	3.91	1.17	0.95	14,682
9	27.00	149.3	3.91	1.20	0.95	17,963

Assume $C_{INC.}/C_{CREST} = 0.95$ since curves for this situation are unavailable.

$H_o = 3'$, $R = 4'$

$C_o = 3.91$ Does D, Fig. 249

No correction for submergence necessary

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Subject NJ Dam Inspection — Middlesex Dam — Rating Above Top of Dam — S.O. No. — Sheet No. 9 of 17 — Drawing No. — Computed by DJG. — Checked by — Date 8/31/78

ASSUMING CRITICAL DEPTH OVER EMBANKMENT

W.S. EL = 51.0

AREA = 1'x400' + 1'x32' + 1'x4 = 436 ft²

Free Surface = 37' + 400 + 5 = 442 ft

D_m = 436/442 = 0.986 ft

$Q = A\sqrt{gD_m}$ = 2457 cfs

EG. EL = 51.0 + 0.986/2 = 51.5±

W.S. EL = 52.0

AREA = 2x400 + 37x2 + 4x2 = 882 ft²

FREE SURFACE = 400 + 37 ft = 464 ft

D_m = 882/464 = 1.90 ft

$Q = A\sqrt{gD_m}$ = 6900 cfs

EG. EL = 52.0 + 1.90/2 = 52.95

W.S. EL = 50.5

AREA = 0.5x400 + 29x0.5 + 4x0.5 = 216.5 ft²

FREE SURFACE = 400 + 4x32 = 436 ft

D_m = 216.5/436 = 0.497

$Q = 216.5\sqrt{gD_m}$ = 866

EG. EL = 50.5 + 0.497/2 = 50.75

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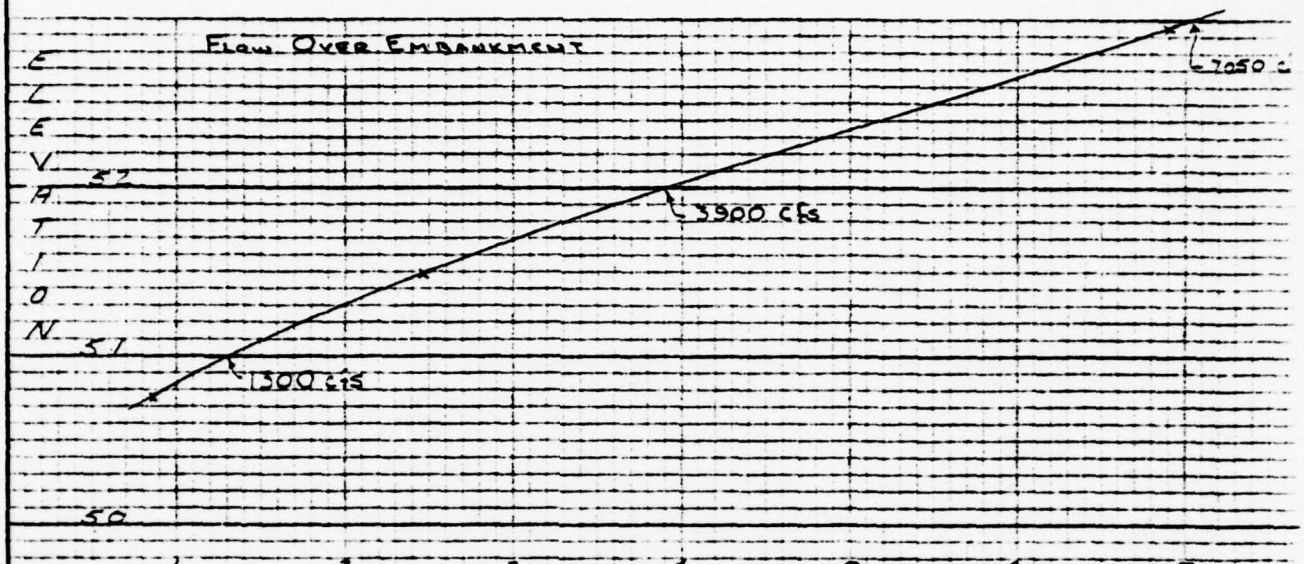
Subject N.J. Dam Inspections — S.O. No.
Middlesex Dam — Sheet No. 10 of 17
Rating Above Top of Dam — Drawing No.
Computed by DJG — Checked by — Date 8/31/73

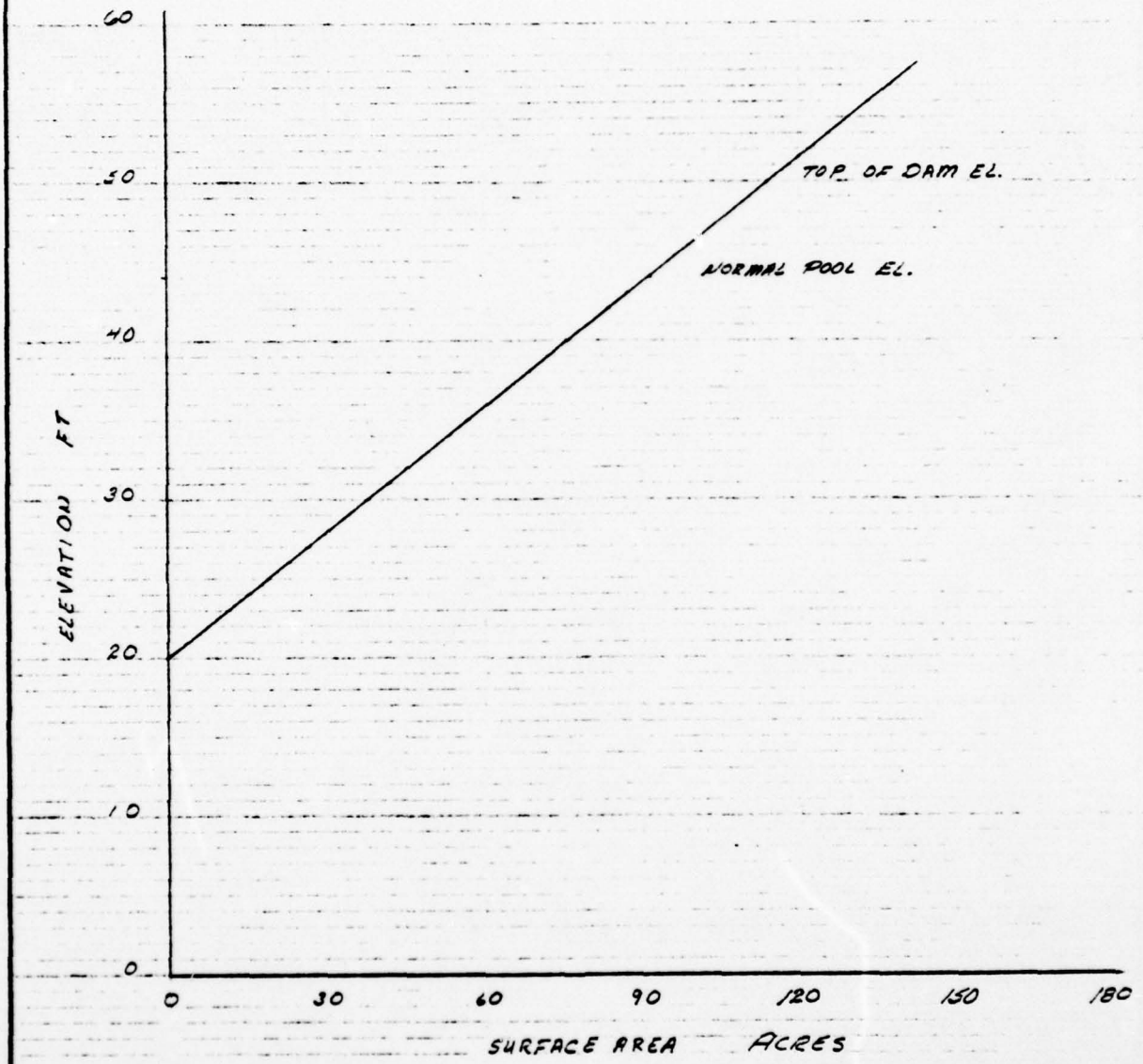


ELEV. Ft	SPILLWAY FLOW CFS	EMBANKMENT FLOW CFS	TOTAL FLOW CFS	STORAGE Ac-Ft
50	8,966	—	8966	619.6
51	11,606	1,300	12,906	736.3
52	14,682	3,900	18,582	856.9
53	17,968	7,050	25,018	981.3

MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

Subject STAGE VS SURFACE AREA S.O. No.
MIDDLESEX RESERVOIR Sheet No. 11 of 17
AREA NORMAL POOL PLANIMETERED ON QUAD Drawing No.
Computed by JLP Checked by Date 07/21/78



MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

Subject ELEVATION VS. SURFACE AREA S.O. No. _____
MIDDLESEX RESERVOIR Sheet No. 12 of 17
TABULATED FROM GRAPH (SHEET 1.) Drawing No. _____
Computed by ALB Checked by _____ Date 07/21/72

ELEVATION	SURFACE AREA	AVERAGE SURFACE AREA	INCREMENTAL AREA (ACRE-FT)	CUMULATIVE AREA (ACRE-FT)
44.0	91.8			0
		91.8	91.8	
45.0	95.6			93.7
		93.7	93.7	
46.0	99.4			191.2
		97.5	97.5	
46.5	101.4			241.4
		100.4	50.2	
47.0	103.3			292.6
		102.4	51.2	
47.5	105.2			344.7
		104.3	52.1	
48.0	107.1			397.8
		106.2	53.1	
48.5	109.0			451.8
		108.1	54.0	
49.0	110.9			506.8
		110.0	55.0	
49.5	112.8			562.7
		111.9	55.9	
50.0	114.8			619.6
		113.8	56.9	

MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

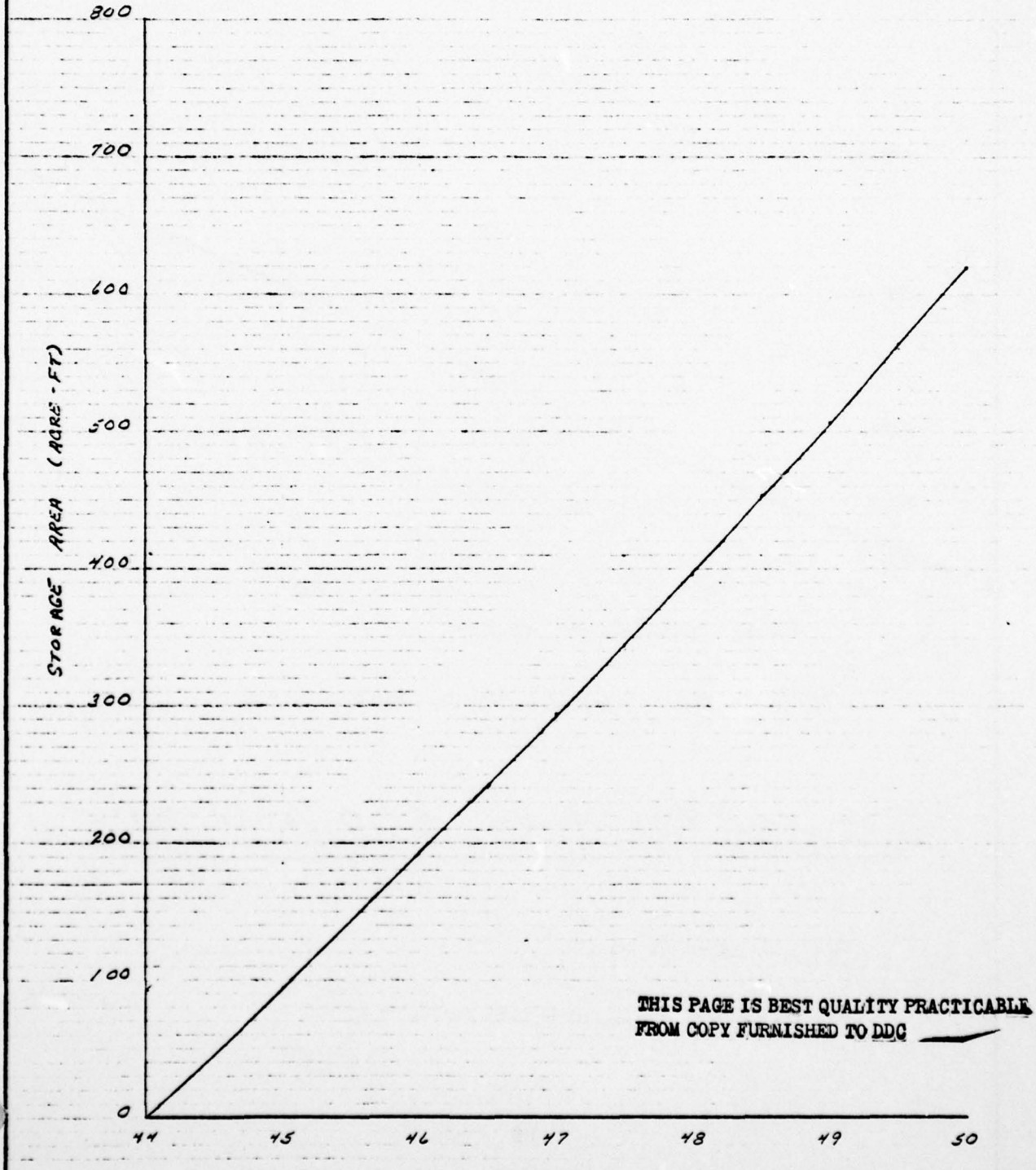
Subject NJ Dam Inspections S.O. No.
Middlesex Dam Sheet No. 13 of 17
Storage Curve Extension Drawing No.
Computed by DJG Checked by Date 9/31/78

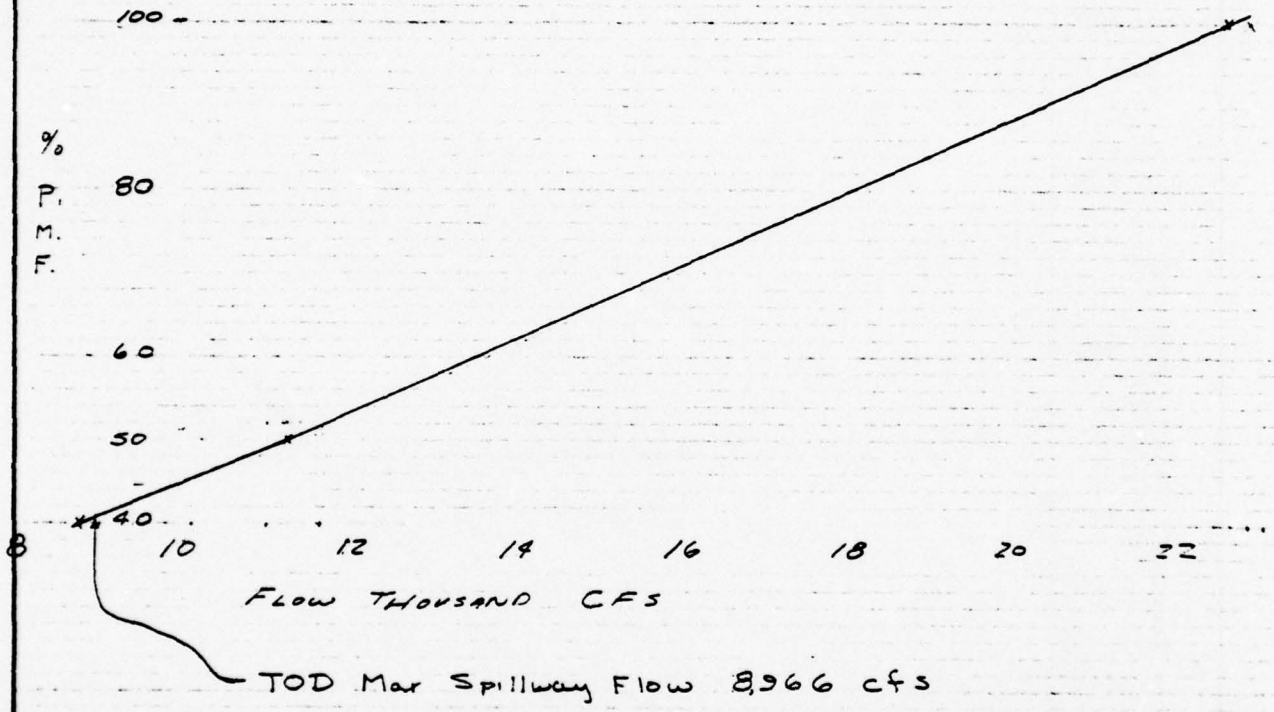
ELEVATION FT	SURFACE AREA ACRES	INCREMENTAL VOLUME AC-FT.	CUMULATIVE VOLUME AC-FT
50.0	114.8		619.6
50.5	116.1	57.9	677.5
51.0	118.6	58.8	736.3
51.5	120.6	59.8	796.1
52.0	122.5	60.8	856.9
52.5	124.9	61.7	918.6
53.0	126.3	62.7	981.3

MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

Subject STORAGE AREA Vs ELEVATION S.O. No.
MIDDLESEX RESERVOIR Sheet No. 14 of 17
FROM TABULATION (SHEET 2) Drawing No.
Computed by ALB Checked by Date 07/21/78





DAM WILL PASS ABOUT 41.0 % of PMF

SDF ⇒ PMF
SPILLWAY INADEQUATE

MICHAEL BAKER, JR., INC.	Subject Middlesex Dam	S.O. No.
THE BAKER ENGINEERS	Data on Upstream	Sheet No. 16 of 17
Box 280	Road Crossing	Drawing No.
Beaver, Pa. 15009	Computed by DJG Checked by	Date 7/25/78

DATA SCALED FROM PHOTO by MIDDLESEX WATER AUTH.

55 TOP of BRIDGE

52 BOTTOM ELEV. LOW CHORD

80' WIDE

170' BREADTH

34 BOTTOM CULVERT

AREA = 80 X (52-34) = 1440 ft^2

CRITICAL DEPTH @ ELEV. 50 T.O.D.

$Q = \sqrt{g D_m}\, A \qquad D_m = \frac{A}{F_s} = \frac{18 \times 80}{80} = 18\ ft$

$Q = \sqrt{32.2(18)}\,(18 \times 80) = 34{,}668$ cfs

PMF - FLOW = 22,806 cfs

∴ Tailwater is above CRITICAL DEPTH

$H = \left(1 + K_c + \frac{29 n^2 L}{R^{1.33}}\right)\frac{V^2}{2g} \qquad V = Q/A = \frac{22806}{1440} = 15.84\ ft/sec.$

$H = \left[1 + 0.5 + \frac{29(0.012)^2\, 170}{\left(\frac{1440}{196}\right)^{1.33}}\right]\frac{(15.84)^2}{2(32.2)} = 6.04\ ft$

Elev. = 34 + 16 + 6.04 = 56.04 (Top Culvert 52) STORAGE IN BEHIND Roadway

1/2 PMF FLOW = 11,403 cfs $V = Q/A = 7.92$ ft/sec. $\frac{H}{D} = \frac{[illegible]}{16} = 1.33$ $\frac{H}{D} > 1.2$ check inlet control

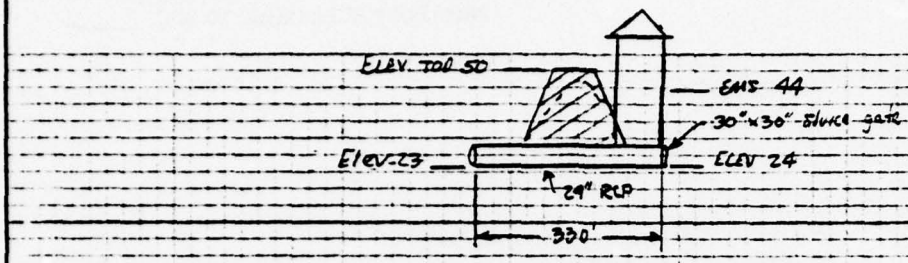
H = 1.51 ft Elev. 34+16+1.5 = 51.5 Smaller Surcharge

No need [illegible]
this shows upper reservoir
will store & Retard Some flow.

MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

Subject MIDDLESEX RESERVOIR
RESERVOIR EMPTYING POTENTIAL
S.O. No.
Sheet No. 17 of 17
Drawing No.
Computed by TWS Checked by Date 8-15-79



STORAGE
EL 50 2090 ac ft
EL 44 1470 ac ft

(1) ELEV	(2) AVAILABLE STORAGE	(3) Δ STORAGE (ac-ft)	(4) DISCHARGE ACTUAL* (cfs)	(5) AVERAGE (cfs)	(6) AVERAGE DISCHARGE 1.98347 × (5) ac-ft/day	(7) DURATION (3)/(6) days
50	2090	310	57	55	109	2.84
47	1780**	310	53	51.5	102	3.04
44	1470	294	50	42.5	84	3.50
40	1176**	363	45	41	81	4.54
35	998**	363	37	32.25	64	5.75
30	440**	220	27.5	23.25	46	4.79
27	220**	220	19	9.5	19	11.58
24	0	2090	0			36 days

Drawdown

ELEV 50	Top to Empty 36 days
ELEV 44	SPILLWAY TO Empty 30 days

* Determined from using fig B-10 p. 567 Design of Small Dams for a 24" RCP with L = 330' 90

** Storage determined by straight line interpolation

A1 / A11

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A                             MIDDLESEX RESERVOIR     PMF
A                               NEW JERSEY
A                             HYDROGRAPH BY CLARK METHOD
B      48        1
1       3
K       0        1                           2         1
M       0        0      19.1        0
C       6
1    0.35     1.55      2.40     7.08     2.46      1.96
T
V     5.0      4.9         6
1       0     0.85      2.85     6.94    12.37     15.10
X                          1
K       1        1                           2         1
Y                                  1
1       1                                                      -1
2       0     93.7     191.2    292.6    397.8     506.8    619.6    736.3    856.9    981.3
3       0      491      1517     2882     4614      6656     8966    12906    18582    25018
K      99
A
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A2 / A4

FINAL

****
HEC-1 VERSION DATED JAN 1973

****

MIDDLESEX RESERVOIR PMF
NEW JERSEY
HYDROGRAPH BY CLARK METHOD

JOB SPECIFICATION

NQ	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
48	1	0	0	0	0	0	0	0	0

JOPER	NWT
3	0

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

SUB-AREA RUNOFF COMPUTATION

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

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
0	0	19.10	0.0	0.0	0.0	0.0	0	0	0

PRECIP DATA

NP	STORM	DAJ	DAK
6	0.0	0.0	0.0

PRECIP PATTERN

0.35	1.55	2.40	7.08	2.46	1.96

LOSS DATA

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

UNIT HYDROGRAPH DATA

TC= 5.00 R= 4.90 NTA= 6

UNIT GRAPH TIME-AREA ORDINATES

0.0	0.85	2.85	6.94	12.37	19.10

RECESSION DATA

STRTQ= C.0 QRCSN= 0.0 RTIOR= 1.00

UNIT HYDROGRAPH 30 END-OF-PERIOD ORDINATES, LAG= 5.83 HOURS, CP= 0.78 VOL= 1.00

51.	212.	536.	1005.	1545.	1661.	1354.	1103.	899.	732.
597.	486.	396.	323.	263.	214.	175.	142.	116.	94.
77.	63.	51.	42.	34.	28.	23.	18.	15.	12.

END-OF-PERIOD FLOW

TIME	RAIN	EXCS	COMP Q
1	0.35	0.35	18.
2	1.55	1.55	153.
3	2.40	2.40	637.
4	7.08	7.08	2050.
5	2.46	2.46	5009.
6	1.96	1.96	9805.
7	0.0	0.0	15609.
8	0.0	0.0	20336.

AD-A059 768 BAKER (MICHAEL) JR INC BEAVER PA F/G 13/2
NATIONAL DAM SAFETY PROGRAM. MIDDLESEX RESERVOIR DAM (NJ-00377)--ETC(U)
AUG 78 M BAKER DACW61-78-C-0141
UNCLASSIFIED NL

2 OF 2
ADA
059768

END
DATE
FILMED
12-78
DDC

9	0.0	0.0	22806.
10	0.0	0.0	20995.
11	0.0	0.0	17894.
12	0.0	0.0	14581.
13	0.0	0.0	11881.
14	0.0	0.0	9680.
15	0.0	0.0	7888.
16	0.0	0.0	6427.
17	0.0	0.0	5237.
18	0.0	0.0	4267.
19	0.0	0.0	3477.
20	0.0	0.0	2833.
21	0.0	0.0	2308.
22	0.0	0.0	1881.
23	0.0	0.0	1533.
24	0.0	0.0	1249.
25	0.0	0.0	1018.
26	0.0	0.0	829.
27	0.0	0.0	676.
28	0.0	0.0	550.
29	0.0	0.0	449.
30	0.0	0.0	365.
31	0.0	0.0	294.
32	0.0	0.0	224.
33	0.0	0.0	159.
34	0.0	0.0	59.
35	0.0	0.0	24.
36	0.0	0.0	0.
37	0.0	0.0	0.
38	0.0	0.0	0.
39	0.0	0.0	0.
40	0.0	0.0	0.
41	0.0	0.0	0.
42	0.0	0.0	0.
43	0.0	0.0	0.
44	0.0	0.0	0.
45	0.0	0.0	0.
46	0.0	0.0	0.
47	0.0	0.0	0.
48	0.0	0.0	0.
SUM	15.80	15.80	193801.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	22806.	18803.	7953.	4037.	193800.
INCHES		9.16	15.49	15.73	15.73
AC-FT		9329.	15782.	16025.	16025.

A3/A11

CVN

A 4/A 11

HYDROGRAPH ROUTING

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

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME
0.0	0.0	0.0	1	0

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

STORAGE=	0.	94.	191.	293.	398.	507.	620.	736.	857.	981.
OUTFLOW=	0.	491.	1517.	2882.	4614.	6690.	8966.	12906.	18582.	25018.

TIME	EOP STOR	AVG IN	EOP OUT
1	3.	18.	18.
2	8.	85.	42.
3	32.	395.	168.
4	109.	1344.	653.
5	268.	3529.	2554.
6	502.	7407.	6604.
7	740.	12707.	13060.
8	884.	18273.	19988.
9	934.	21971.	22554.
10	916.	21900.	21663.
11	858.	19445.	18640.
12	791.	16238.	15465.
13	726.	13231.	12560.
14	665.	10780.	10487.
15	602.	8784.	8605.
16	536.	7157.	7291.
17	470.	5832.	5987.
18	413.	4752.	4897.
19	363.	3872.	4044.
20	319.	3155.	3324.
21	282.	2571.	2734.
22	248.	2095.	2277.
23	217.	1707.	1869.
24	192.	1391.	1527.
25	169.	1133.	1287.
26	148.	923.	1066.
27	130.	752.	876.
28	115.	613.	717.
29	103.	499.	585.
30	92.	407.	483.
31	82.	330.	428.
32	70.	259.	368.
33	58.	192.	305.
34	45.	109.	236.
35	32.	42.	166.
36	21.	12.	111.
37	14.	0.	72.
38	9.	0.	46.
39	6.	0.	30.
40	4.	0.	19.
41	2.	0.	12.
42	2.	0.	8.

A5/A11

43		1.	0.			5.	
44		1.	0.			3.	
45		0.	0.			2.	
46		0.	0.			1.	
47		0.	0.			1.	
48		0.	0.			1.	
	SUM			193839.			
		PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME	
	CFS	22554.	18562.	7920.	4038.	193839.	
	INCHES		9.04	15.43	15.73	15.73	
	AC-FT		9209.	15717.	16028.	16028.	

A6 /A11

RUNOFF SUMMARY, AVERAGE FLOW

		PEAK	6-HOUR	24-HOUR	72-HOUR	AREA
HYDROGRAPH AT	1	22806.	18803.	7953.	4037.	19.10
ROUTED TO	1	22554.	18562.	7920.	4038.	19.10

HEC-1 VERSION DATED JAN 1973

A7 / A11

FINAL

MIDDLESEX RESERVOIR 0.5PMF
NEW JERSEY
HYDROGRAPH BY CLARK METHOD

JOB SPECIFICATION

NQ	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
48	1	0	0	0	0	0	0	0	0

JOPER	NWT
3	0

SUB-AREA RUNOFF COMPUTATION

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

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
0	0	19.10	0.0	0.0	0.0	0.500	0	0	0

PRECIP DATA

NP	STORM	DAJ	DAK
6	0.0	0.0	0.0

PRECIP PATTERN

0.35	1.55	2.40	7.08	2.46	1.96

LOSS DATA

STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOR	STRTL	CNSTL	ALSMX	RTIMP
0.0	0.0	1.00	0.0	0.0	1.00	0.0	0.0	0.0	0.0

UNIT HYDROGRAPH DATA

TC= 5.00 R= 4.90 NTA= 6

UNIT GRAPH TIME-AREA ORDINATES

0.0	0.85	2.85	6.94	12.37	19.10

RECESSION DATA

STRTQ= 0.0 QRCSN= 0.0 RTIOR= 1.00

UNIT HYDROGRAPH 30 END-OF-PERIOD ORDINATES, LAG= 5.83 HOURS, CP= 0.78 VOL= 1.00

51.	212.	536.	1005.	1545.	1661.	1354.	1103.	899.	732.
597.	486.	396.	323.	263.	214.	175.	142.	116.	94.
77.	63.	51.	42.	34.	28.	23.	18.	15.	12.

END-OF-PERIOD FLOW

TIME	RAIN	EXCS	COMP Q
1	0.35	0.35	18.
2	1.55	1.55	153.
3	2.40	2.40	637.
4	7.08	7.08	2050.
5	2.46	2.46	5009.
6	1.96	1.96	9805.
7	0.0	0.0	15609.
8	0.0	0.0	20936.

10	0.0	0.0	20995.
11	0.0	0.0	17894.
12	0.0	0.0	14581.
13	0.0	0.0	11881.
14	0.0	0.0	9680.
15	0.0	0.0	7888.
16	0.0	0.0	6427.
17	0.0	0.0	5237.
18	0.0	0.0	4267.
19	0.0	0.0	3477.
20	0.0	0.0	2833.
21	0.0	0.0	2308.
22	0.0	0.0	1881.
23	0.0	0.0	1533.
24	0.0	0.0	1249.
25	0.0	0.0	1018.
26	0.0	0.0	829.
27	0.0	0.0	676.
28	0.0	0.0	550.
29	0.0	0.0	449.
30	0.0	0.0	365.
31	0.0	0.0	294.
32	0.0	0.0	224.
33	0.0	0.0	159.
34	0.0	0.0	59.
35	0.0	0.0	24.
36	0.0	0.0	0.
37	0.0	0.0	0.
38	0.0	0.0	0.
39	0.0	0.0	0.
40	0.0	0.0	0.
41	0.0	0.0	0.
42	0.0	0.0	0.
43	0.0	0.0	0.
44	0.0	0.0	0.
45	0.0	0.0	0.
46	0.0	0.0	0.
47	0.0	0.0	0.
48	0.0	0.0	0.
SUM	15.80	15.80	193801.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	22806.	18803.	7953.	4037.	193800.
INCHES		9.16	15.49	15.73	15.73
AC-FT		9329.	15782.	16025.	16025.

OVN

A9 / A11

RUNOFF MULTIPLIED BY 0.50

9.	76.	319.	1025.	2504.	4903.	7805.	10468.	11403.	10497.
8947.	7290.	5940.	4840.	3944.	3214.	2618.	2134.	1738.	1417.
1154.	940.	766.	624.	509.	415.	338.	275.	224.	183.
147.	112.	80.	30.	12.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.		

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	11403.	9402.	3976.	2019.	56900.
INCHES		4.58	7.75	7.87	7.87
AC-FT		4664.	7891.	8012.	8012.

99

DVN

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

A 10 / A 11

HYDROGRAPH ROUTING

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

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME
0.0	0.0	0.0	1	0

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

STORAGE=	0.	94.	191.	293.	398.	507.	620.	736.	857.	981.
OUTFLOW=	0.	491.	1517.	2882.	4614.	6696.	8966.	12906.	18582.	25018.

TIME	EOP STOR	AVG IN	EOP OUT
1	2.	9.	9.
2	4.	43.	21.
3	16.	198.	84.
4	56.	672.	293.
5	146.	1765.	1046.
6	291.	3703.	2861.
7	459.	6354.	5782.
8	611.	9136.	8801.
9	687.	10936.	11241.
10	677.	10950.	10902.
11	636.	9722.	9528.
12	578.	8119.	8124.
13	510.	6615.	6754.
14	447.	5390.	5549.
15	393.	4392.	4535.
16	346.	3579.	3761.
17	304.	2916.	3077.
18	268.	2376.	2553.
19	235.	1936.	2112.
20	207.	1577.	1730.
21	183.	1285.	1428.
22	161.	1047.	1197.
23	141.	853.	989.
24	124.	695.	811.
25	110.	567.	663.
26	98.	462.	541.
27	88.	376.	462.
28	78.	307.	406.
29	67.	250.	351.
30	57.	203.	298.
31	48.	165.	251.
32	40.	130.	208.
33	32.	96.	168.
34	24.	55.	128.
35	17.	21.	90.
36	11.	6.	60.
37	7.	0.	39.
38	5.	0.	25.
39	3.	0.	16.
40	2.	0.	10.
41	1.	0.	7.
42	1.	0.	4.

100

43	1.	0.	3.
44	0.	0.	2.
45	0.	0.	1.
46	0.	0.	1.
47	0.	0.	0.
48	0.	0.	0.

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SUM 96919.

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	11241.	9225.	3952.	2019.	96919.
INCHES		4.49	7.70	7.87	7.87
AC-FT		4577.	7843.	8014.	8014.

RUNOFF SUMMARY, AVERAGE FLOW

		PEAK	6-HOUR	24-HOUR	72-HOUR	AREA
HYDROGRAPH AT	1	11403.	9402.	3976.	2019.	19.10
ROUTED TO	1	11241.	9225.	3952.	2019.	19.10