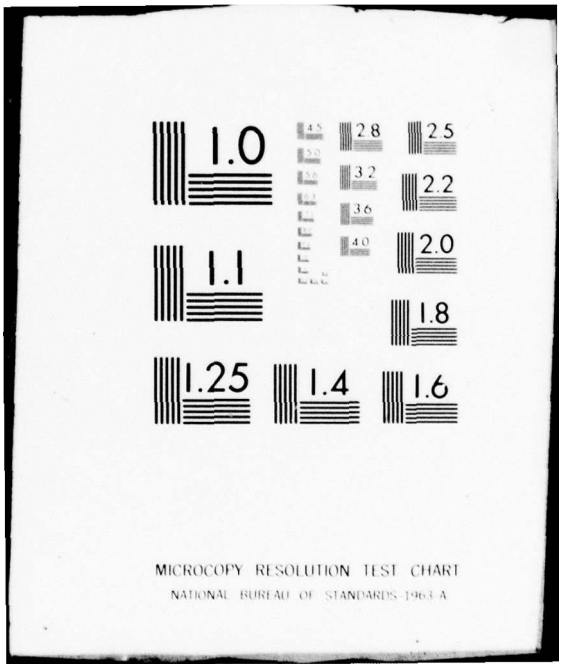
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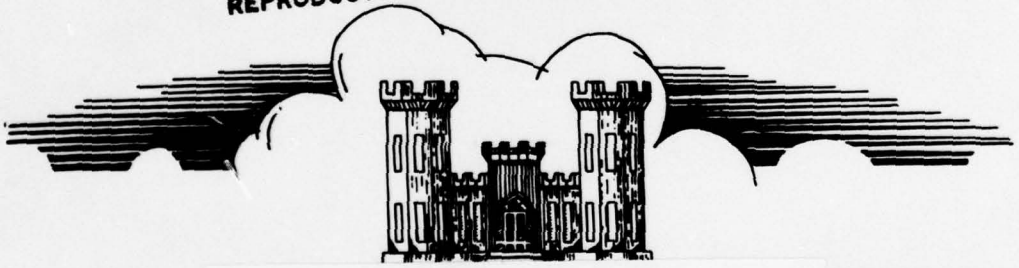
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PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

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DELAWARE RIVER BASIN

NOCKAMIXON STATE PARK DAM
BUCKS COUNTY, PENNSYLVANIA
NATIONAL I.D. NO. PA 00734

National Dam Inspection Report. Nockamixon State Park Dam (PA-00734), Delaware River Basin, Tohickon Creek, Bucks County, Pennsylvania. Phase I Inspection Report.

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

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John H. Frederick, Jr.
William S. Gardner

DAC-U31-78-C-0048

Prepared by:

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DEPARTMENT OF THE ARMY
Baltimore District, Corps of Engineers
Baltimore, Maryland 21203

JULY 1978

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PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

Name of Dam: Nockamixon State Park Dam
County Located: Bucks County
State Located: Pennsylvania
Stream: Tohickon Creek
Coordinates: Latitude 40° 28.2' Longitude 75° 11.2'
Date of Inspection: 21 June 1978

Nockamixon State Park Dam has been in continual service since 1974, and is jointly owned and operated by the Department of Environmental Resources and the General State Authority. It has been classified as a "Large" dam with a "High" hazard potential. Based on the visual inspection, evaluation of records, and past operational performance, the dam is judged to be in good condition with remedial work necessary for future operation of the outlet works. The dam was designed to pass, without overtopping, the probable maximum flood (PMF). Therefore, the spillway is considered "Adequate".

The visual inspection of the dam and reservoir facilities detected no symptoms of uncontrolled seepage, instability, significant deterioration or other conditions that would suggest impending hazardous conditions.

In summary, examination of the available data and results of the visual inspection reveals no condition or evidence detrimental to the integrity of the dam or appurtenances.

It is suggested that the following recommendations be implemented as soon as practical:

1. Debris should be removed from the inside of the control tower and exterior entrance to the bottom sluice gate.

2. Sluice gates in the control tower should be inspected in detail and repaired, as necessary, to meet design specifications.

3. Missing access ladders, landings, etc., should be installed.

4. Piezometers should be rehabilitated or replaced.

5. Monuments and piezometers should be monitored periodically.

6. The Parshall flume located downstream should be repaired and measurements performed in accordance with the Permit requirements.

7. A 13-inch deep concrete core hole drilled into the right wall of the right "horseshoe" conduit near the base of the intake tower should be filled.

8. The rock channel below the upper wier should be inspected yearly in accordance with the designer's recommendations. Rock talus accumulations along this channel should be removed.

Because of the location upstream from populated areas, a formal procedure of observation and warning during periods of high flows or development of potentially hazardous conditions should be developed and implemented. The maintenance inspection procedure should be amended to include an inspection checklist to insure that all items are inspected regularly.

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Maryland Registration 7301
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11 Aug 78
Date

William S. Gardner, P.E.
Penna. Registration 4302E
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11 Aug 78
Date

APPROVED BY:

JOHN H. KENWORTHY
LTC, Corps of Engineers
Acting District Engineer

25 Aug 78
Date

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OVERVIEW
NOCKAMIXON STATE PARK DAM, BUCKS COUNTY PENNSYLVANIA

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM
NOCKAMIXON STATE PARK DAM
NATIONAL ID #PA 00734
DER #9-166

SECTION 1
PROJECT INFORMATION

1.1 General

a. Authority. The Dam Inspection Act, Public Law 92-367, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of inspection of dams throughout the United States.

b. Purpose. The purpose of the inspection is to determine if the dam constitutes a hazard to human life or property.

1.2 Description of Project

a. Dam and Appurtenances. Nockamixon State Park Dam is a zoned earth and rock-fill dam situated across Tohickon Creek in Bedminster and Nockamixon Townships, Bucks County, Pennsylvania. The dam has created a 1,450 acre lake which is presently utilized for recreation, but is designed and constructed for possible future water supply use. The lake impounds 40,000 acre-feet of water and is situated in a 73.3 square mile watershed with elevations that range from 1,000 to 395 at the spillway crest.

The dam has a maximum height of 112 feet, length of 1,511 feet, top width of 20 feet and a top of dam elevation of 412 feet. Construction consists of a relatively impervious earth core with a rock shell. A 12 foot wide filter zone separates the core from the rock fill on both the upstream and downstream sides. The core was constructed with side slopes of 2.5:10 (H:V).

The upstream slope has a 2:1 (H:V) inclination from the crest to a 10 foot wide berm at elevation 342. This berm is the top of the earth diversion cofferdam used during construction.

The downstream slope has a 1.75:1 (H:V) inclination from the crest to the 13 foot wide access road below which the slope steepens to 1.5:1 (H:V). Elevation of the access road varies with elevation decreasing from the right abutment towards the left abutment.

Foundation preparation included a two-zoned single line grouting program of the bedrock. The first zone extends 20 feet below the excavated foundation and the second zone extends from 20 to 50 feet below the first zone. Primary hole spacing was 20 foot on centers with split spacing conducted to a maximum center-to-center spacing of 5.0 feet. All grout holes were made an angle of 30 degrees from vertical and oriented normal to the prevailing strike of the joint pattern. A double grout line may have been used but confirmation was not found in the data reviewed.

The outlet works consists of an intake structure containing four gates and two "horseshoe" concrete conduits (each 10.5 feet wide at the base and 10.5 feet high). A 72-inch I.D. steel pipe extends 344 feet through the right "horseshoe" conduit and discharges through a Howell-Bunger valve. A 10-inch I.D. steel pipe is suspended from the left tunnel ceiling and maintains minimum flow requirements downstream. Intake gates are located at elevations 385.0, 358.5 and 328.0. The fourth gate, elevation 311.0, was used for stream diversion and closure during construction. It can be used to drain the reservoir.

A spillway for normal and emergency flows has been excavated into rock in the right abutment and has an ogee weir (crest elevation 395.0) extending across the 350 foot width. A 4-inch deep notch 50 feet long was constructed in the crest to pass normal flow. The spillway makes a 90 degree bend to the north, parallel to the dam axis, at approximately 400 feet downstream of the first ogee and narrows to a width of 250 feet. The first stilling basin begins at the 90 degree bend. Flows from this stilling basin are controlled by a second ogee weir (crest elevation 326.0) extending across the spillway section approximately 250 feet downstream of the first ogee weir. A second stilling basin is located below the second weir and discharges into the downstream channel converging with flow from

the outlet works. A rock spoil area is located between the dam and the spillway to provide erosion protection from spillway flows.

b. Location. Nockamixon State Park Dam is located on Tohickon Creek in Bedminster and Nockamixon Townships, Bucks County, Pennsylvania. The dam is located 4,400 feet north of Fretz Valley Road. The left abutment is located in Nockamixon Township with the right abutment and spillway located in Bedminster Township. The dam site and reservoir are shown on USGS Quadrangle entitled "Bedminster, Pennsylvania" at coordinates N 40° 28.2', E 75° 11.2'. A Regional Location Plan of Nockamixon State Park Dam and Reservoir is enclosed as Plate 1, Appendix E.

c. Size Classification. The dam is classified as a "Large" dam consistent with its 112 feet height.

d. Hazard Classification. This dam has a "High" hazard classification because of the potential for extensive property damage and loss of life downstream.

e. Ownership. The dam is jointly owned and operated by the General State Authority and the Commonwealth.

f. Purpose of the Dam. Recreation, water supply (future).

g. Design and Construction History. Primary design consultants were Pickering, Corts and Summerson, Inc. Other consultants for this project included Justin and Courtney, geotechnical engineers and Albert J. Depman, geolgist. Aero Service Corporation performed aerial mapping. Miller-McNichol Associates performed laboratory testing of soils. Exploratory borings were performed by the Foundation Services Company and Vagnoni Brothers. Because of the unique spillway configuration, model studies were performed at Lehigh University, Institute of Research by Messrs. David R. Vasco, John B. Herbich and Paul D. Erfle.

The design presented in the initial design report by Pickering, Corts and Summerson, Inc. dated

May 17, 1965 proposed a two-stage structure. The first stage established a reservoir at elevation 375 by a concrete spillway. Thereafter, 20 foot high gates would be installed for the second stage to develop the reservoir elevation at 395.0. Subsequent to the initial report, an interim report was issued on November 9, 1965 by Pickering, Corts and Summerson, Inc. which presented a revised design for a single stage construction using a concrete ogee weir at elevation 395.0.

The contractor for this project was Glasgow Construction Company, Inc., of Glenside, Pennsylvania. Some information concerning construction activity was included in the State files. Other sources of information were obtained from conversations with State personnel and the designer. Correspondence indicates that construction began in late 1968 or in the first half of 1969. Stream flow was directed through the two "horseshoe" conduits in September of 1969. Reports indicated that rock fill began in October, 1969 and core construction began in the Spring of 1970. The park superintendent indicated that all essential features of construction were completed by November 13, 1973. However, two completion reports were filed for this date and April 25, 1974.

Casagrande-type piezometers were installed during construction and monitored before, during and following filling of the reservoir. Readings became erratic and were discontinued shortly after the reservoir was filled. It was learned from Mr. Sam Reed, DER, that the State provided construction inspection services including concrete and soil quality control testing.

h. Normal Operating Procedures. The minimum flow requirement is supplied downstream via a 10-inch steel pipe. The pipe passes through the left "horseshoe" shaped conduit and the flow rate is controlled at the outlet structure.

Excess water above normal pool (elevation 395) flows over the spillway. Three gates in the tower are normally in the open position and the water is discharged through a 72-inch pipe located in the right

"horseshoe" conduit. Flow is controlled by a Howell-Bunger valve at the end of the conduit.

1.3 Pertinent Data

A summary of pertinent data is presented as follows:

a. Drainage Area (square miles)	73.3
b. Discharge at Dam Site (cfs)	
Maximum Known Flood at Dam Site (7/14/75)	6,460
Maximum Design Flood (PMF)	96,000
Minimum Required Discharge	11.0
Howell-Bunger Discharge Pipe (Max.)	1,200+
Maximum Non-Damaging Discharge	44,000
c. Elevations (above MSL)	
Top of Dam	412.0
Normal Pool (Spillway Crest)	395.0
Maximum Pool (Top of Dam)	412.0
Maximum Pool of Record	397.9
Intake Tower	
Upper Sluice Gate	385.0
Middle Sluice Gate	358.5
Lower Sluice Gates	328.0
Drain Sluice Gate	311.0
Minimum Flow Intake Invert	326.0
d. Reservoir	
Length at Normal Pool	6.0
Fetch at Normal Pool	0.6
Shoreline	24 miles
Time to Drain	32 days
e. Storage (acre-feet)	
Normal Pool	40,000
200-year Storm (Elev. 399.5)	47,000
Max. Volume (Elev. 412, Crest)	71,000
f. Reservoir Surface (acres)	
Normal Pool	1450 acres
g. Dam Data	
Type	Earth and Rock Fill
Length	1511 feet
Height	112 feet
Crest Width	20 feet

Side Slopes	
Upstream	
Crest to Elev. 342	2.0H:1V
Elev. 342 to Toe	2.5H:1V
Downstream	
Crest to Access Road	1.75H:1V
Access Road to Toe	1.5 H:1V
Zoning	Rock fill with impervious core. 12 foot filter zone on upstream and downstream side of core
Grout Curtain	Two zone, split spaced procedure with max. spacing of 5 feet.

h. Intake Tower and Facilities

Sluice Gates	
Upper (Elev. 385.0)	36" x 36"
Middle (Elev. 358.5)	36" x 36"
Lower (Elev. 328.0)	2-36" x 60"
Drain (Elev. 311.0)	48" x 60"
Min. Flow Pipe (Elev. 326.0)	10" CIP
Outlet Conduit	
Length	344 feet
Height x Width	10'6" x 10' 6"
Pipe (Diameter)	72"
Valve (Fixed Cone Dispersion)	60"

i. Spillway

Type	2-Level Ogee Crest with Stilling Basins
Upper Ogee Crest	
Length	350 feet
Elev.	395.0
Upper Stilling Basin	
Entrance Width	330 feet
Exit Width	250 feet
Floor Elevation	320.0
Lower Ogee Crest	
Length	250 feet
Crest Elevation	326.0
Lower Stilling Basin	
Entrance Width	250 feet
Exit Width into Natural Stream Channel	80 feet

SECTION 2
ENGINEERING DATA

2.1 Design

a. Data Available. A summary of engineering data is presented in the checklist attached as Appendix A. Principal documents containing pertinent data used for this report are listed below.

1. "Report Upon the Application of the General State Authority and the Department of Forests and Waters", by Joseph J. Ellam, Hydraulic Engineer, dated April 1, 1968.

2. "Recommended Design of Dam" by Pickering, Courts and Summerson, Inc.", dated May 17, 1965.

3. "Interim Report One Stage Construction", by Pickering, Corts and Summerson, Inc.", dated November 9, 1965.

4. "Model Study of Ninety Degree Spillway for Nockamixon Dam", Lehigh University, by David R. Basco, John B. Herbich, Paul D. Erfle.

5. Construction Drawings (24) prepared by Pickering, Corts and Summerson, Inc. dated July 31, 1967.

6. "Project No. G.S.A. 19412 Contract No. G.S.A. 194-12.1 for Construction of Dam Nockamixon State Park, Bucks County, Pennsylvania, The General State Authority" prepared by Pickering, Corts and Summerson, Inc.

7. Construction Progress Reports, Inspection Reports, Memos and Correspondence included in the State files.

Reports by Pickering, Corts and Summerson, Inc., and the spillway model study were obtained directly from the design engineers.

b. Design Features. A complete description of the design features of this project is discussed in Section 1.2, "Description of Project".

2.2 Construction

A description of the construction history as determined from the design engineer, Park personnel and DER files is described in Section 1.2.

2.3 Operation Data

The application report requires that the minimum flow requirement of 11 cfs, 7.1 million gallons per day, be discharged into Tohickon Creek. It is reported in the application report and in other documents that the minimum flow is to be monitored by means of a Parshall flume located downstream. However, the inspection revealed that this Parshall flume was washed out on both sides and was no longer functioning as designed. There were no records to indicate that measurements were ever taken on this flume. The reservoir level measurements are recorded on a Stevens-type gauge located in the intake tower and are kept at the nearby sewage treatment plant. There are no other operational records available.

2.4 Evaluation

a. Availability. All engineering data reproduced in this report and studied for this investigation were provided by the Department of Environmental Resources or from Pickering, Corts and Summerson, Inc., design consultants. The Owner's representative, Mr. Jerry Koder, Park Foreman was present during the visual inspection and provided information concerning the construction and operation of the dam.

b. Adequacy. Data included in the State file along with information from the design consultants is considered adequate to evaluate the dam and appurtenant structures.

c. Validity. There is no reason to question the validity of the avilable data.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. General. The observations and comments of the field inspection team are contained in the checklist contained herein as Appendix B and are summarized and evaluated as follows. In general, the appearance of the facility indicated that the dam and its appurtenances were properly constructed and are reasonably well maintained. It is noted that the intake tower has not been rehabilitated to the design requirements and that considerable work is required to complete the rehabilitation.

b. Dam.. During the visual inspection, there were no indications or evidence observed of distortions in alignment or grade that would be indicative of movement of the embankment or the foundation. A careful inspection of the dam including the downstream area disclosed no evidence of seepage emergence on the downstream slope, the toe or along the left abutment downstream of the embankment. Although not observed, internal drain systems have not produced evidence of a malfunctioning condition. No erosion or deterioration were observed along the abutment between the dam and the natural ground surface on either the downstream side or the upstream side to the water's edge. Since the structure is a rock fill structure, very little vegetation exists on the slopes. The road across the dam crest and the access road on the downstream slope were in good condition.

c. Appurtenant Structures. The intake tower and approach bridge from the top of the dam to the tower was inspected and observed to be in good condition. All gates and valves at the top of the intake structure were exercised and observed to work properly. However, the gates leaked in the closed position. It was noted that all gates were in the open position at the time of the inspection. In order to obtain access to the tower the gates were closed and the Howell-Bunger valve opened to drain the intake tower. The exterior concrete at the tower above the water line is in good condition.

The park superintendent stated that the tower facilities were damaged during the initial

operation of the system. Primary components were repaired but more work is required to restore the tower to the designed condition. The interior portion of the tower was inspected down to elevation 355. Access below this level was prohibited due to high inflow of water leaking through the lower sluice gates. The three lower gates were leaking profusely and it appears that gate seals were not functioning properly. Interior ladders and platforms were torn out during initial operation of the outlet works and have not been restored. They currently do not meet pertinent codes for ladders, landing, etc. The concrete work down to elevation 355 is in good condition. There were no cracks or signs of distress or evidence of seepage through horizontal construction joints.

Access to the two tunnels beneath the embankment which connect to the intake structure was achieved at the downstream toe of the dam. Both of these tunnels are in good condition. Minor cracking, mostly at construction joints, was observed. Isolated longitudinal cracks along the crown and the invert slab were also observed near the center of the dam. One seepage hole, 2 inches in diameter, was flowing clear in the left tunnel. A 6-inch diameter by 13-inch deep concrete core hole approximately 4 feet from the invert slab and 10 feet from the intake tower wall was observed in the right side of the right tunnel. Apparently, this core was taken to test the quality of the concrete. Walls at tunnels were inspected and there were no significant cracks, seepage or other forms of deterioration. The Howell-Bunger valve was exercised and appeared to be functioning properly. There was no evidence or signs of seepage at the junction of the two tunnels with the surrounding embankment.

The control house for the Howell-Bunger valve was inspected and observed to be in good condition. There were no cracks, spalling or other signs of deterioration. The piezometer control panel is mounted on one interior wall of the control house. This panel was inspected but the piezometers were not functioning. Mr. Koder, park foreman, indicated that these piezometers malfunctioned during and following the filling of the reservoir and readings had been discontinued several months after the reservoir had been filled.

The spillway consisting of two ogee crest weirs, natural rock channel and stilling basins were observed and inspected. Discharge over the spillway was flowing through the 4-inch notch in center of the first spillway. Concrete surfaces were inspected and observed to be in good condition. Alignment was good. Although an uneven rock surface was exposed, there was no evidence of significant undercutting at the toe of the upper ogee weir. There were no significant horizontal or vertical cracks observed through the weir. The downstream natural rock channel and side rock walls appeared to be in stable condition. There is evidence that previous sloughing and spalling of rock has occurred in the past. This is evidenced by fresh rock faces and accumulation of talus at the toe of the rock slopes. The stilling pool edges were inspected and the vertical retaining wall around the base of the pool was found to be in good condition with no evidence of significant spalling or softening of rock. The lower spillway weir was in good condition with no evidence of misalignment, movement, excessive cracking or spalling of concrete. Minor shrinkage cracks were observed between construction joints along the retaining wall. Alignment was good with only minor separation at a few construction joints. Minor surface cracks were observed on panels near the center of the spillway.

d. Reservoir. Reconnaissance of the reservoir disclosed no evidence of siltation, slope instability, or other features that would significantly affect the storage capacity of the reservoir. The reservoir drainage area slopes are covered with predominately hardwoods. or farmland. There was no evidence of slope creep, rock slides or other landslides. Currently, there is little residential development in the drainage basin but development is expected to increase rapidly in the near future.

e. Downstream Channel. Slopes of the downstream channel immediately below the dam are heavily wooded. The downstream channel has side slopes varying from near-vertical to approximately 2.5:1 (H:V) and the flood plain is relatively narrow immediately downstream at the dam. Isolated homes are located along the channel principally near road crossings. Flooding is expected in these areas during high flow conditions.

3.2 Evaluation

The inspection of the dam disclosed no evidence of apparent past or present movement that indicate an existing instability of the dam, spillway or outlet works. There were no signs of seepage or any other forms of uncontrolled leakage through the dam. The condition of the gates are not known because of this seepage and could be a problem if they are not repaired. The outlet works sluice gates leak.

The overall condition of the intake tower was good. It is noted that some remedial work has been accomplished in the intake structure but it is evident that this rehabilitation is incomplete. The ladder and balcony gradings along the interior of the tunnel are loose or non-existent. The base of the tower contains some debris which could clog the outlet pipe. The outlet tunnels were inspected and observed to be in good condition. The Howell-Bunger was exercised and observed to work properly.

The emergency spillway was inspected and both weirs, the rock channel, side walls and retaining walls were observed to be in good condition. The downstream channel was observed to be stable with no significant signs of erosion except in the area of the Parshall flume. The Parshall flume should be restored and measurements taken in accordance with the design engineer's recommendations.

SECTION 4
OPERATIONAL PROCEDURES

4.1 Procedures

Operational procedures are discussed in detail in Section 1.2.

An operating procedure written by the design engineer was reviewed at the Park Office. This procedure included a description of the dam, its appurtenant facilities, and other pertinent features of the structure. Included in this procedure was a complete description of the controlling devices in the intake tower together with manufacturer's recommendations for usage. Included in this manual was a complete description of each valve, its size, its location, and in many cases its flow capacity. The Park Foreman was not aware of this manual until this inspection at which time the administrative staff searched the files for information regarding the dam.

4.2 Maintenance of Dam

The dam is reportedly maintained by the Park Commission personnel who periodically check all structures and perform repairs as necessary.

4.3 Maintenance of Operating Facilities

The valve control mechanisms in the intake tower were all exercised and observed to be clean, painted and well lubricated. However, complete rehabilitation of the gates and intake tower landing and ladder has not been performed although conditions observed have existed for the past two to three years.

4.4 Warning System in Effect

There are no formal warning systems or procedures established to be followed during periods of exceedingly heavy rainfall. However, the Park Superintendent does have a list of personnel to contact in the event that high flow is expected to be discharged through the dam or over the emergency spillway.

4.5 Evaluation

Although there is an operating procedure as previously mentioned, this procedure was not found until the inspection of the Superintendent's files. It is understood that the Park Foreman will read these procedures and comply with them henceforth. The only formal procedures documented in this manual is the method for lowering the reservoir through the Howell-Bunger valve. It is expected that this system would be used to lower the reservoir during the winter months to prevent ice damage along the docks; prior to impending high inflow storm; or, when maintenance is required at some elevation below normal pool. Since there is no formal warning procedure, it is recommended that a procedure be developed and implemented such that residents downstream could be amply warned of possible high volumes of flow downstream or a potentially hazardous condition.

SECTION 5
HYDROLOGY/HYDRAULICS

5.1 Evaluation of Features

a. Design/Evaluation Data. Original design information was obtained from Pickering, Corts and Summerson, Inc. and consisted of the "Recommended Design of Dam", May 17, 1965; "Interim Report One-Stage Construction", November 9, 1965; and "Model Study of 90 Degree Spillway for Nockamixon Dam", March, 1967 (Lehigh University). The data reviewed were the results of their investigations and analyses rather than actual design calculations.

The watershed is large, 73.3 square miles, irregularly shaped with elevations ranging from 1,000 feet in the upper reaches to approximately 395 at the spillway crest. Currently the drainage area contains very few residential developments, which are concentrated principally near the city of Quakertown. The watershed is predominantly farmland. Less than 50 percent of the basin is wooded.

The dam was designed for future watershed conditions expected to occur after the year 2000. Prior to construction, a model of the spillway and waste channel was constructed and tested at Fritz Engineering Laboratory, of Lehigh University. As a result of this study, the forebay and wasteway channel was modified to improve flow conditions. The elevation-discharge curve and flood-routing analysis performed for the original spillway configuration remained unchanged. The spillway is capable of discharging 96,000 cfs when the reservoir surface is at the top of the dam (see Appendix C).

The original PMF inflow hydrograph calculations resulted in a peak inflow rate of 147,000 cubic feet per second. As the actual calculations were not available to review, results were evaluated by approximate methods (see Appendix C).

In accordance with the criteria established by the Federal (OCE) Guidelines, the recommended spillway design flood for this "Large" size dam with a "High" hazard potential is the Probable Maximum Flood (PMF).

b. Experience Data. Records of reservoir water levels are maintained at the park sewage treatment plant located to the right of the emergency spillway. Reservoir levels are recorded automatically inside the intake tower by means of a Stevens Recorder. Examination of selected rolls of water level data disclosed a maximum water level above the weir of 2.9 feet on July 14, 1975, producing a spillway discharge of 6,460 cfs.

c. Visual Observations. On the date of the inspection, no conditions were observed to indicate that the outlet capacity would be significantly reduced during a PMF event. Observations regarding the downstream channel, spillway conditions and the reservoir are located in Appendix B.

d. Overtopping Potential. The peak PMF inflow was determined by Justin and Courtney to be 147,000 cfs resulting from 2.5 times the six-hour point rainfall as assumed for future conditions. The spillway was designed to pass 96,000 cfs and store water to the dam crest (Elevation 412). These design results were checked by approximate methods (see Appendix C), and it appears that the analysis is reasonable and the spillway is capable of passing the PMF without overtopping.

e. Spillway Adequacy. Based on the above information which shows that the spillway can pass the PMF, the spillway is judged "Adequate". The tailwater rating curve included in Appendix C estimates the tailwater to be 50 feet or more below the top of the dam during the passing of the PMF.

f. Downstream Conditions. Approximately 2,000 feet downstream of the dam, Tohickon Creek passes through a 65.5 feet by 40 feet (at mid-span) bridge under South Park Road. Approximately 2,400 feet further downstream, the creek passes through an eight-span bridge under Fretz Valley Road (LR 09152). Analysis of tailwater conditions immediately below the dam indicate that this later bridge is the hydraulic control for discharge. An estimated 44,000 cfs could pass under the bridge without flooding the entire structure. The low approach on the north side may be flooded. Should Nockamixon Dam fail, significant property damage to more than a dozen homes and probable loss of life would occur in the first 5.5 miles downstream.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observation. The visual observations do not indicate any existing embankment stability problems. No seepage was observed during the inspection which would be detrimental to the structural integrity of the dam. Therefore, it is judged that potentially hazardous conditions are not developing.

The visual inspection of the spillway did not reveal any evidence of instability at the ogee weirs, rock channel or stilling basins. Spalling of rock walls appears to have reached a point of equilibrium and further movement of the rock should be negligible.

The intake tower, outlet conduits and control mechanisms are generally in good condition except for the three upper sluice gates and landings at the intake tower which were discussed in Section 3. Stability of the gates under hydrostatic pressure when closed and the tower drained is not known and is most likely reduced due to existing damage.

b. Design and Construction Data. The stability of the dam is judged to be "Adequate" based on review of the available data. The report entitled "Recommended Design of Dam" contains material strength data and the results of stability analyses performed for the initial design of the dam at crest elevation 405. The Swedish circle analyses presented, indicates a minimum factor of safety of 1.56 and 1.75 for rapid drawdown and steady state seepage conditions, respectively. Stability analyses of the final dam configuration (crest Elevation 412) was not provided for review by the design engineer. The results are reported to be similar to the original evaluations.

Quality control construction documentation were not available for this review.

c. Operating Records. Operating records consist of reservoir water level data. Although records of flow over the Parshall flume, located downstream, are required in the "Report Upon the Application", records have not been maintained.

d. Post-Construction Changes. Other than partial rehabilitation of the intake tower, there are no reports or evidence of modifications or alterations having been made to this dam. Erosion around the abutments of the Parshall flume has occurred but has not been repaired. A small amount of rock spalling has occurred in the rock channel at the spillway and appears to have stabilized.

e. Seismic Stability. Nockamixon State Park Dam is located in Seismic Zone I. Normally, it can be considered that, if a dam in this zone is stable under static loading conditions, it can be assumed safe for any expected earthquake conditions. Therefore, it is judged that the structure satisfies seismic stability requirements.

SECTION 7
ASSESSMENT/REMEDIAL MEASURES

7.1 Dam Assessment

a. Assessment. Based on the visual inspection, available records, calculations and past operational performance, Nockamixon State Park Dam is judged to be in good condition. The hydrologic and hydraulic analyses available for this inspection were reviewed and indicate that the dam would pass the PMF event. Therefore, the spillway is considered to be "Adequate". Although the spillway design passes the PMF, significant property damage is likely downstream due to the high flow rates. Damage would be expected to occur at low-lying houses along the creek with some damage to highway bridges expected.

b. Adequacy of Information. It is concluded that the information obtained for this assessment is adequate.

c. Urgency. It is considered that the recommendations presented below be implemented as soon as practical.

d. Necessity of Additional Studies. No additional studies are recommended at this time.

7.2 Remedial Measures

a. Facilities. The following remedial measures are recommended.

1. All debris should be removed from the inside of the intake structure. Debris obstructing the drain gate should also be removed.

2. All gates in the control tower should be inspected in detail and restored to design specifications.

3. Access structures within the tower (ladders, landings, etc.) should be replaced as required.

4. Piezometers should be rehabilitated or replaced and monitored periodically.

5. Monuments constructed on the dam should be surveyed periodically.

6. Piezometer and monument readings should be reviewed periodically.

7. The 13-inch deep concrete core hole in the right "horseshoe" conduit near the base of the intake tower should be packed with a non-shrink grout.

8. The downstream Parshall flume should be repaired and flow measurements made in accordance with the Permit.

9. The rock channel below the upper weir should be inspected yearly in accordance with the designer's recommendations. Rock talus accumulation along this channel should be removed.

b. Operation and Maintenance Procedures. Because of the location of the dam upstream from populated areas, a formal procedure of observation and warning during periods of high precipitation or during potentially hazardous conditions should be developed and implemented. The Park personnel should review, modify (if necessary) and implement the operational procedure which is currently in their files. Park personnel should also implement a maintenance inspection procedure to include an inspection checklist of critical items which should be inspected on a periodic basis. Provisions should also be incorporated in the operation procedure to minimize the risk of damaging the sluice gates and access facilities again.

APPENDIX

A

CHECK LIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION
PHASE I

NAME OF DAM *Nockamixon State Park Dam*

ID # *PA 00734*

ITEM	REMARKS
AS-BUILT DRAWINGS	*No. However, a 25-sheet set of design drawings prepared by Pickering, Corts and Summerson, Inc., Newtown, Pennsylvania, dated July, 1967 were available and reviewed.*
REGIONAL VICINITY MAP	*Yes. Prepared by the Design Engineer and enclosed are Plate 1, Appendix E.*
CONSTRUCTION HISTORY	*No formal documentation was availabe but several discussions were conducted with Park personnel, the Design Engineer, DER and other state representatives.*
TYPICAL SECTIONS OF DAM	*Yes. These are included with the design drawings.*
OUTLETS - PLAN DETAILS CONSTRAINTS DISCHARGE RATINGS	*All of this data was either provided by the Design Engineer or from DER files.*
RAINFALL/RESERVOIR RECORDS	*Records were not available but summarizes of the data were included with the Design Engineer's calculations.*

ITEM	REMARKS
DESIGN REPORTS	*Yes. A complete "Recommended Design of Dam" report prepared by Pickering, Corts and Summerson, Inc., dated May 17, 1965 was available and reviewed. Report included geology, soils, H&H data, stability, study summaries and soil test results. Structural calculations were not available for review.*
GEOLOGY REPORTS	*Yes. The Design Report contains a geologic section prepared by the Designer. Mr. Albert J. Depman was the consulting engineering geologist.*
*DESIGN COMPUTATIONS **HYDROLOGY & HYDRAULICS **DAM STABILITY *SEEPAGE STUDIES	1. * *This information was not available for review but the conclusions and results of the analysis was avaialable and reviewed.* 2. ** *Some calculations and the input assumptions and results were available. The preponderance of these calculations were not available.*
MATERIALS INVESTIGATIONS BORING RECORDS LABORATORY FIELD	*Test boring locations, logs of borings and soil type results were available and reviewed. This work was performed by The Foundation Service Company, Vagnoni Brothers and Miller-McNichol Associates.*
POST-CONSTRUCTION SURVEYS OF DAM	*No records were available. Design Engineer requested that these records be kept and the program reinitiated.*
BORROW SOURCES	*Data was available and reports from park personnel indicates that the designated sources were used during construction.*

ITEM	REMARKS
MONITORING SYSTEMS	*Monitoring systems include piezometers and alignment monuments. All locations were noted but records were not available.*
MODIFICATIONS	*The control system in the intake tower (sluice gates) were rebuilt after they were damaged during the intitial exercising of the gates. At the time of the inspection repair work was still incomplete.*
HIGH POOL RECORDS	*These records are in storage at the sewage treatment plant; they were reviewed and pertinent data is presented in the report.*
POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS	*None known except for the rehabilitation of the intake tower.*
PRIOR ACCIDENTS OR FAILURE OF DAM DESCRIPTION REPORTS	*None*
MAINTENANCE OPERATION RECORDS	*A maintenance and operation manual exists and was reviewed. However, the Park personnel only located it during the inspection. Records were not available.*

ITEM	REMARKS
SPILLWAY PLAN SECTIONS DETAILS	*This data was presented with the design drawings.*
OPERATING EQUIPMENT PLANS & DETAILS	*The operations manual contains details of the controling equipment.*

MISCELLANEOUS DOCUMENTS

1. *Contract Specifications, Project GSA 194-12.1, Nockamixon State Park Dam, by Pickering Corts and Summerson, Inc.*
2. *"Report Upon the Application of the General State Authority, dated April 1, 1968.*
3. *Letter report on repair of the intake tower, to Mr. G.R. Robinson, Regional Park Superintendent; from John K. Wiediger, Park Superintendent.*
4. *Assorted letters and memos pertaining to consruction.*
5. *"Model Study of Ninety Degree Spillway for Nockamixon Dam", Lehigh University, Institute of Research, by D.R. Basco, et al., Report No. 326.2, March 1967.*

APPENDIX

B

CHECK LIST
VISUAL INSPECTION
PHASE I

Name Dam *Nockamixon State Park Dam* County *Bucks* State *Pennsylvania* National ID # *PA 00734*

Type of Dam *Earth and Rockfill* Hazard Category *High*

Date(s) Inspection *21 June 1978* Weather *Cloudy & Rain* Temperature *60's °F*

Pool Elevation at Time of Inspection *395.0* M.S.L. Tailwater at Time of Inspection *310.0* M.S.L.

Inspection Personnel:

Mary Beck (Hydrologist) *Brady Bisson (Geotechnical/Civil)*

John Boschuk, Jr. (Geotechnical/Civil) *Robert Griffin (Structural)*

Vince McKeever (Hydrologist)

John Boschuk, Jr. Recorder

Remarks:

Mr. Jerry Koder (Park Foreman) was on site and supplied information about operation maintenance and construction history.

Mr. John Wiediger (Park Superintendent) was not available during the inspection.

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
ANY NOTICEABLE SEEPAGE	*NONE*	
STRUCTURE TO ABUTMENT/EMBANKMENT JUNCTIONS	*NONE*	
DRAINS	*NONE*	
WATER PASSAGES	*NONE*	
FOUNDATION	*NONE*	

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS CONCRETE SURFACES	*NONE*	
STRUCTURAL CRACKING	*NONE*	
VERTICAL AND HORIZONTAL ALIGNMENT	*NONE*	
MONOLITH JOINTS	*NONE*	
CONSTRUCTION JOINTS	*NONE*	

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS	*NONE OBSERVED*	
UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE	*NONE OBSERVED*	
SLOUGHING OR EROSION OF EMBANKMENT AND ABUTMENT SLOPES	*NONE OBSERVED*	
VERTICAL AND HORIZONTAL ALIGNMENT OF THE CREST	*Alignment appears good with no distorsions observed*	
RIPRAP FAILURES	*NONE OBSERVED*	*Gradation of rock fill appears reasonable and rock quality is good.*

EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
JUNCTION OF EMBANKMENT AND ABUTMENT, SPILLWAY AND DAM	*No seepage, erosion, or distortions observed.*	
ANY NOTICEABLE SEEPAGE	*None observed at the toe of the dam or along the downstream channel to the weir.*	
STAFF GAGE AND RECORDER	*There is a staff gage on the control tower and a recorder inside the tower (Stevens Type).*	
DRAINS	*Seepage drains all appeared to be operating and in good condition.*	

OUTLET WORKS

(FROM INTAKE TOWER TO OUTLET CHANNEL)

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CRACKING AND SPALLING OF CONCRETE SURFACES IN OUTLET CONDUIT	*Both tunnels were inspected and are in good condition. Minor cracking was observed at construction joints, isolated longitudinal cracks along the crown near center of dam and in invert slab. Left tunnel had a 2 inch weep hole with a constant, clear flow. The right tunnel had a 4 inch by 12 inch core hole which should be repaired.*	
INTAKE STRUCTURE	*Bridge to intake structure and exterior concrete above water line are in good condition. Interior was inspected from El. 412 (floor) to El 355, profuse leakage from sluice gates prevented inspection to the bottom. (El. 311). Existing condition of interior ladders and platform present a safety hazard and do not meet pertinent code requirements. Observed concrete is in good condition with no cracks or signs of distress although there is evidence of seepage through horizontal construction joints.*	
OUTLET STRUCTURE	*Structure is in good condition. Minor shrinkage cracks in channel side walls, erosion at water line and some erosion and spalling at end of side walls. The handrails have been lifted out of their sockets.*	
OUTLET CHANNEL	*The rocklined pool and channel immediately downstream of the outlet structure are in good condition.*	
MINIMUM FLOW	*A 10 inch pipe discharges the required minimum downstream flow (11 cfs). The pipe is suspended from the ceiling of the left tunnel and is controlled by a valve outlet.*	

UNGATED SPILLWAY

(EMERGENCY SPILLWAY SYSTEM)

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE WEIR	*Concrete surface is in good condition and alignment is good.*	
APPROACH CHANNEL	*The side walls of the 350 ft. wide channel are in good condition. Weep holes were dry at the time of inspection*	
DISCHARGE CHANNEL	*The discharge channel is cut through rock and has a slope of 0.150. Some movement of rock was noted at the toe of the rock chute. The discharge channel should be inspected regularly to determine if deterioration is taking place.*	
STILLING BASIN	*A second ogee weir at elevation 324 maintains 5 ft. of water in the stilling basin. The concrete walls of the stilling basin are in good condition with minor shrinkage cracks midway between construction joints. Wall alignment appears good with only minor separation at a few construction joints. The weir itself appears to be in good condition. Rock walls along the right channel are in good condition.*	

GATED SPILLWAY

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE SILL	*None*	
APPROACH CHANNEL	*None*	
DISCHARGE CHANNEL	*None*	
BRIDGE AND PIERS	*None*	
GATES AND OPERATION EQUIPMENT	*None*	

INSTRUMENTATION

VISUAL EXAMINATION	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
MONUMENTATION/SURVEYS	*Monuments are on the crest and 111.3 ft. downstream from the first row of monuments. The park operators did not have survey records nor did they know who read them or when they were read. The Design Engineer also did not have records and was surprised that readings were not available or being taken.*	
OBSERVATION WELLS	*None*	
WEIRS	*Yes, located downstream of the spillways. However, the ends were washed out and are no longer operating. The weir should be repaired and flow monitored.*	
PIEZOMETERS	*Yes, but they have not been operating since the dam was completed. According to the Owner's representative, no attempts were made to clean or repair the piezometers. The Design Engineer requested that they be repaired or replaced. It is recommended that at least all critical piezometers be replaced and records maintained because of the high hazard classification of the structure and volume of water it retains.*	
GENERAL	*All instrumentation should be read and the data reported to the Design Engineer on a regular basis as determined by the Design Engineer.*	

RESERVOIR

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	*Adjacent slopes to the reservoir are flat to steep, well vegetated and stable. Rock is very near to the surface or exposed around the reservoir.*	
SEDIMENTATION	*Reservoir sedimentation is insignificant. The surrounding watershed is well vegetated and sediment is expected to be slight for the near future.*	
DRAINAGE AREA	*The drainage area is well vegetated.*	

DOWNSTREAM CHANNEL

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONDITION (OBSTRUCTIONS, DEBRIS, ETC.)	*Downstream channel generally flows through a fairly wide, wooded flood plain. A new highway bridge is located approximately 2200 ft. downstream.*	
SLOPES	*The valley gradient is approximately 1.77%. The channel sides are generally stable and often rocky. The channel bottom is stoney. The flood plain has flat to moderate slopes which are predominately wooded or farmland.*	
APPROXIMATE NO. OF HOMES AND POPULATION	*The first house which would be subject to damage if the dam failed is located approximately 3200 ft downstream. Approximately 4.6 miles downstream are many homes which are subject to damage from large flows in Tohicken Creek. The population along the flood plain for a distance of 5 miles downstream includes at least 50 residents. In the event of failure, severe property damage (including several bridges) would be expected. During the PMF, flows downstream would be significantly augmented by the contributing drainage area downstream of the dam.*	

APPENDIX

C

Nockamixon Dam

CHECK LIST
HYDROLOGIC AND HYDRAULIC
ENGINEERING DATA

DRAINAGE AREA CHARACTERISTICS: *Predominantly farm land, less than 50% wooded*

ELEVATION TOP NORMAL POOL (STORAGE CAPACITY): *395.0 (40,000 Ac-Ft)*

ELEVATION TOP FLOOD CONTROL POOL (STORAGE CAPACITY): *412 (70,500 Ac-Ft)*

ELEVATION MAXIMUM DESIGN POOL: *405.6*

ELEVATION TOP DAM: *412*

SPILLWAY

a. Elevation *395.0*

b. Type *ogee*

c. Width *350 feet*

d. Length *Total length of discharge channel is over 1,900 feet.*

e. Location Spillover *Left abutment*

f. Number and Type of Gates *None*

OUTLET WORKS:

a. Type *Concrete intake tower (wet)*

b. Location *300 feet from left abutment*

c. Entrance inverts *325.5, 357.0, 383.4*

d. Exit inverts *312.75*

e. Emergency draindown facilities *2-10.5 feet horseshoe diversion tunnels entrance inverts 311.0*

HYDROMETEOROLOGICAL GAGES:

a. Type *Standard rain gage, read during forest fire season*

b. Location *Sewage treatment plant*

c. Records *Sent to state, for forest fire hazard*

MAXIMUM NON-DAMAGING DISCHARGE: *44,000 cfs-maximum flow under Fretz Valley Road Bridge although approach to bridge is flooded.*

DAM SAFETY ANALYSIS
HYDROLOGIC/HYDRAULIC DATA

Date: 7/20/78
By: MFB
Sheet: 2 of 12

DAM Nockamixon Dam Nat. ID No. PA00734 DER No. 9-166

	ITEM/UNITS	Permit/Design Files (A)	Calc. from Files/Other (B)	Calc. from Observations (C)
1.	Min. Crest Elev., ft.	412.0 ft.		
2.	Freeboard, ft.	0		
3.	Spillway[1] Crest Elev, ft.	395.0 ft.		
3a.	Secondary[2] Crest Elev, ft.	—		
4.	Max. Pool Elev., ft.	412.2 ft		
5.	Max. Outflow[3], cfs	96,000 cfs		
6.	Drainage Area, mi^2	79.3 $mile^2$		78.6 $mile^2$
7.	Max. Inflow[4], cfs	142,000 cfs		
8.	Reservoir Surf. Area, Acre	14,500 Ac.		
9.	Flood Storage[5], ft^3 Ac-Ft			
10.	Inflow Volume, ft^3			

Reference all figures by number or calculation on attached sheets:

Example: 3A - Drawing No. xxx by J. Doe, Engr., in State File No. yyyy.

NOTES:

(1) Main emergency spillway.

(2) Secondary ungated spillway.

(3) At maximum pool, with freeboard, ungated spillways only.

(4) For columns B, C, use PMF.

(5) Between lowest ungated spillway and maximum pool.

Date: 7/20/78
By: MFB
Sheet: 3 of 12

HYDROLOGIC/HYDRAULIC CALCULATIONS (cont.)

Item (from Sheet 2)	Source
1A, 3A, 8A	Construction Drawings dated Aug. 1967
4A, 5A,	"Interim Report One Stage Construction" Pickering, Corts & Summerson, Inc. Nov. 9, 1965
7A, 6A	"Recommended Design of Dam" Pickering, Corts & Summerson, Inc. May 17, 1965
6C	USGS Maps Bedminster (1973) Telford (1973) Quakertown (1973) Riegelsville (1973) Allentown East (1972) Hellertown (1972) Milford Square (1973)

BY MB DATE 7/20/78 SUBJECT Nockimixon Dam Hydrology / Hydraulics SHEET 4 OF 12

CHKD. BY RHC DATE 7/25/78 JOB No.

Classification (Ref. Recommended Guidelines for Safety Inspection of Dams)

1. The hazard classification is HIGH.
2. The size classification is LARGE based on its greater than 100 foot height and 70,500 A.-Ft. capacity
3. The spillway design flood should be the PMF based on the above classification of the dam.

Hydrology and Hydraulic Analysis.

1. Hydrological Data was limited to the results, ie the inflow hydrographs located in "Recommended Design of Dam" (sheet 5) The PMF peak inflow was calculated to be 147,000 cfs.

   Contact with Corps of Engineers, Baltimore District indicates, in lieu of original hydrological design information, peak PMF inflow value should be estimated from the supplied curve for Delaware River Basin or,

   $$1080\ cfs/mile^2 \times 79.3\ mile^2 =$$

   $$79,164\ cfs.$$

   Therefore, the value used in design is not unconservative.

2. Spillway capacity - the unusual spillway design was model tested at Lehigh University and the spillway was altered to produce the optimum discharge characteristics. The spillway rating curve is included as sheet 6
   The spillway capacity with water at the top of dam is 96,000 cfs.

Standard Project Flood
(2.5 x 5 hr. Point Rainfall
Moisture Condition II)

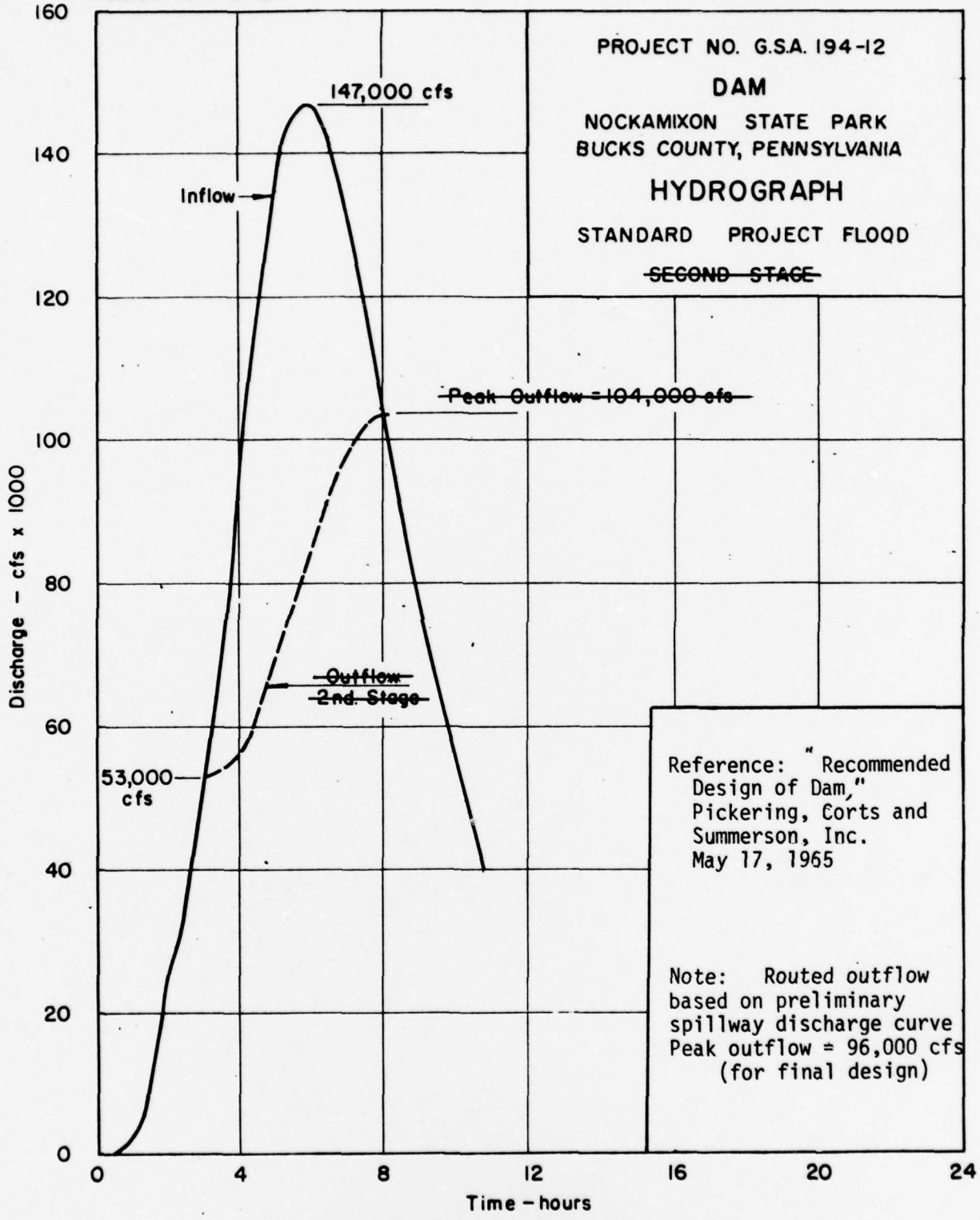
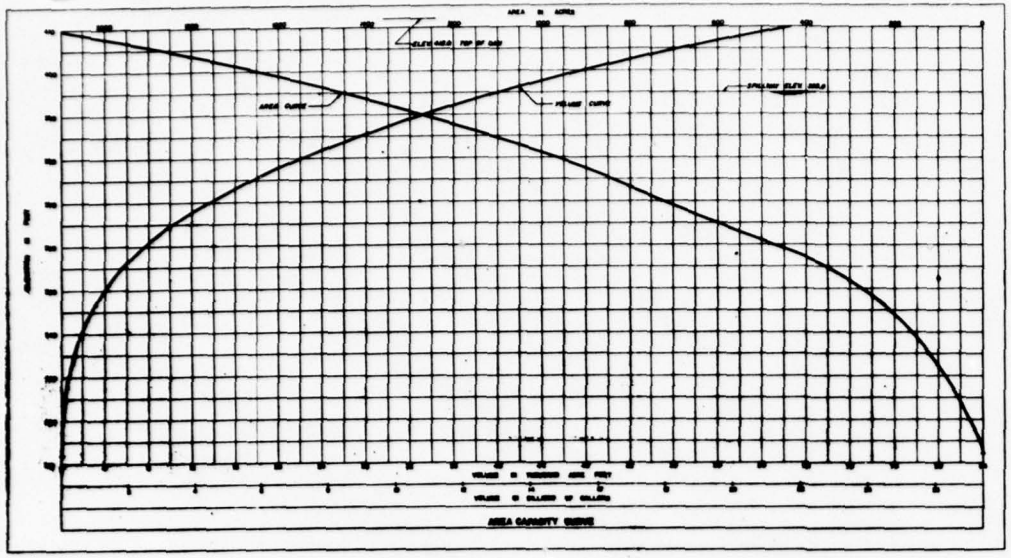
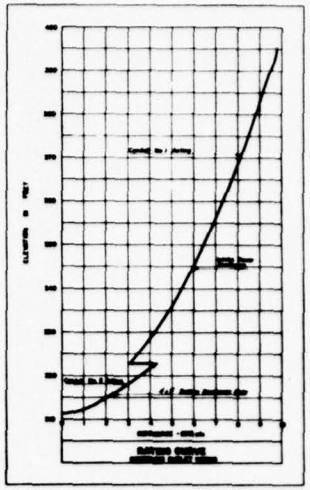
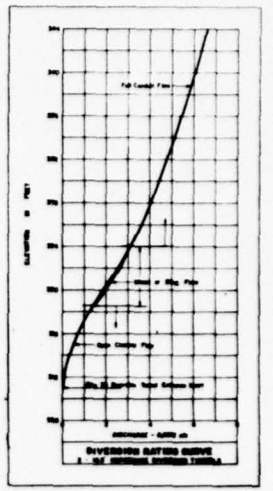
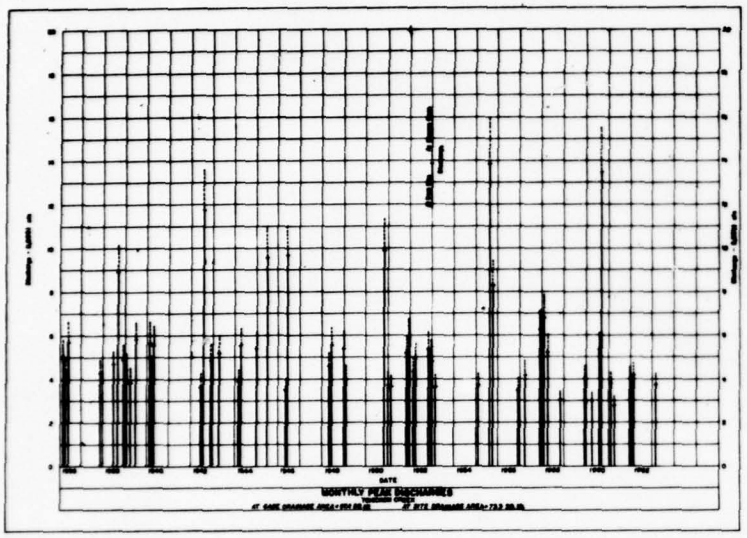


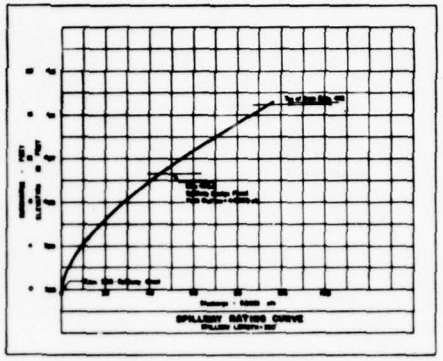
FIGURE 14

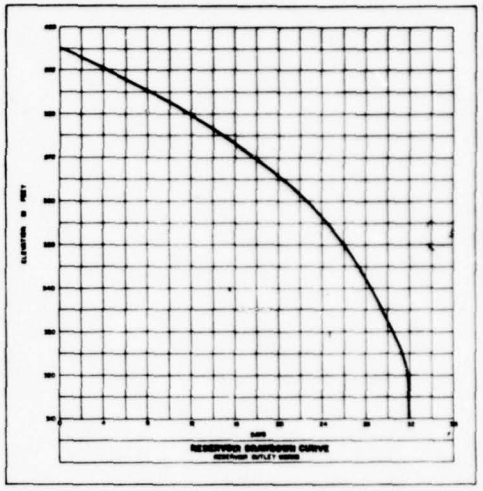












HYDRAULIC AND HYDROLOGIC DATA		
NOCKAMIXON STATE PARK DAM		
NAT. ID NO. PA.00734		BUCKS COUNTY
DATA OBTAINED FROM THE GENERAL STATE AUTHORITY, PROJECT NO. GSA 194-12, DRAWING 2, DATED 8/31/67		
		SHEET 6 OF 12

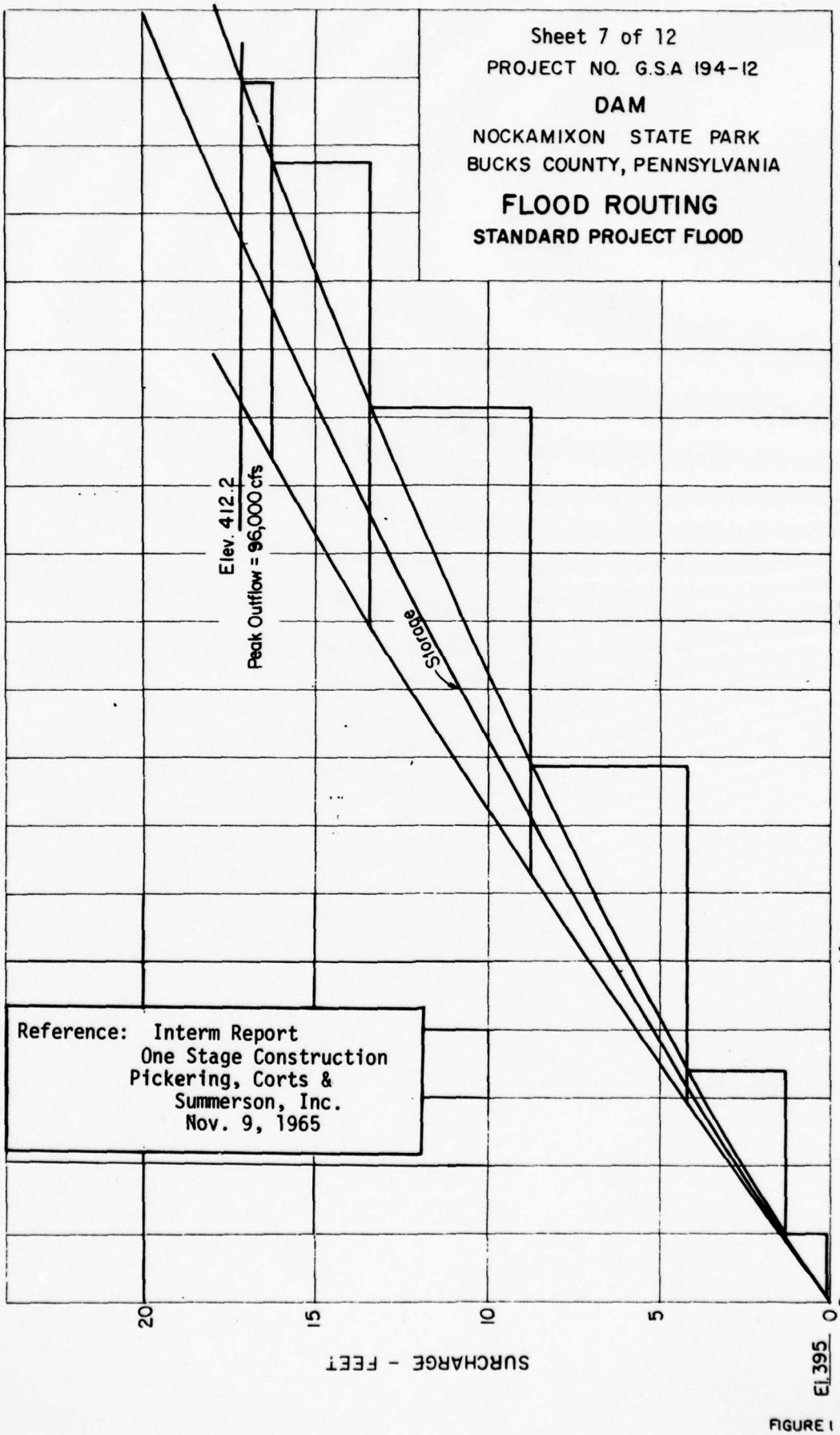

Sheet 7 of 12
PROJECT NO. G.S.A 194-12
DAM
NOCKAMIXON STATE PARK
BUCKS COUNTY, PENNSYLVANIA
FLOOD ROUTING
STANDARD PROJECT FLOOD
Elev. 412.2
Peak Outflow = 96,000 cfs
Storage
Reference: Interm Report
One Stage Construction
Pickering, Corts &
Summerson, Inc.
Nov. 9, 1965
SURCHARGE - FEET
20
15
10
5
0
El. 395
0
10
20
30
1,000 ACRE FEET

FIGURE 1

9. Overtopping Potential. Design Reports indicate the dam will not be overtopped during the PMF. As the spillway system is a single stage system, flood routing can be approximated by the procedure outlined in "Preliminary Engineer Technical Letter No. 1110-2- , 25 January 1978. (see sheet 9 and 10)

Q_I = 142,000 cfs
Q_o = 96,000 cfs

Available Flood Water Storage V_s = 31,000 Ac-Ft.
Volumn of Inflow - V_I

PMP = 25.5 inches 6 hr - 100 sq. mile (TP-40)
assume 90% runoff
assume no reduction for 73.3 mile^2 drainage area

$$V_I = \frac{0.9 \cdot 25.5}{12} \cdot 640 \cdot 73.3$$

$$= 89,719 \text{ Ac-Ft.}$$

Flood Storage Required - V_R

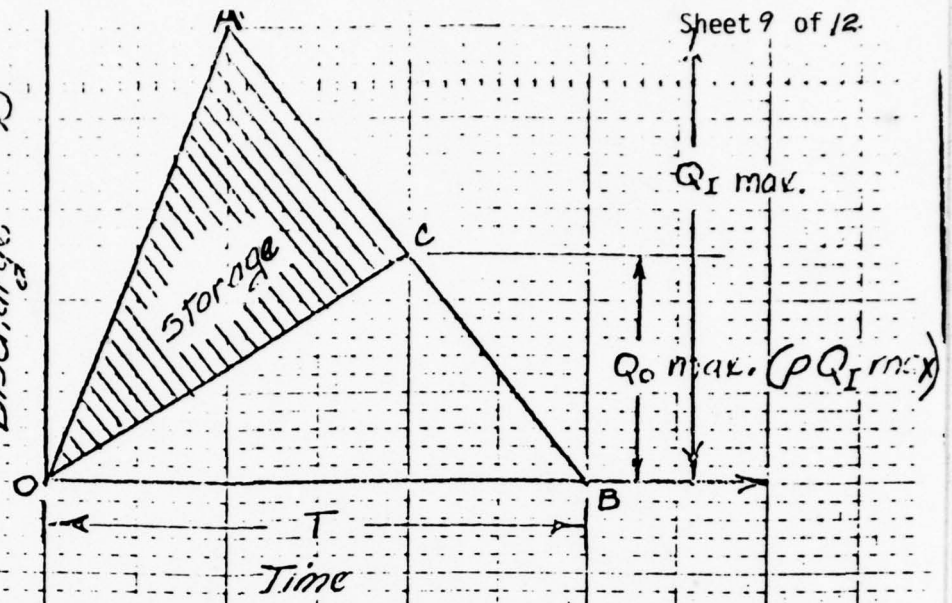
$$V_R = \left(1 - \frac{Q_o}{Q_I}\right) V$$

$$= \left(1 - \frac{96,000}{142,000}\right) 89,719$$

$$= 31,127 \text{ Ac-Ft} \simeq V_s$$

Therefore, dam does not overtop during PMF and the spillway is "Adequate".

It is noted that the flood routing indicated a top of dam of 412.2 vs actual 412.0. The uncertainties in assumptions and procedures are such that the difference in elevations is not significant



PURPOSE: Establish relationship between maximum spillway discharge and storage required to pass flood hydrograph without exceeding maximum pool level.

$$\frac{\Delta AOC}{\Delta AOB} = \frac{\Delta AOB - \Delta COB}{\Delta AOB} = 1 - \frac{\Delta COB}{\Delta AOB}$$

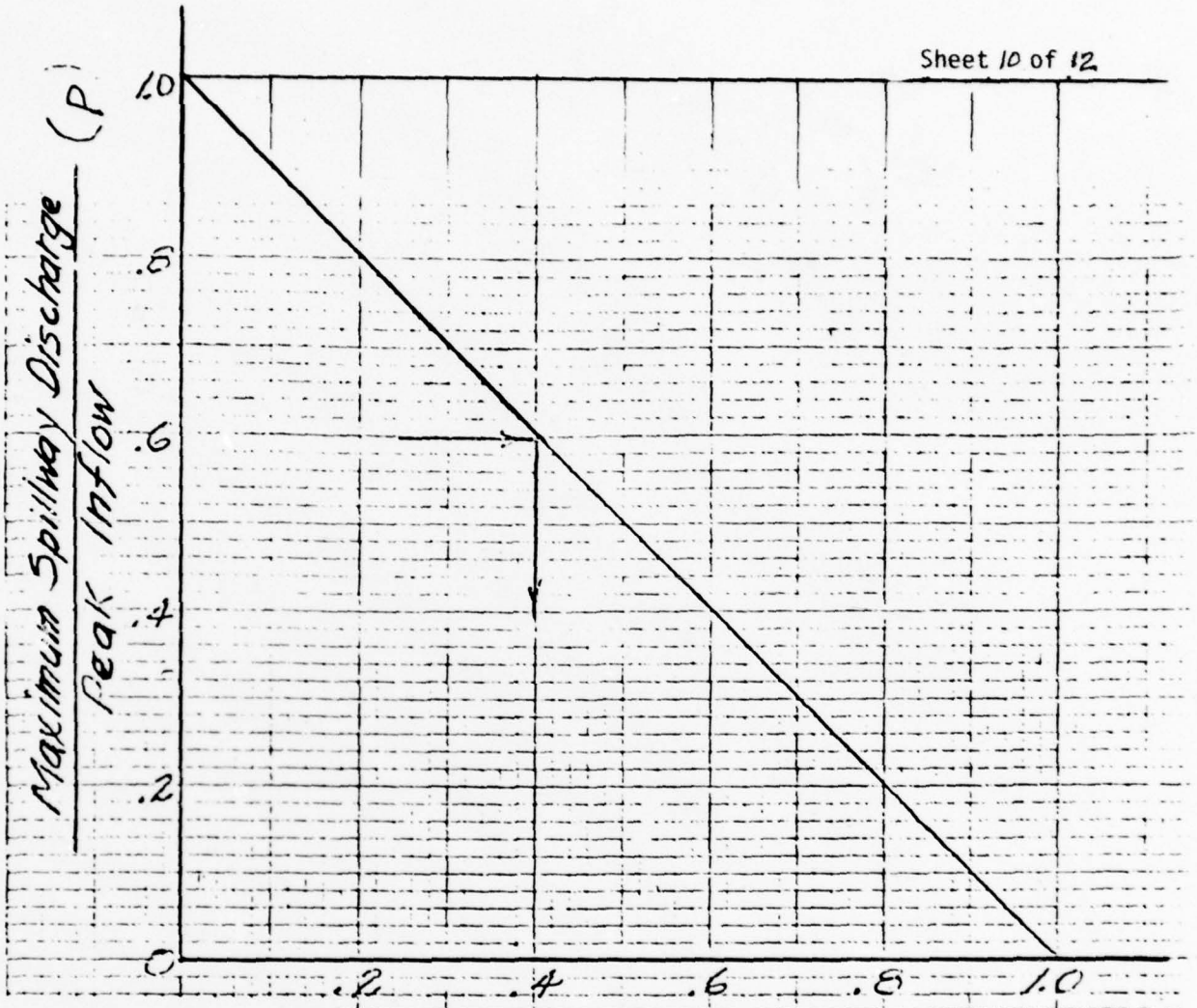
$$\frac{\Delta AOC}{\Delta AOB} = 1 - \frac{T \rho Q_{I\,max}/2}{T\, Q_{I\,max}/2} = 1 - \rho$$

$$\Delta AOC = (1-\rho)\,\Delta AOB \quad \text{where } 0 \le \rho \le 1.0$$

ρ	ΔAOC
1.00	0
0.75	0.25 ΔAOB
0.50	0.50 ΔAOB
0.25	0.75 ΔAOB
0	1.00 ΔAOB

REFERENCE

PRELIMINARY ENGINEER TECHNICAL LETTER NO. 1110-2- 25 January 1978



Steps to obtain required reservoir to pass inflow hydrograph without overtopping dam.

1. Obtain maximum spillway discharge
2. Develop inflow hydrograph
3. Compute relationship of maximum spillway capacity to peak inflow
4. Read relationship of required reservoir storage to volume of inflow hydrograph from curve

4. Downstream Conditions. The original studies determined that the Frete Valley Road Bridge (L.R. 09152) forms a central section for high flows. The bridge is located about 4400 ft. downstream of bridge. The bridge has 8 spans varying in length from 20 to 22 ft. and in height from 10.5 to 15 ft.

Assume a total area of
$8 \times 21 \times 12.75 = 2142$ sq. ft.

Original design indicates 44,000 cfs is the maximum capacity under the bridge and 63,000 cfs floods the bridge with 2½ ft. of water.

A new bridge under South Park Road (LR 586) has been built about 2000 ft. downstream of the dam. Opening dimensions (perpendicular to flow) is about 69.5 ft by 40 ft. at center of span.

$69.5 \times 40 = 2780 \text{ ft}^2 > 2142 \text{ ft}^2$

Therefore, assume Frete Valley Road bridge still forms the hydraulic control and the tailwater rating curve is valid (sheet 12).

(Bridge opening information supplied by PennDOT)

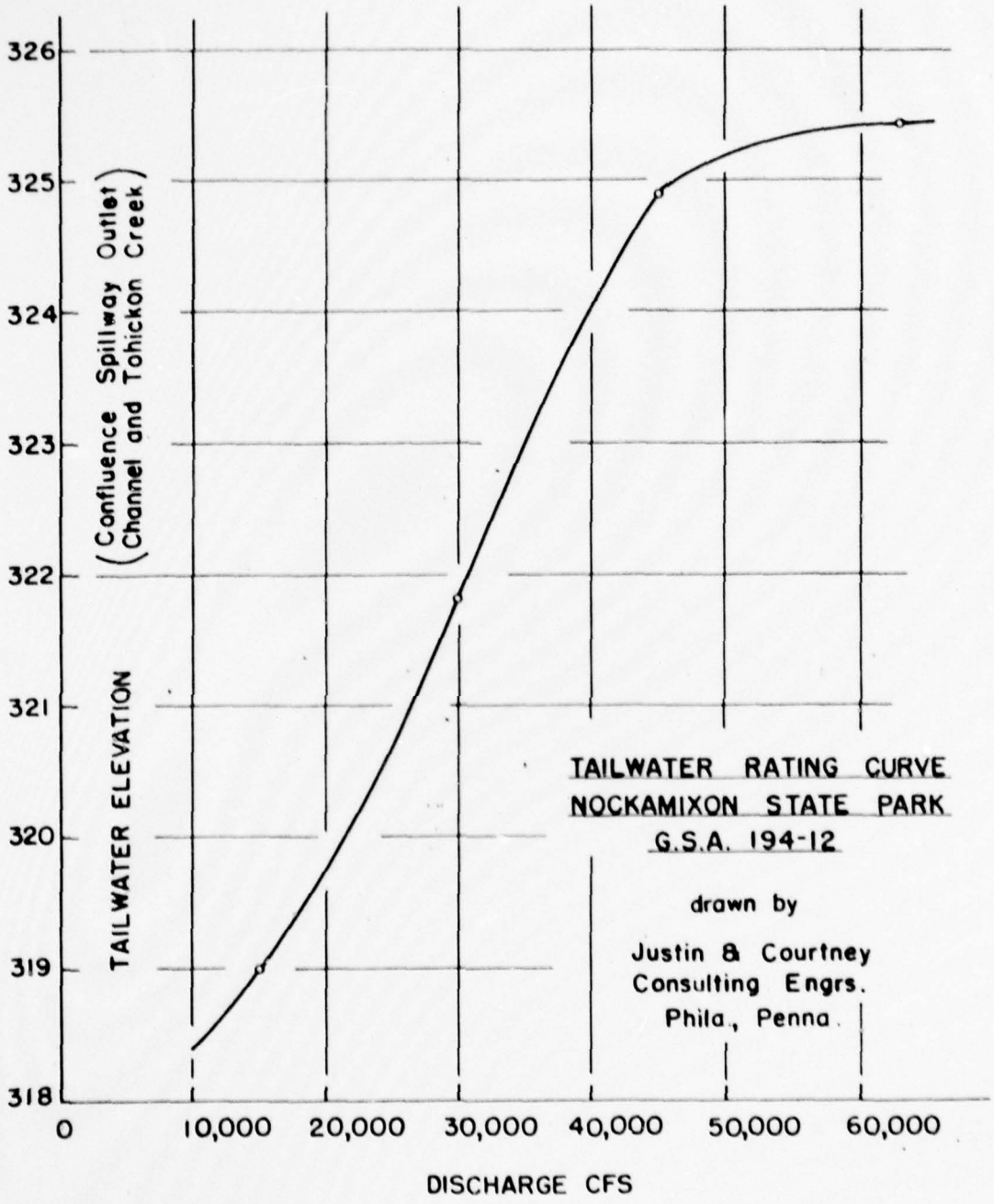


Fig. No. 18

Reference: Model Study Report
Lehigh University
March 1967

APPENDIX

D



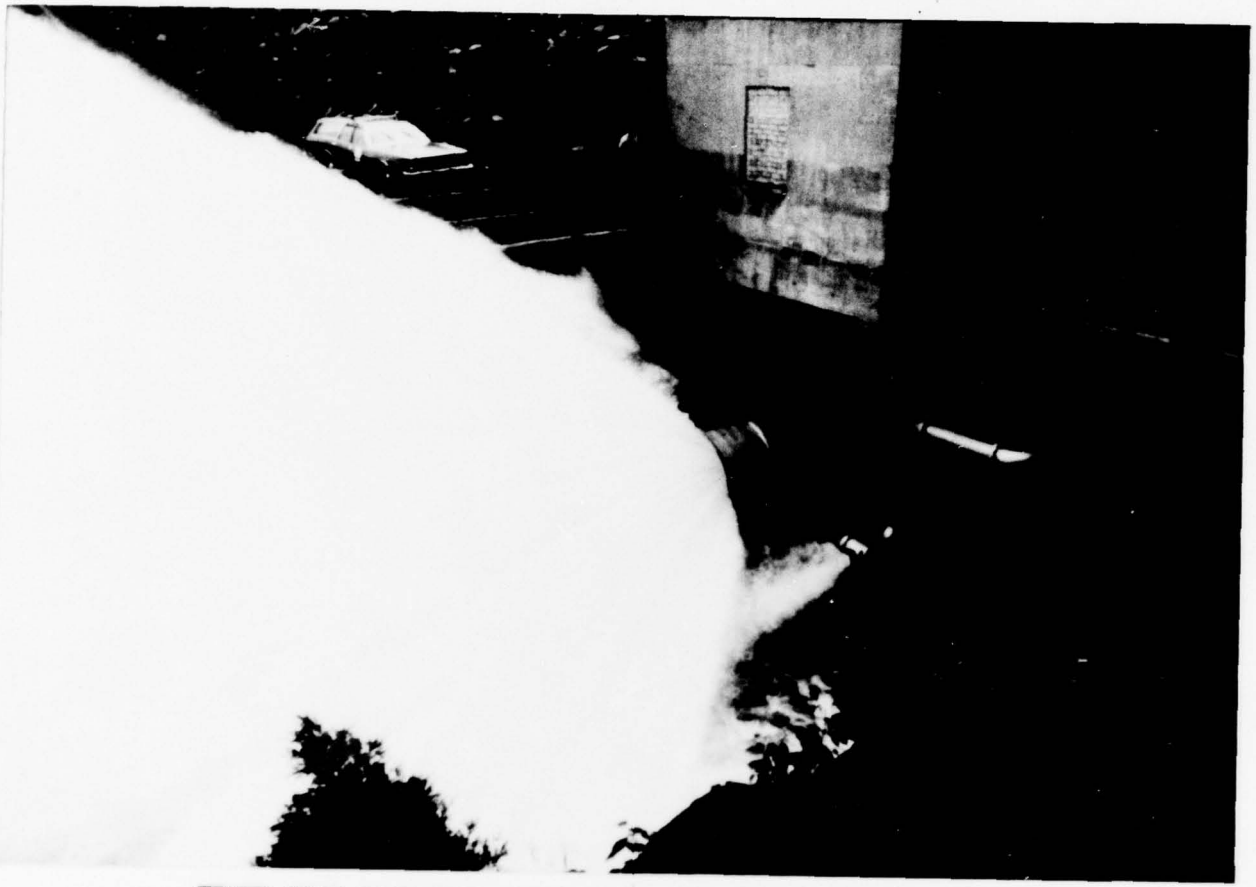
VIEW OF PRINCIPAL INTAKE STRUCTURE, NOTE
STAFF GAGE ON WALL OF TOWER.

PHOTOGRAPH NO. 1



VIEW FROM DAM CREST OF PRINCIPAL OUTLET STRUCTURE AND
DOWNSTREAM CHANNEL. THE EMERGENCY SPILLWAY IS ON THE RIGHT.
WHITE WATER IN CHANNEL IS THE OUTLET FOR LOW FLOW REQUIREMENTS.

PHOTOGRAPH NO. 2



FIXED CONE DISPERSION VALVE AND LOW FLOW PIPE IN FULL OPERATION AT PRINCIPAL OUTLET STRUCTURE. THE CONTROL HOUSE CONTAINS THE PIEZOMETER INSTRUMENTATION READOUT PANEL.

PHOTOGRAPH NO. 3



OVERFLOW WEIR OF EMERGENCY SPILLWAY STILLING BASIN.
SPILLWAY CAN BE SEEN IN "OVERVIEW" PHOTOGRAPH.

PHOTOGRAPH NO. 4



OVERVIEW OF EMERGENCY SPILLWAY SYSTEM. UPPER OGEE IS ON LEFT OUTSIDE OF CAMERA VIEW.

PHOTOGRAPH NO. 5

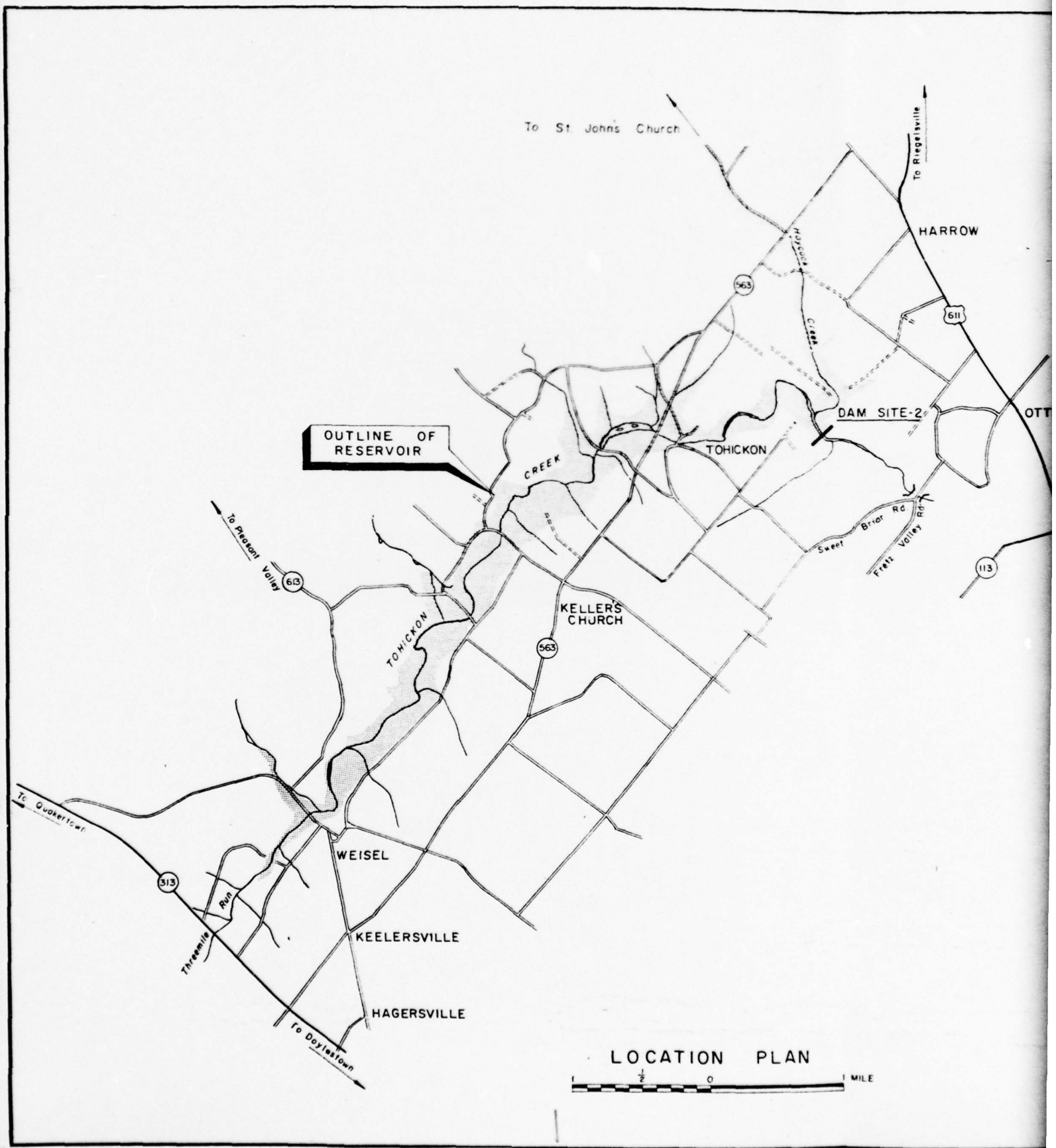


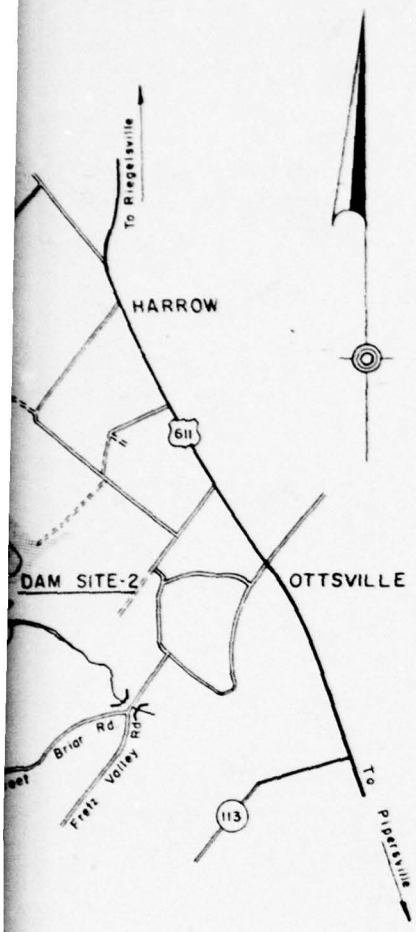
WITH THE EXCEPTION OF RESIDENTIAL DWELLINGS, THIS PHOTOGRAPH REPRESENTS A TYPICAL VIEW OF DOWNSTREAM CHANNEL CONDITIONS.

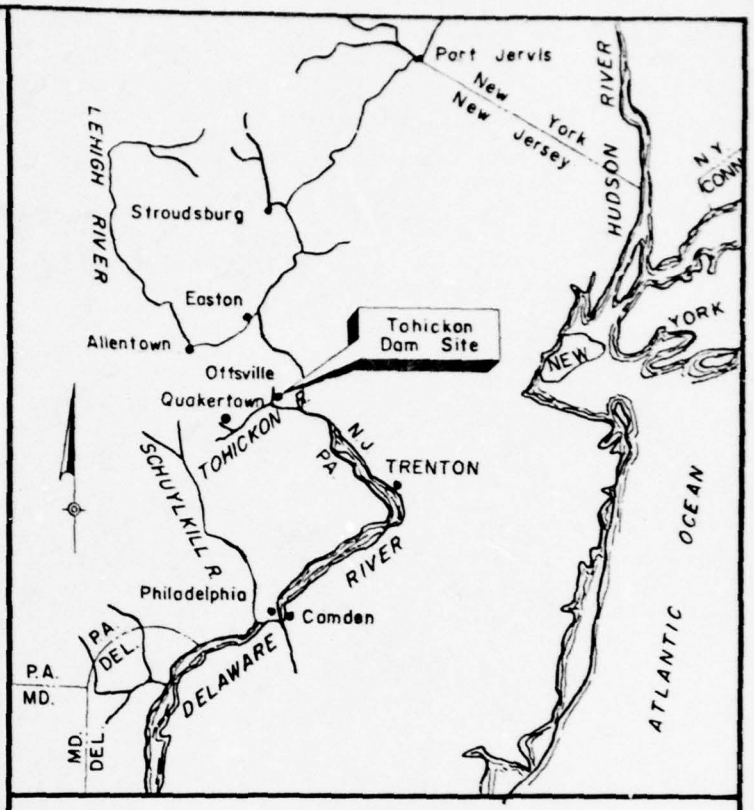
PHOTOGRAPH NO. 6

APPENDIX

E


To St John's Church
To Riegelsville
HARROW
563
611
DAM SITE-2
OTT
OUTLINE OF RESERVOIR
CREEK
TOHICKON
To Pleasant Valley
613
Sweet Briar Rd
Fretz Valley Rd
113
KELLER'S CHURCH
563
TOHICKON
To Quakertown
313
WEISEL
Run
Threemile
KEELERSVILLE
HAGERSVILLE
To Doylestown
LOCATION PLAN
0
1/2
1 MILE





VICINITY MAP

SCALE
5 0 5 10 15 20 25

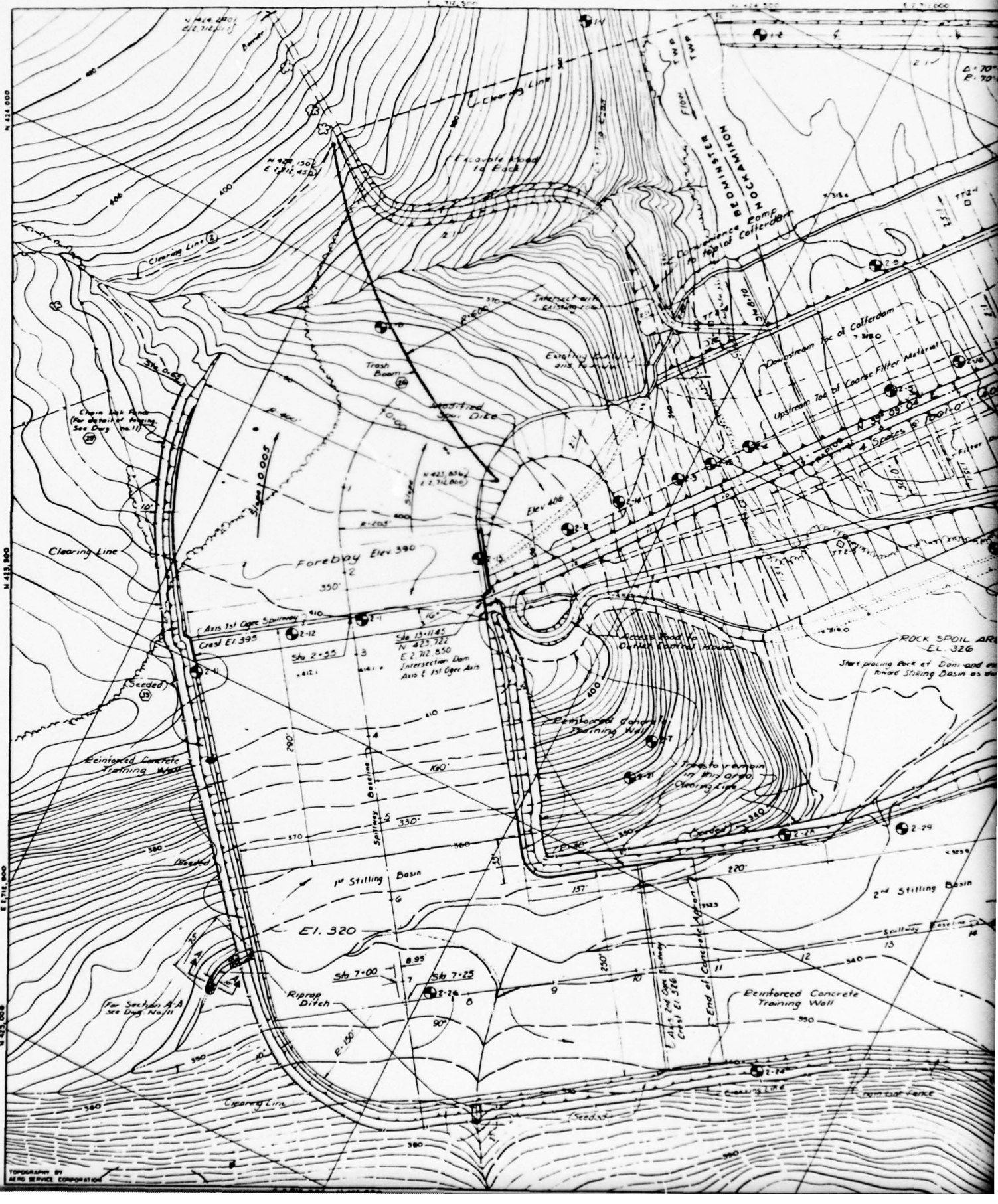
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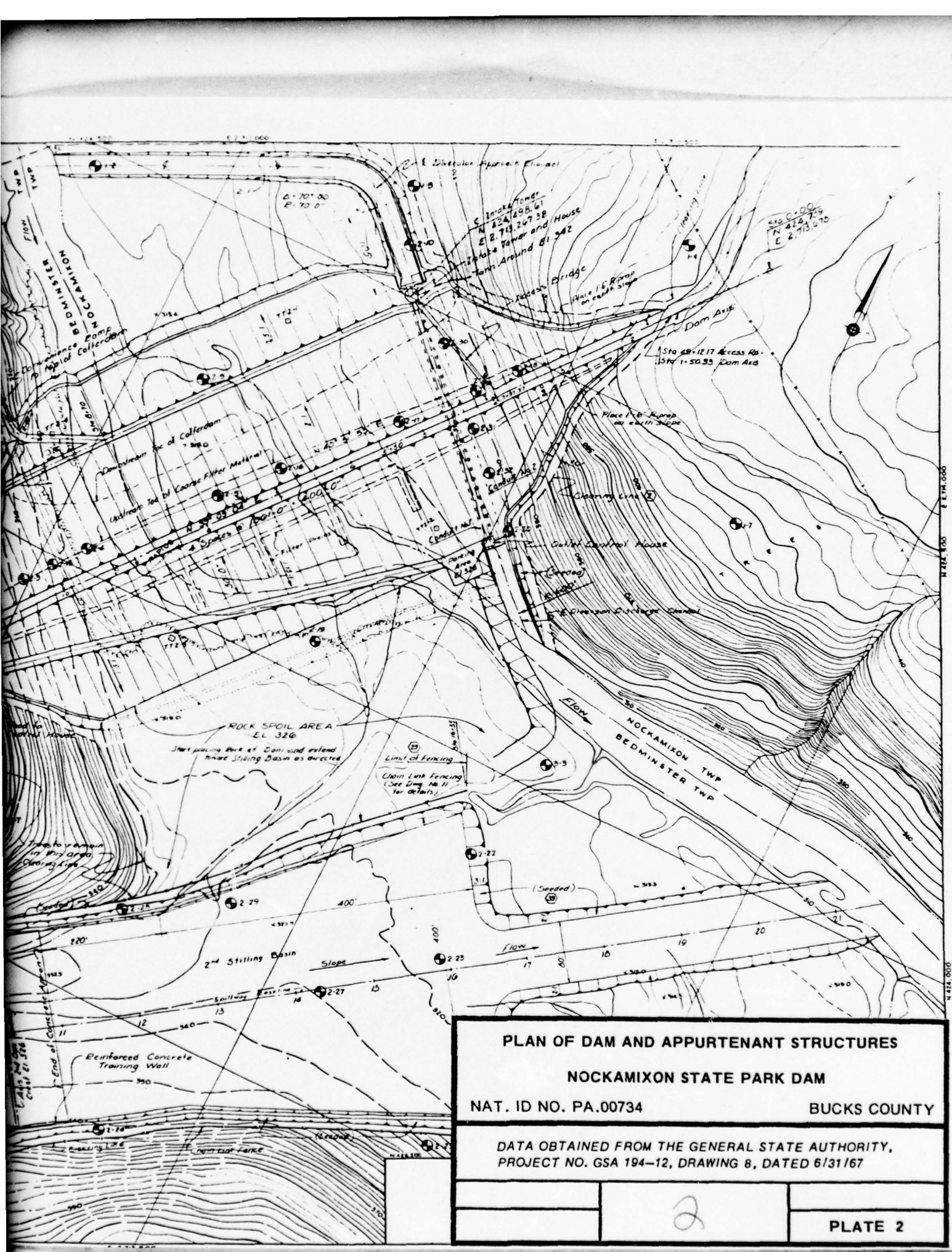
REGIONAL LOCATION PLAN
NOCKAMIXON STATE PARK DAM

NAT. ID NO. PA.00734 BUCKS COUNTY

DATA OBTAINED FROM GSA PROJECT 194-15
DRAWING NO. 1

PLATE 1


Clearing Line
Foreday Elev 390
Axis 1st Oger Spillway
Crest El 395
Sta 2+55
Sta 13+11.45
N 423,722
E 2,712,850
Intersection Dam
Axis & 1st Oger Axis
Trash Boom
Existing Dwellings and Farmsteads
Chain Link Fence
(For details of fencing
See Dwg No 11)
Modified Spur Dike
Slope 10.005
Reinforced Concrete Training Wall
Reinforced Concrete Retaining Wall
Trees to remain in this area
Clearing Line
Access Road to Outlet Control Structure
ROCK SPOIL AR
EL 326
Start placing Rock at Dam and
toward Stilling Basin as
1st Stilling Basin
E1. 320
Sta 7+00
Sta 7+25
Riprap Ditch
For Sections A-A
See Dwg No 11
2nd Stilling Basin
Spillway Baseline
End of Concrete Apron
Reinforced Concrete Training Wall
Clearing Line
Seeded
Seeded
Seeded



PLAN OF DAM AND APPURTENANT STRUCTURES

NOCKAMIXON STATE PARK DAM

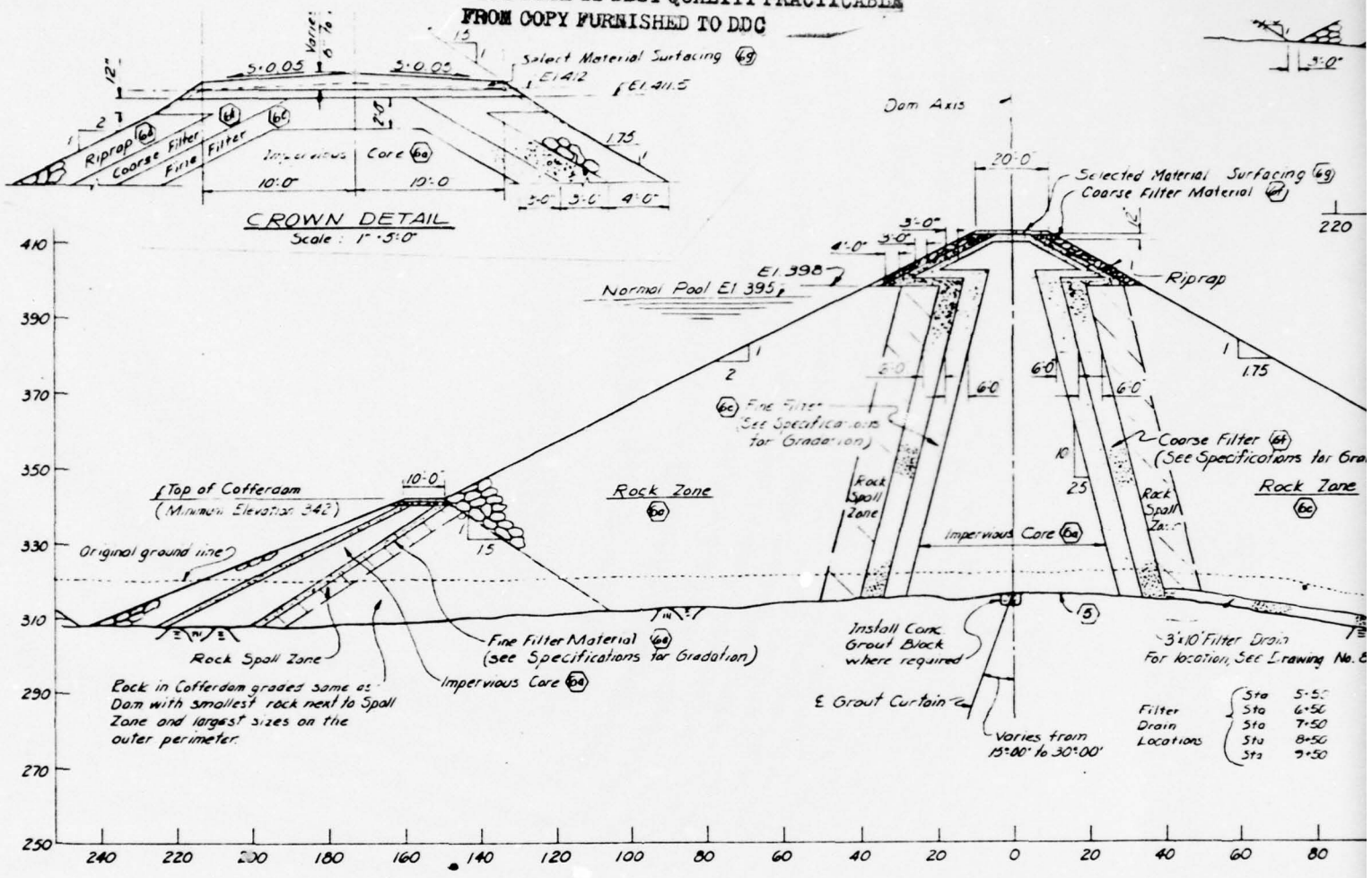
NAT. ID NO. PA.00734 BUCKS COUNTY

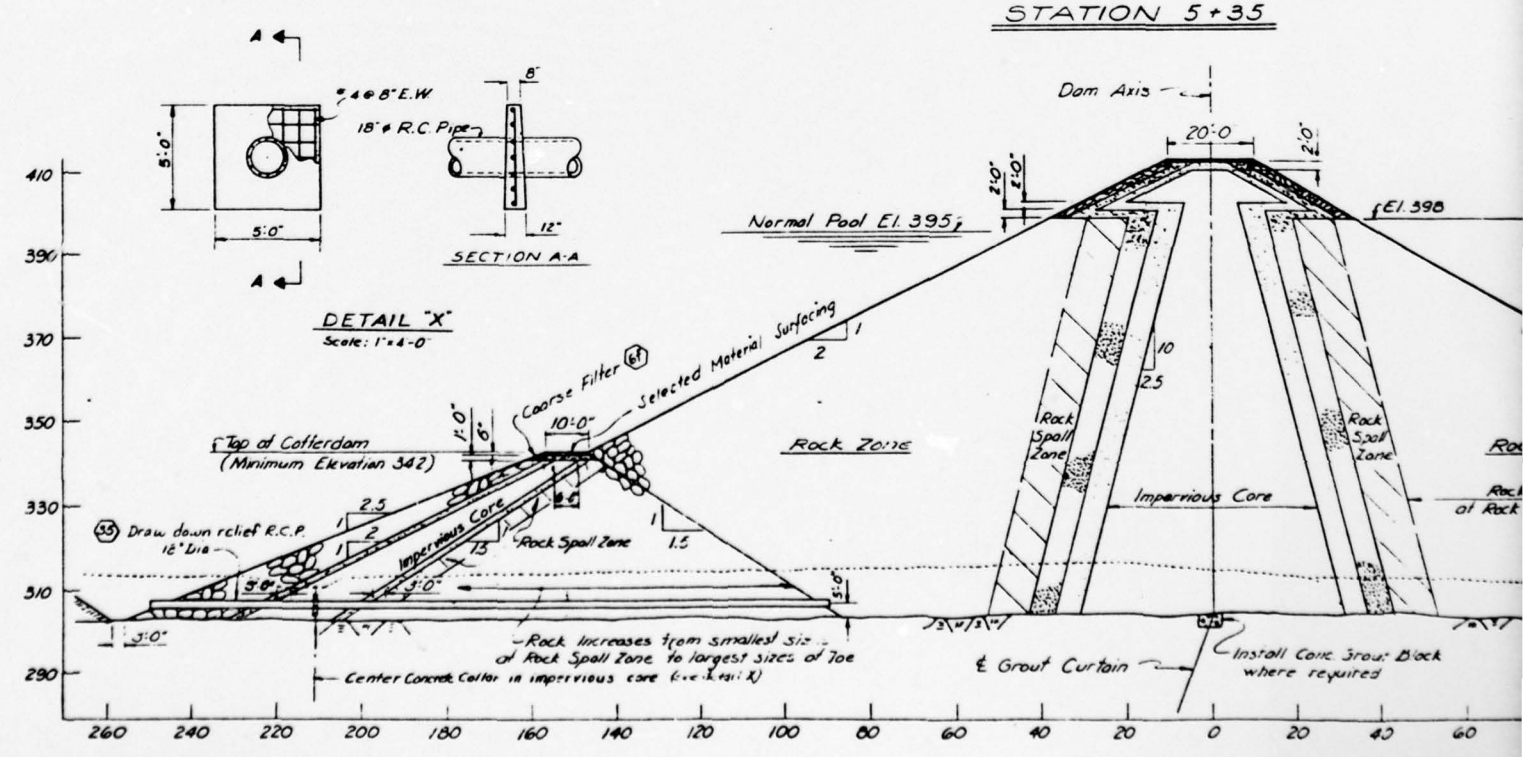
DATA OBTAINED FROM THE GENERAL STATE AUTHORITY, PROJECT NO. GSA 194–12, DRAWING 8, DATED 6/31/67

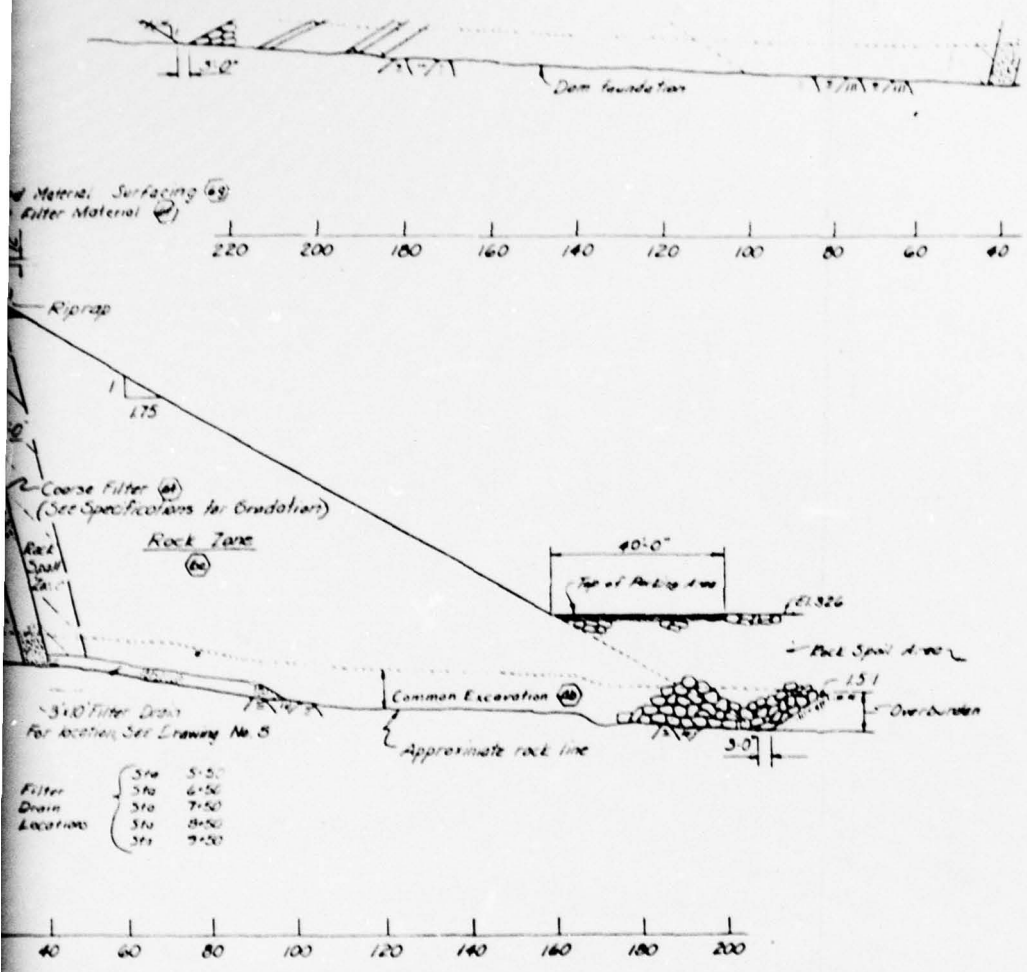
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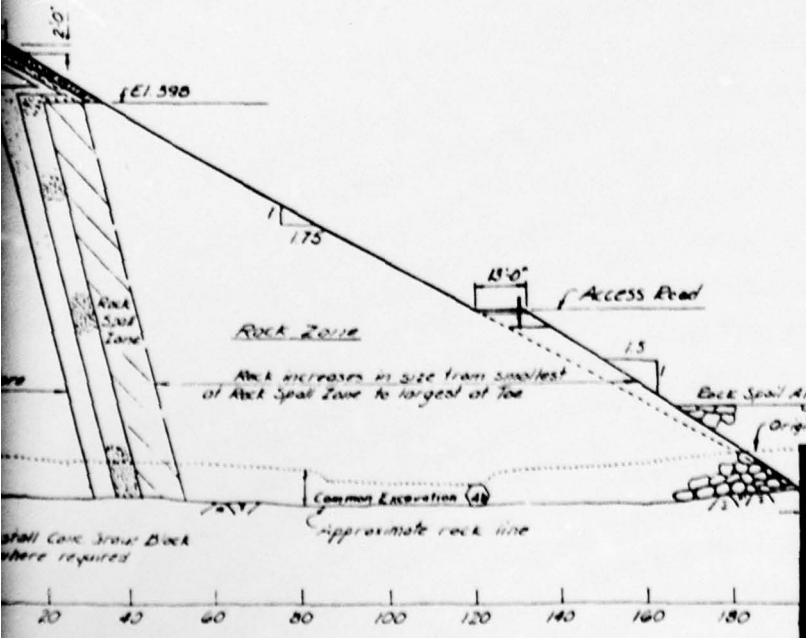
PLATE 2

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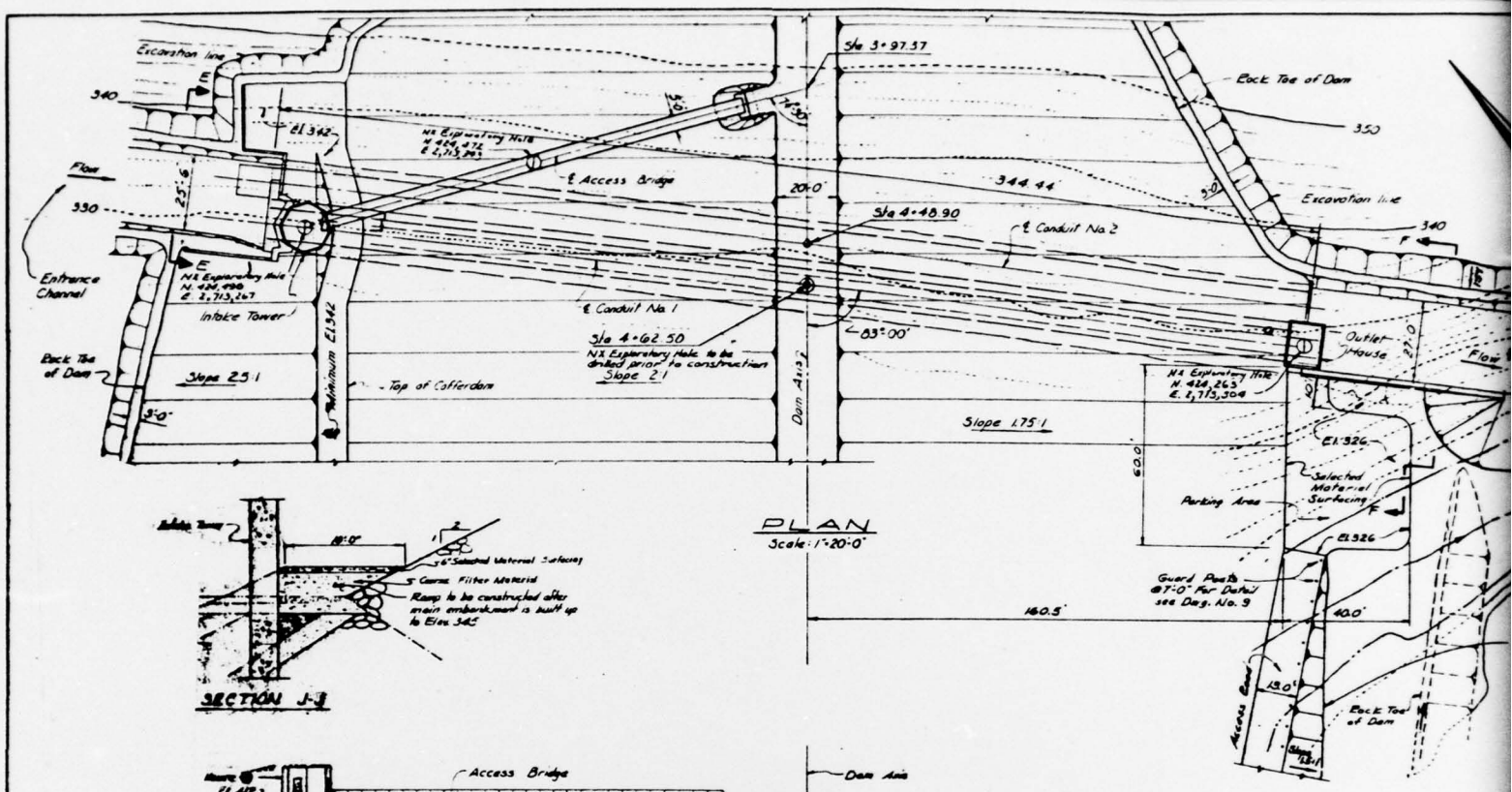
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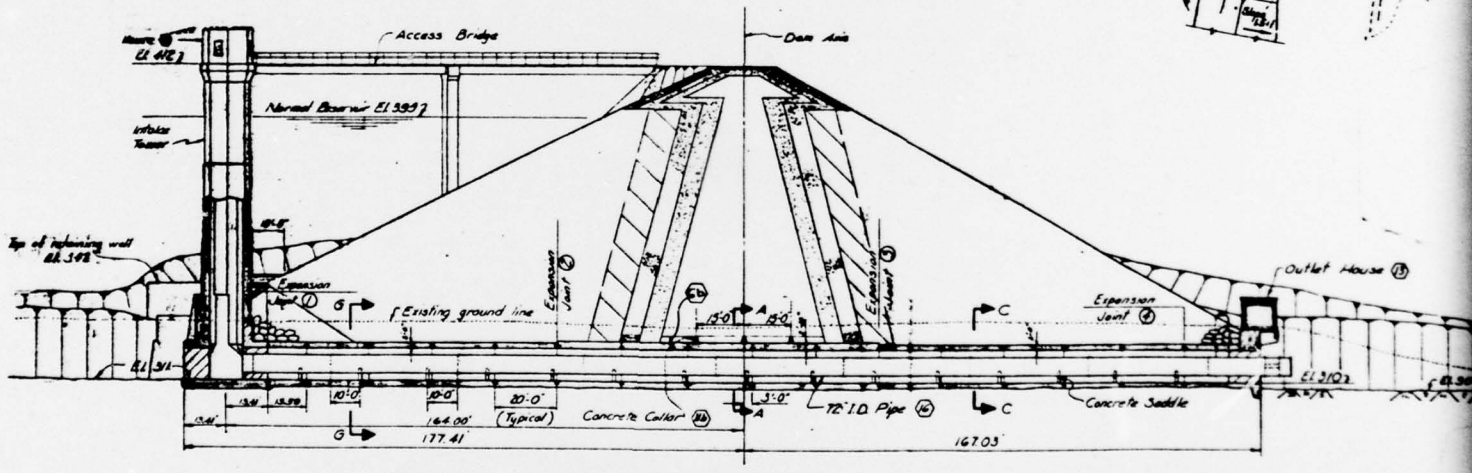
TYPICAL EMBANKMENT SECTIONS
NOCKAMIXON STATE PARK DAM

NAT. ID NO. PA.00734 BUCKS COUNTY

DATA OBTAINED FROM THE GENERAL STATE AUTHORITY, PROJECT NO. GSA 194-12, DRAWING 9, DATED 6/31/67

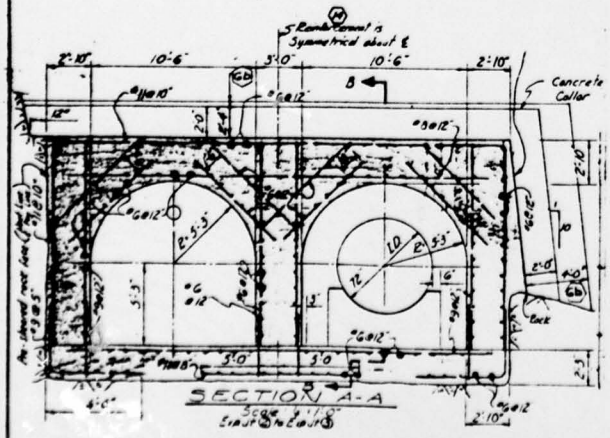
PLATE 3

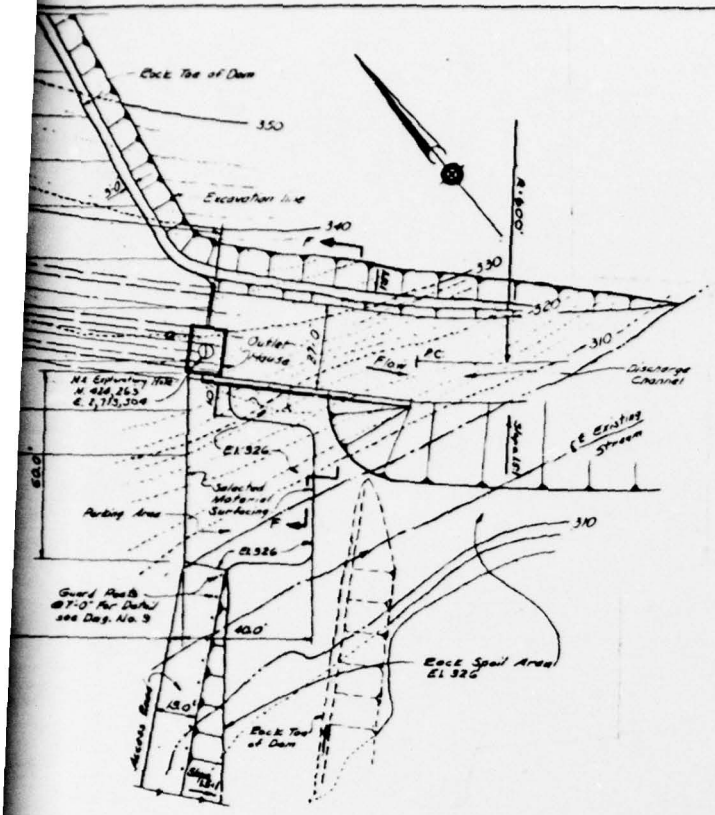


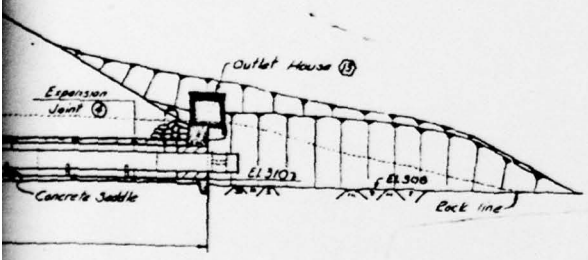


PROFILE ALONG CENTERLINE CONDUIT NO. 1

Scale: 1"=20'-0"


5" Reinforcement is Symmetrical about ℄
2'-10"
10'-6"
3'-0"
10'-6"
2'-10"
Concrete Collar
B
#11@10"
#6@12"
#6@12"
#6@12





NO 1

2

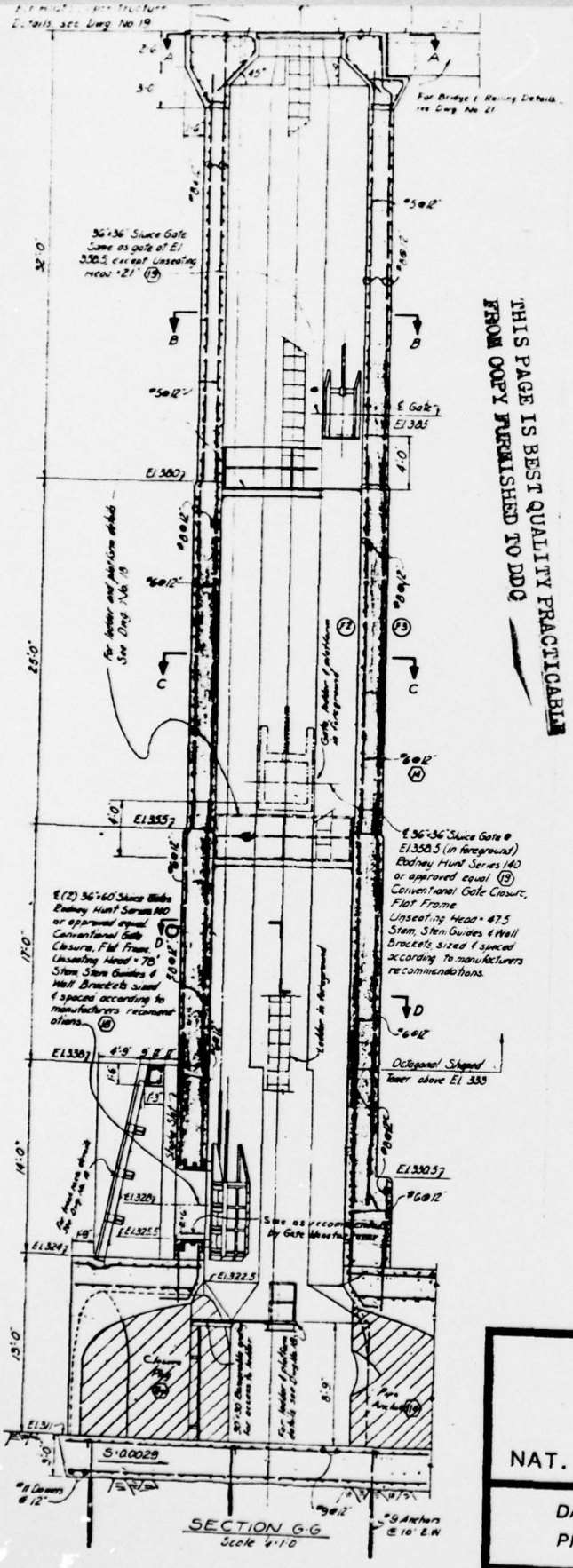
PLAN AND PROFILE OF PRINCIPAL SPILLWAY

NOCKAMIXON STATE PARK DAM

NAT. ID NO. PA.00734 BUCKS COUNTY

DATA OBTAINED FROM THE GENERAL STATE AUTHORITY, PROJECT NO. GSA 194-12, DRAWING 16, DATED 6/31/67

PLATE 4



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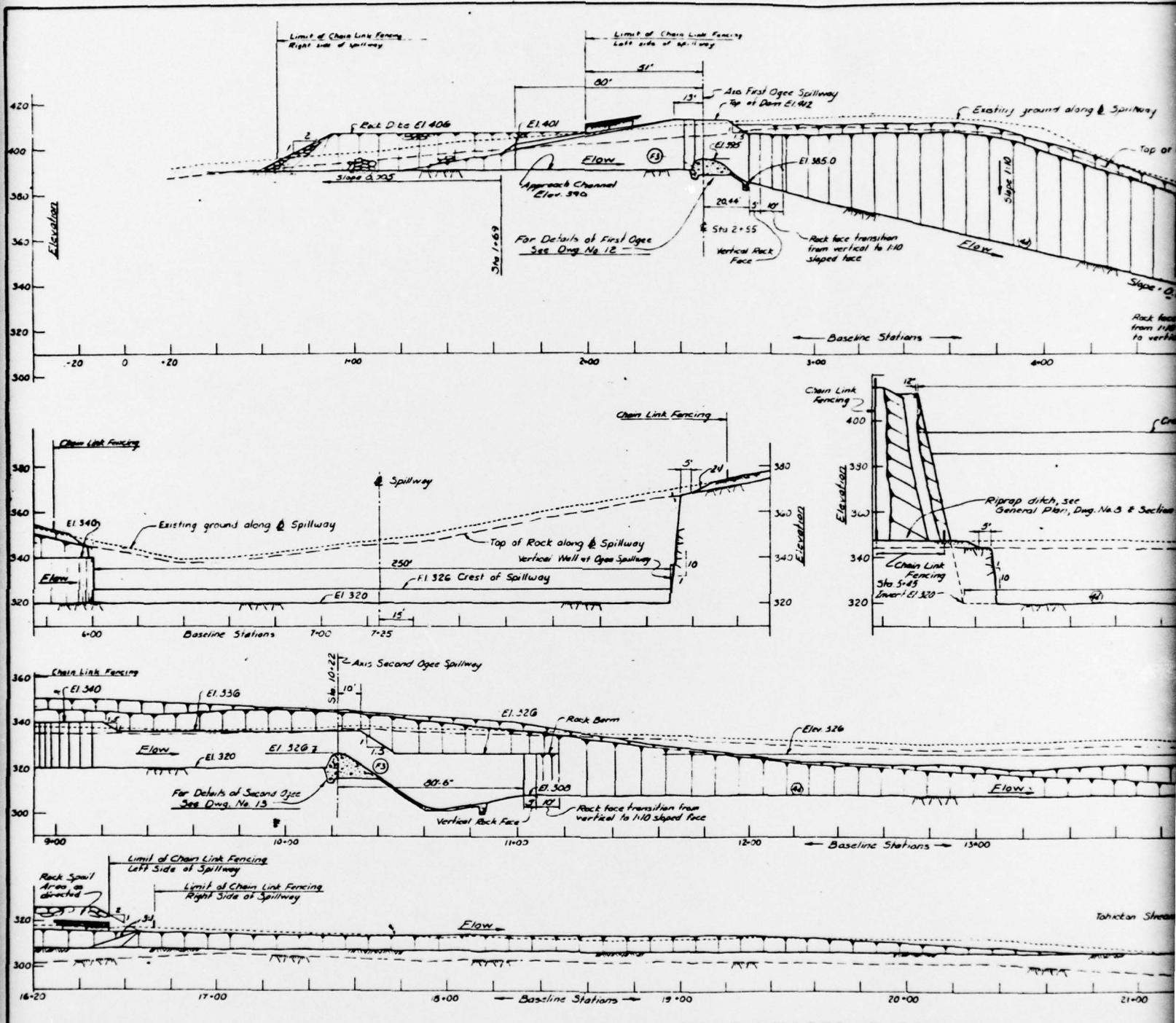
SECTION OF INTAKE TOWER

NOCKAMIXON STATE PARK DAM

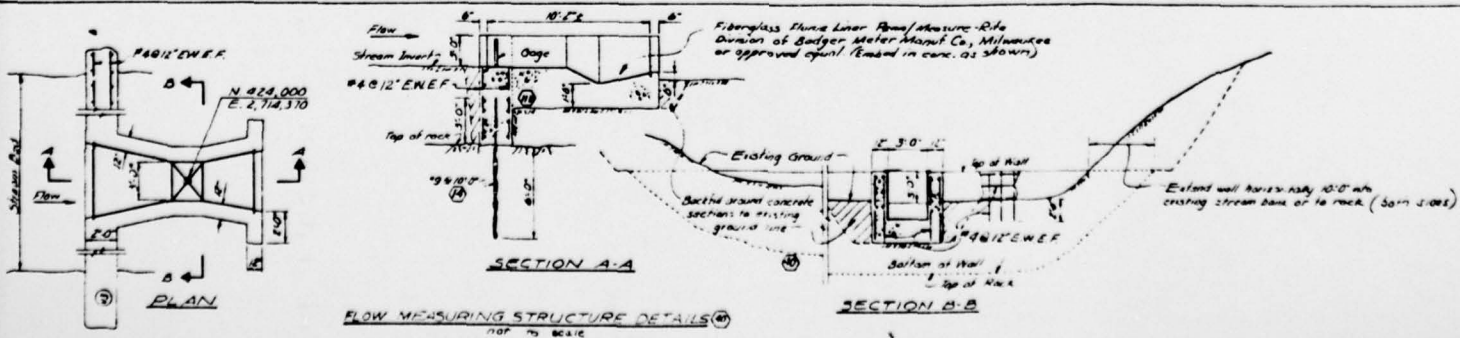
NAT. ID NO. PA.00734 BUCKS COUNTY

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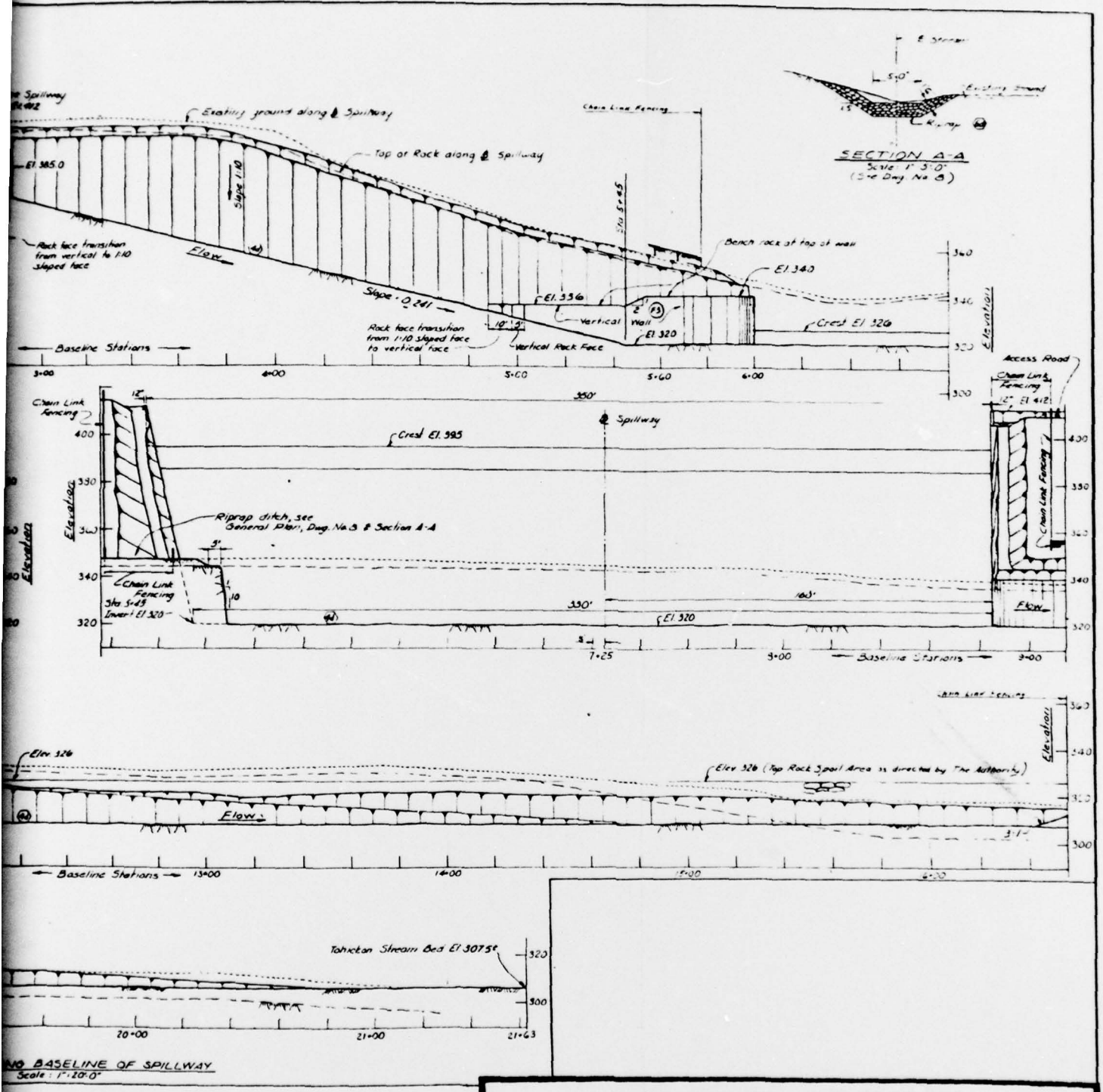
PLATE 5



PROFILE ALONG BASELINE OF SPILLWAY
Scale : 1"=20'-0"



FLOW MEASURING STRUCTURE DETAILS
not to scale
For location see Dwg. No. 1



EMERGENCY SPILLWAY PROFILES

NOCKAMIXON STATE PARK DAM

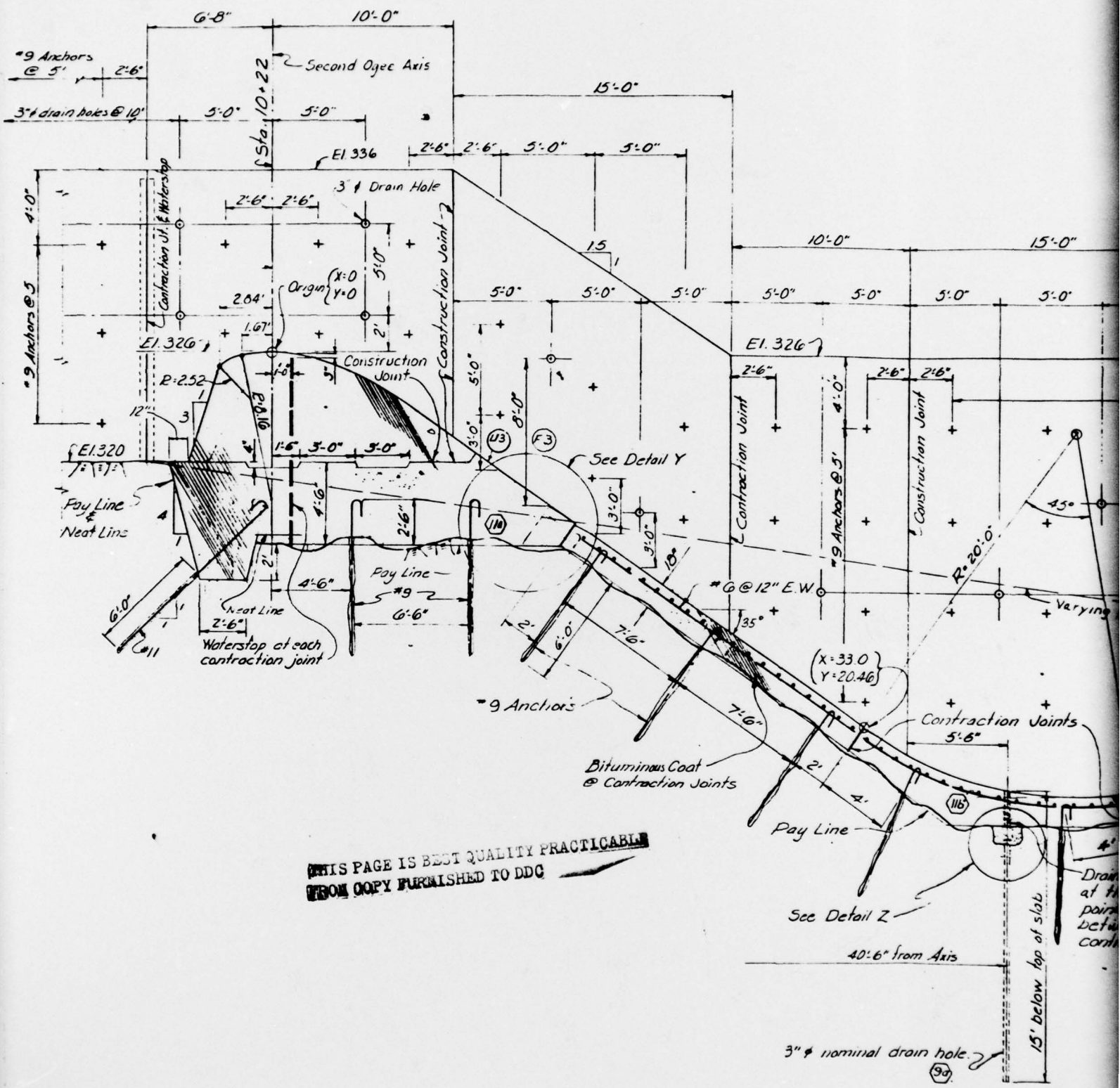
NAT. ID NO. PA.00734 BUCKS COUNTY

DATA OBTAINED FROM THE GENERAL STATE AUTHORITY, PROJECT NO. GSA 194-12, DRAWING 11, DATED 6/31/67

2

PLATE 6

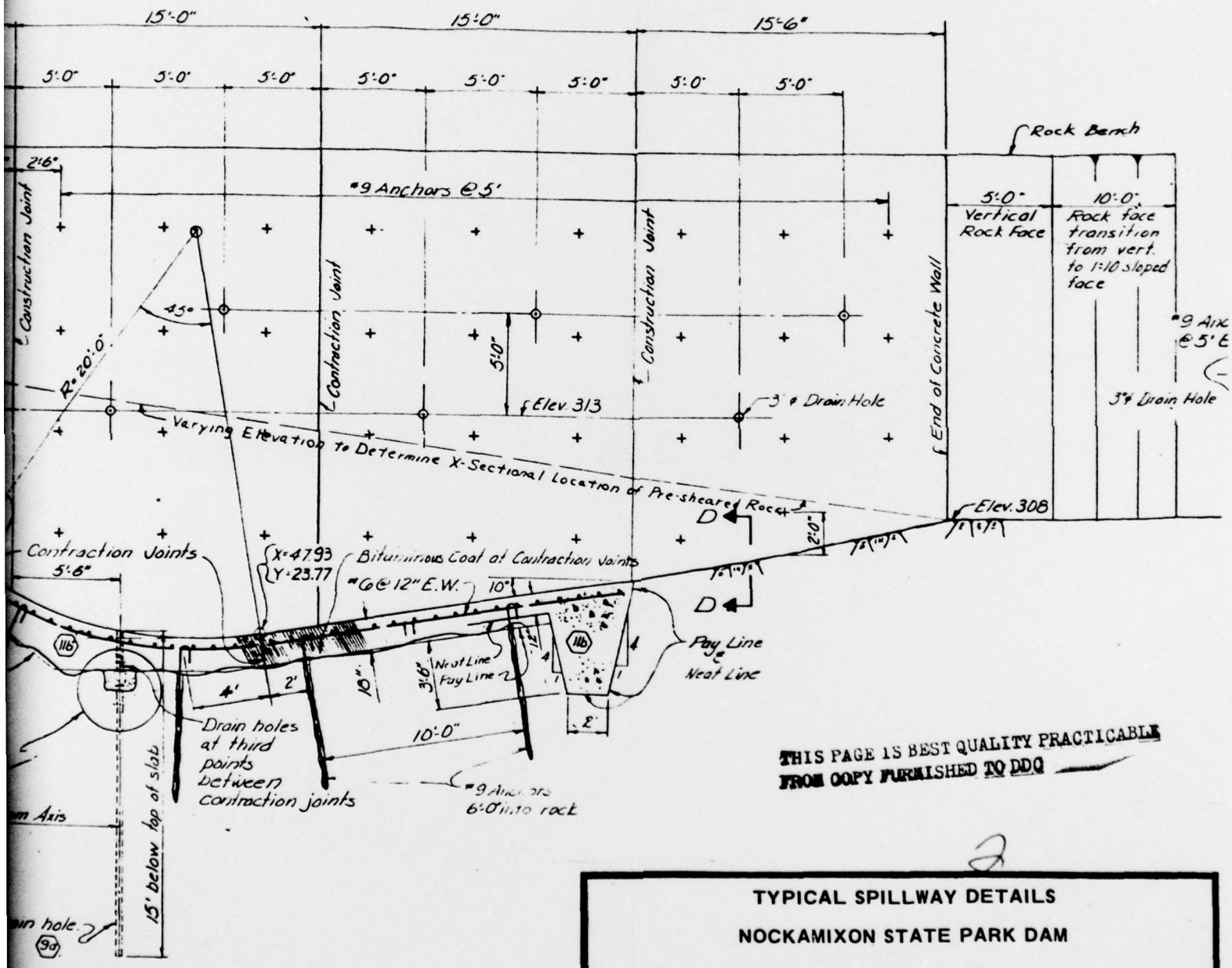
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SECTION A-A

Scale: 1/4" = 1'

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SECTION A-A
Scale: 1/4" = 1'

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2

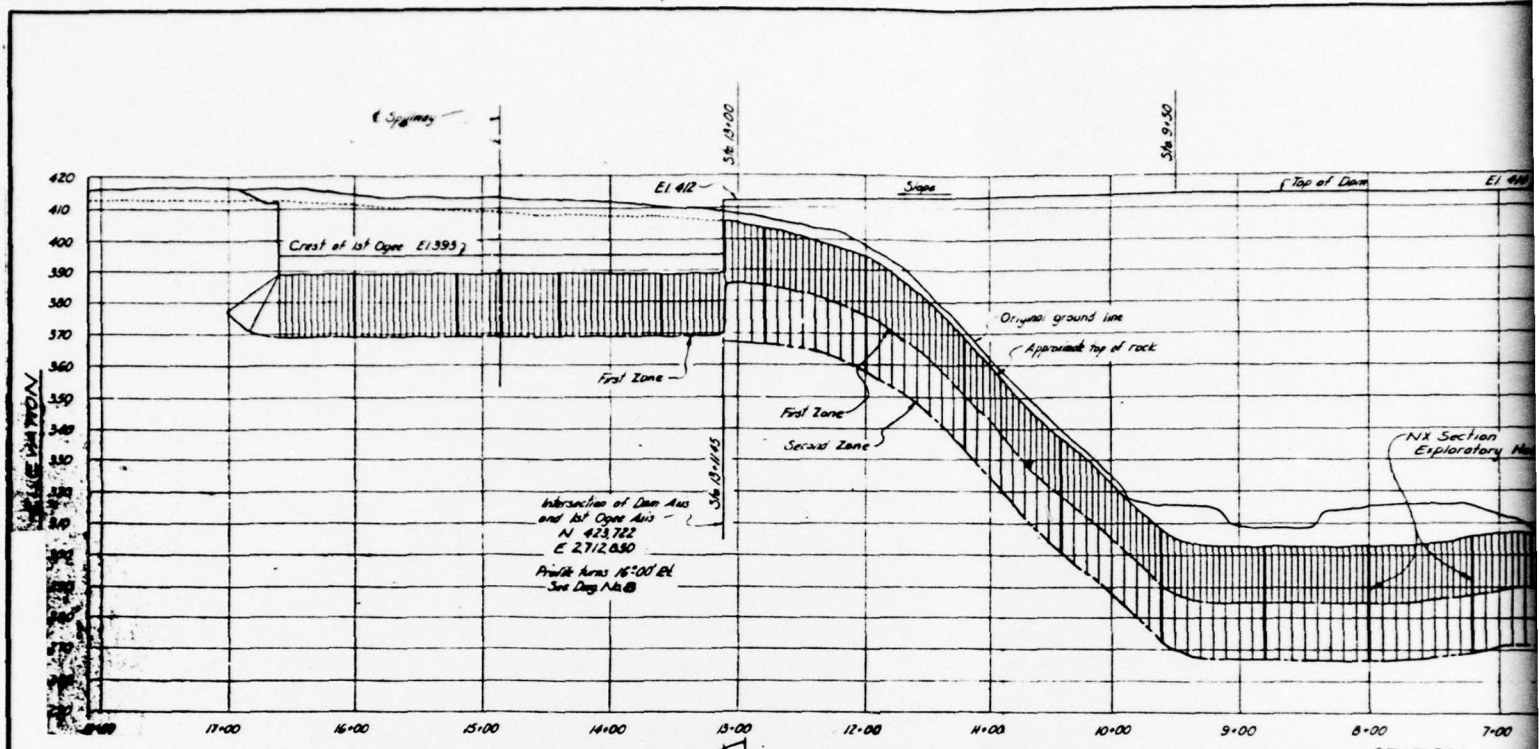
TYPICAL SPILLWAY DETAILS

NOCKAMIXON STATE PARK DAM

NAT. ID NO. PA.00734 BUCKS COUNTY

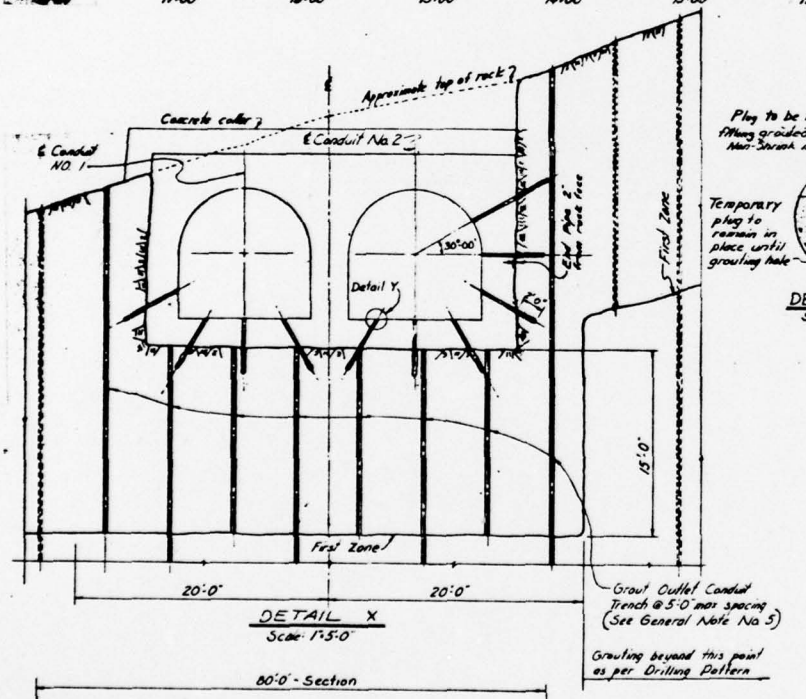
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PLATE 7



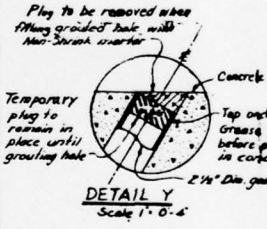
PROFILE ALONG DAM

Scale: Vert. 1"=20'-0"
Horiz. 1"=50'-0"



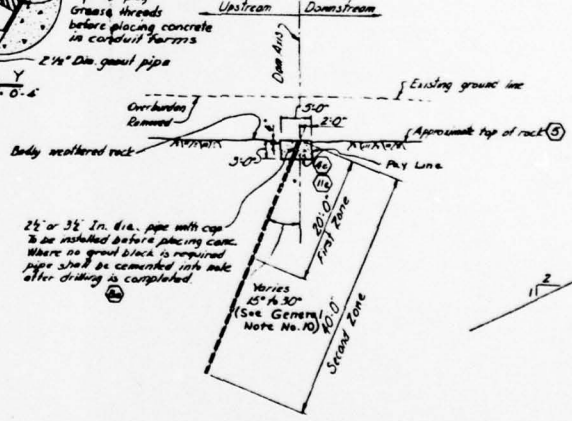
DETAIL X

Scale: 1"=5'-0"



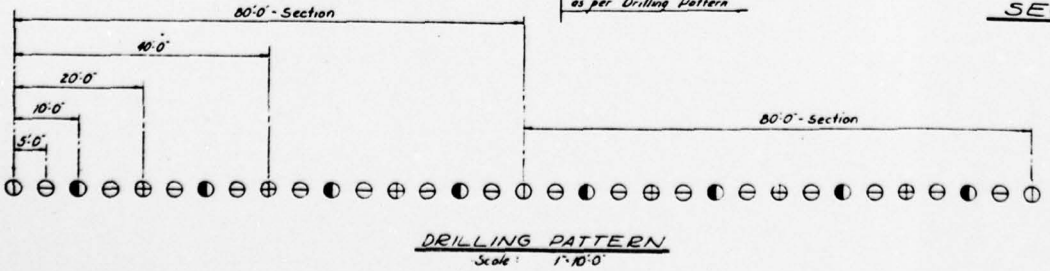
DETAIL Y

Scale 1"=0'-6"



SECTION A-A

Scale: 1"=10'-0"



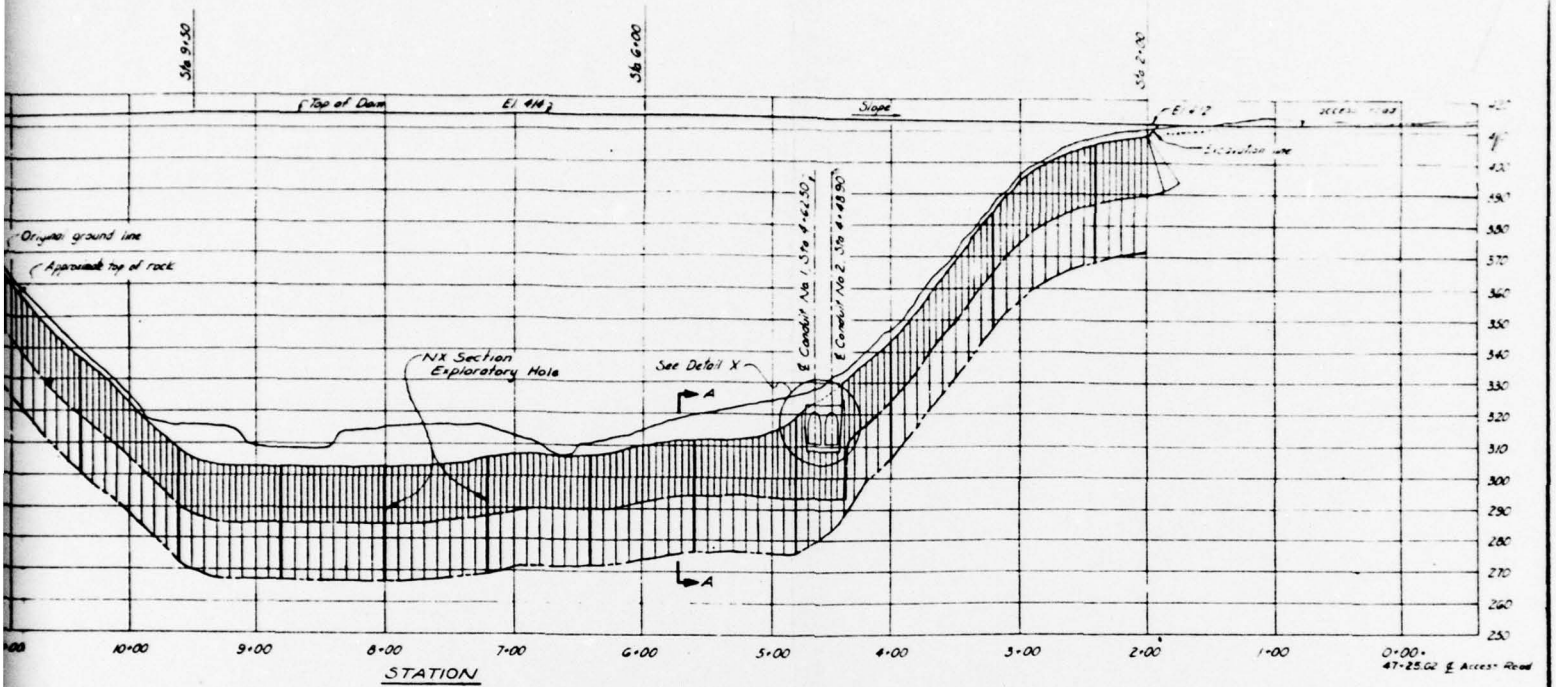
DRILLING PATTERN

Scale: 1"=10'-0"

LEGEND

- NX Section Exploratory Hole (5a)
- EX Primary Grout Hole (4a)
- EX Secondary Grout Hole (4a)
- EX Tertiary Grout Hole (4c)

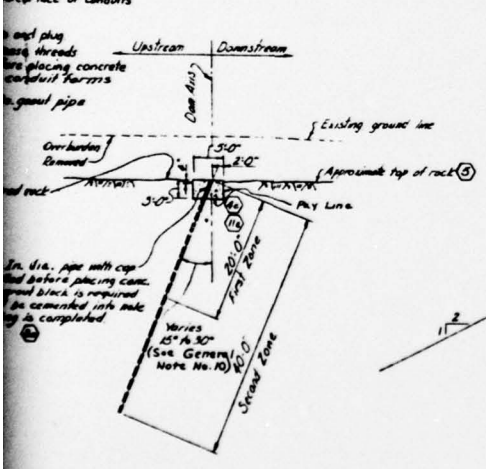
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PROFILE ALONG DAM AXIS

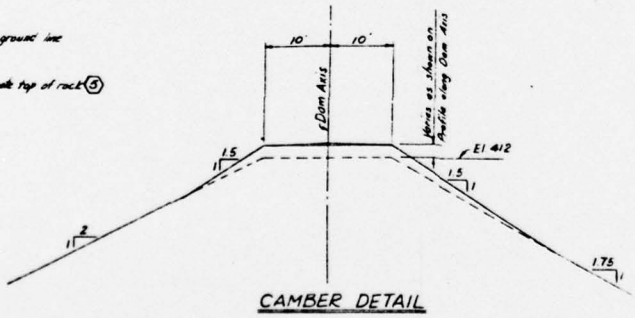
Scale: Vert. 1"=20'-0"
Horiz. 1"=50'-0"

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SECTION A-A

Scale: 1"=10'-0"



CAMBER DETAIL

See Dwg. No. 9 for details of Material Zoning

GENERAL NOTES

1. All holes drilled shall be EX or NX diameter as directed by The Authority.
2. All casings placed in rock shall be flush joint.
3. The limits of drilling and grouting as shown on the drawing are intended as a general guide only. Pattern of drilling and grouting is subject to change as further drilling and grouting progresses.
4. Check Holes, in addition to the holes shown will be designated by The Authority.
5. Where outlet conduits cross the core trench of the dam axis, the trench for the outlet conduits shall be excavated for the full width of the core prior to grouting. Grouting of the outlet conduit trench shall be completed prior to construction of the conduit.
6. Drilling and grouting along axis of ℄ Spgs shall be performed after excavation for Spgs and before placement of concrete.
7. Concrete grouting in conduits at Dam Axis shall be done on the axis and ten (10) feet upstream and downstream of the axis.
8. When grouting has been completed, the holes in the concrete conduit at the location of grout pipes shall be patched with cement mortar mixed and applied as directed by The Authority to result in a smooth surface.
9. Grout block will only be used where character of the rock makes setting grout connections directly in rock impractical.
10. Angle and direction of batter will be determined in the field by The Authority.

LEGEND

- NX Section Exploratory Hole (4)
- EX Primary Grout Hole (8)
- EX Secondary Grout Hole (12)
- EX Tertiary Grout Hole (16)

FOUNDATION GROUTING PLANS

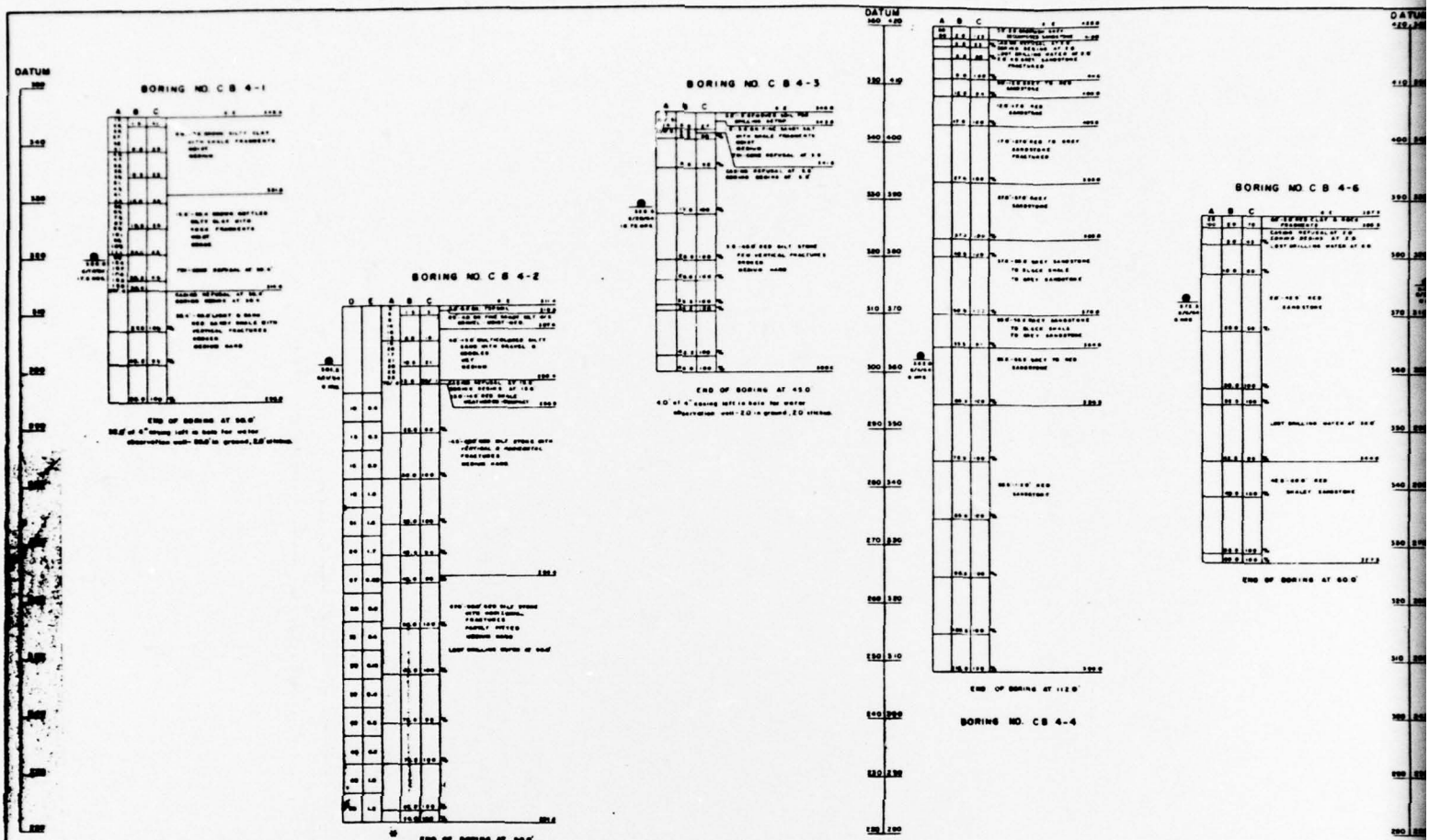
NOCKAMIXON STATE PARK DAM

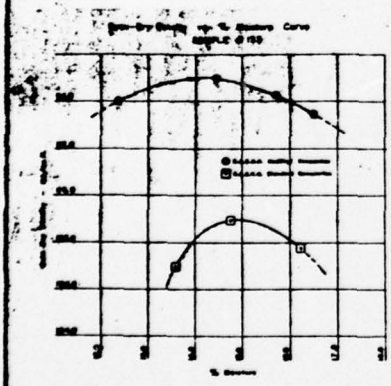
NAT. ID NO. PA.00734 BUCKS COUNTY

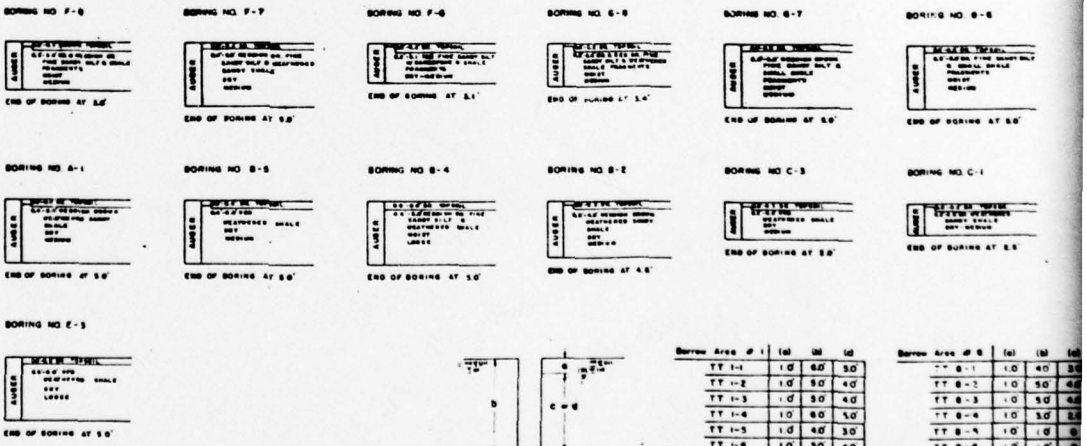
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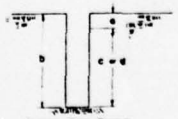
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PLATE 8







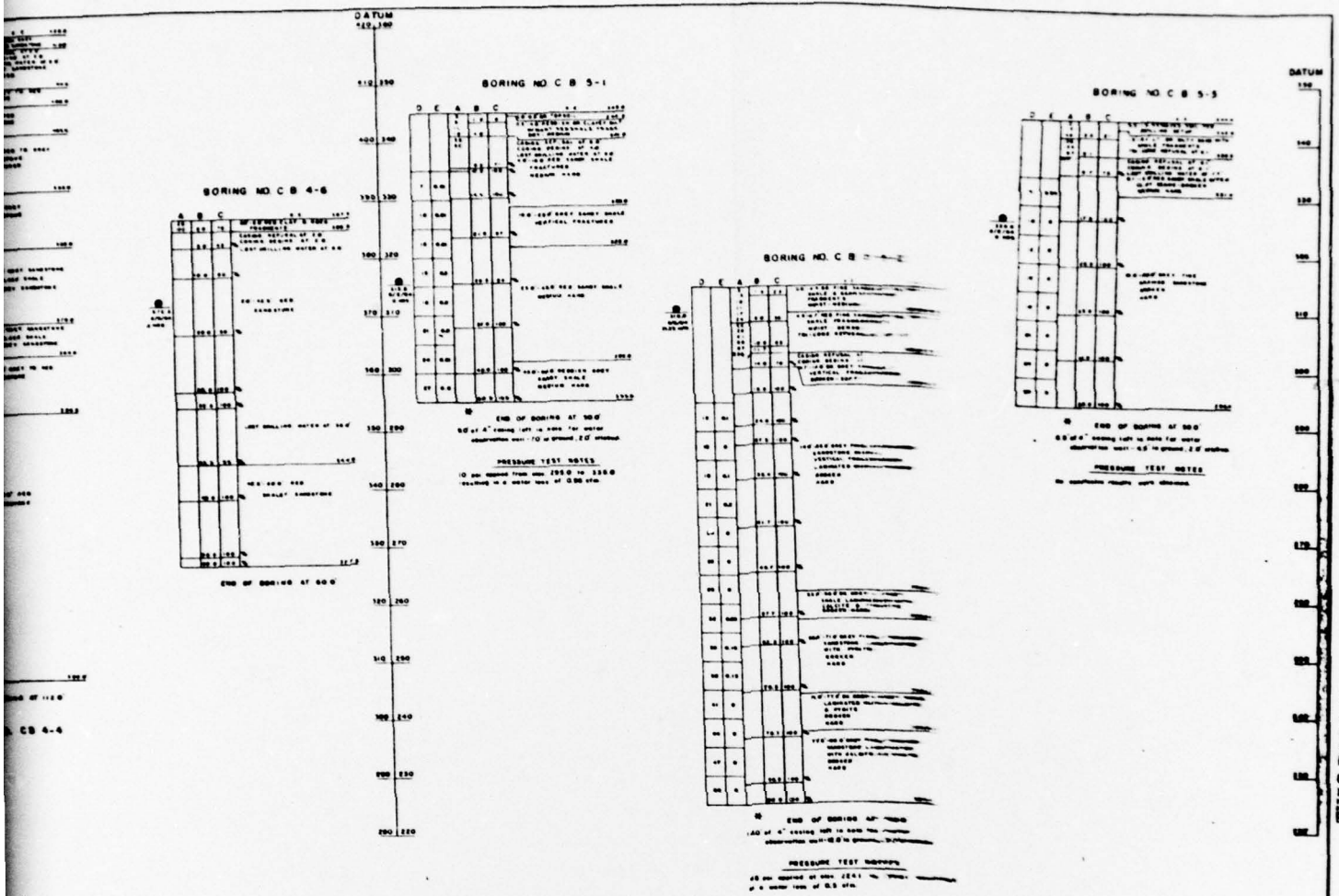


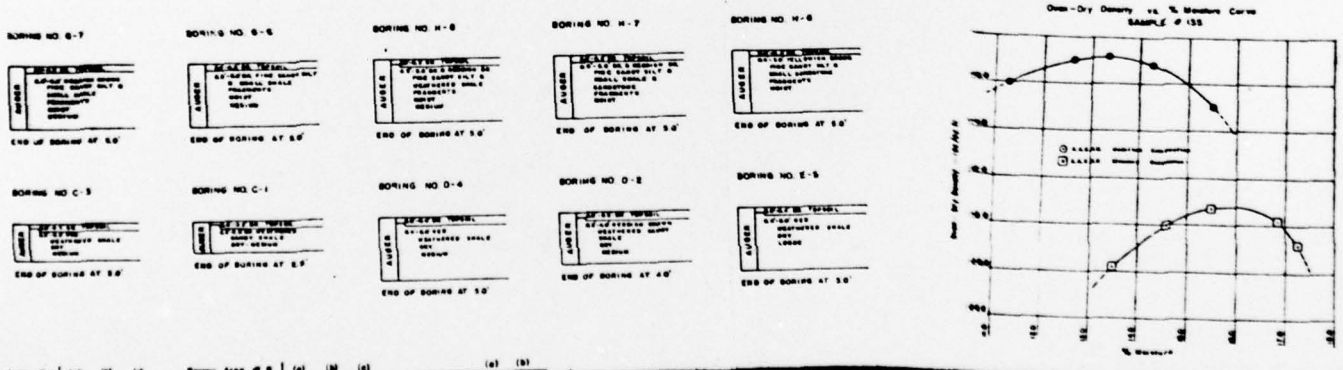
	(a)	(b)	(d)
TT 2-1	1'	12'	11'
TT 2-2	2'	11'	9'
TT 2-3	2'	7'	5'
TT 2-4	4'	7'	3'

Borrow Area # 1	(a)	(b)	(c)
TT 1-1	1.0'	6.0'	5.0'
TT 1-2	1.0'	5.0'	4.0'
TT 1-3	1.0'	5.0'	4.0'
TT 1-4	1.0'	8.0'	7.0'
TT 1-5	1.0'	4.0'	3.0'
TT 1-6	1.0'	5.0'	4.0'
TT 1-7	1.0'	8.0'	7.0'
TT 1-8	1.0'	6.0'	5.0'
TT 2-7	1.5'	6.0'	4.5'
TT 2-6	1.5'	5.0'	3.5'

Borrow Area # 2	(a)	(b)	(c)
TT 2-1	1.0	4.0	3.0
TT 2-2	1.0	5.0	4.0
TT 2-3	1.0	5.0	4.0
TT 2-4	1.0	3.0	2.0
TT 2-5	1.0	1.0	0
TT 2-6	1.0	1.0	0
TT 2-7	1.0	4.0	3.0
TT 2-8	1.0	3.0	2.0
TT 2-9	1.0	5.0	4.0
TT 2-10	1.0	3.0	2.0
TT 2-11	2.0	5.0	3.0
TT 2-12	2.0	5.0	3.0
TT 2-13	3.0	3.0	0
TT 2-14	3.0	3.0	0
TT 2-15	1.0	1.0	0

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Borrow Area # 1	(a)	(b)	(c)
TT 1-1	1.0	60	50
TT 1-2	1.0	50	40
TT 1-3	1.0	50	40
TT 1-4	1.0	60	50
TT 1-5	1.0	40	30
TT 1-6	1.0	50	40
TT 1-7	1.0	80	70
TT 1-8	1.0	60	50
TT 2-7	1.5	60	45
TT 2-6	1.5	50	35

Borrow Area # 6	(a)	(b)	(c)
TT 6-1	1.0	40	30
TT 6-2	1.0	50	40
TT 6-3	1.0	50	40
TT 6-4	1.0	30	20
TT 6-5	1.0	1.0	0
TT 6-6	1.0	1.0	0
TT 6-7	1.0	40	30
TT 6-8	1.0	30	20
TT 6-9	1.0	50	40
TT 6-10	1.0	30	20
TT 6-11	2.0	30	10
TT 6-12	2.0	30	10
TT 6-13	3.0	30	0
TT 6-14	3.0	30	0
TT 6-15	1.0	1.0	0

	(a)	(b)
TT-132	1.5	60
TT-133	1.2	30
TT-134	1.0	†
TT-135	1.0	†
TT-136	1.0	†
TT-137	1.0	†
TT-138	1.0	†
TT-139	1.0	36
TT-140	1.0	36
TT-141	1.0	36
TT-142	1.0	46
TT-143	1.0	22

TYPICAL FOUNDATION BORING LOGS

NOCKAMIXON STATE PARK DAM

NAT. ID NO. PA.00734

BUCKS COUNTY

DATA OBTAINED FROM THE GENERAL STATE AUTHORITY, PROJECT NO. GSA 194-12, DRAWING 4, DATED 6/31/67

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PLATE 9

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APPENDIX

F

SITE GEOLOGY
NOCKAMIXON STATE PARK DAM

The geologic setting of the site was extracted from the design report prepared by Pickering, Corts and Summerson, Inc., dated May 17, 1965.

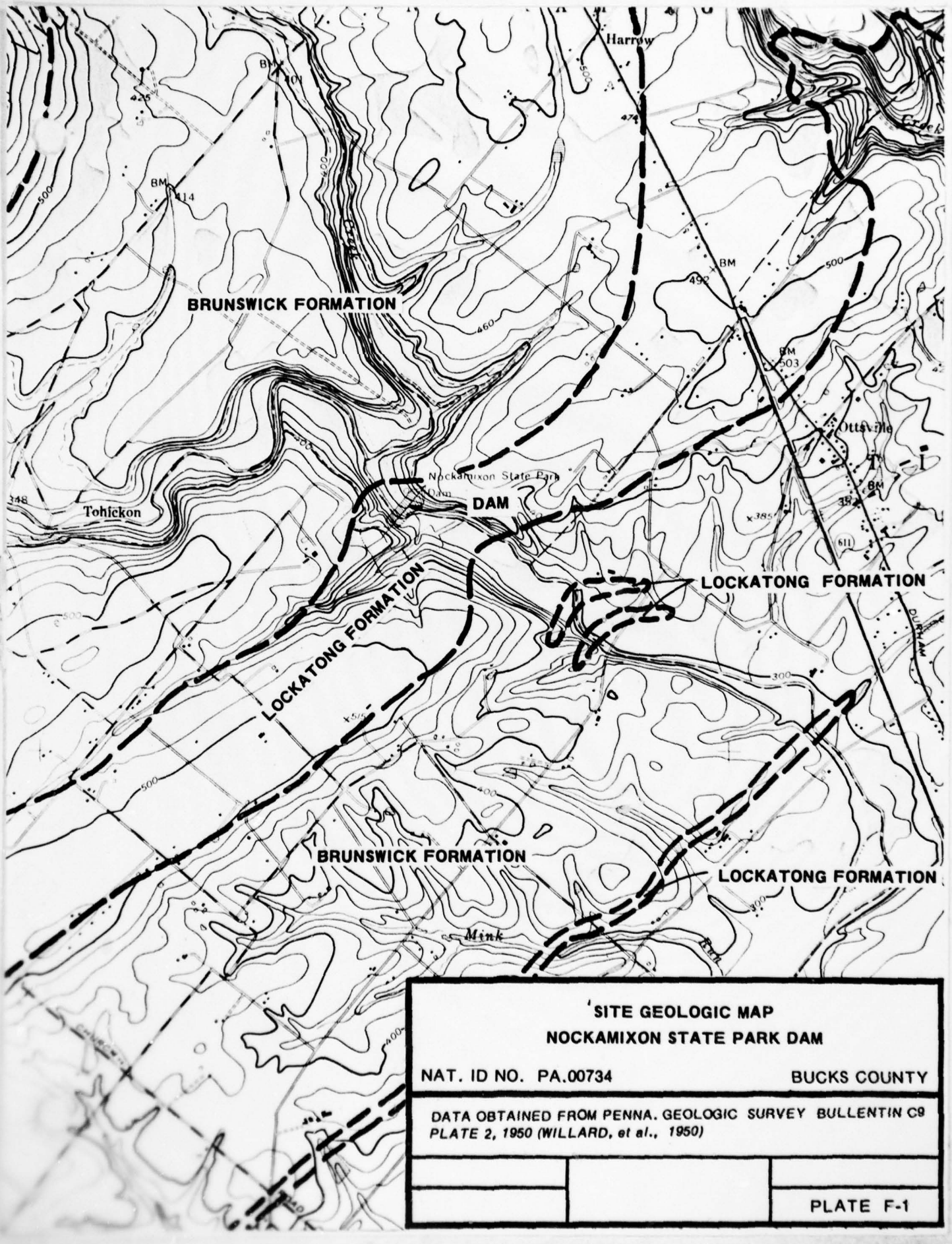
"The dam site is located in Tohicken Creek Valley, downstream of the confluence with Haycock Creek. At this location the creeks have incised their valleys into beds of red and gray fine-grained sandstone, siltstone and argillite of Brunswick and Lockatong lithofacies.

Except for some slickensides, a few zones of thin clayey gouge and some mylonitic streaks there does not appear to be any evidence of major faulting or folding. The rocks generally appear to strike NW-SE and dip gently NE; some local beds strike NE-SW and dip NW.

The bedrock decomposes to a red-brown clayey soil. Decomposition decreases rapidly with depth and as a result only a few feet of soil occur in the higher elevations.

The rock in the area is jointed with one primary and at least two discernable secondary joint patterns. The major joint system strikes locally NE-SW with some variance"

The bedrock in the vicinity of the dam site is shown on Plate F-1. Downstream seepage should be minimal due to the impervious nature of the rock; the bedding and jointing striking approximately parallel to the dam axis; and lack of faulting at the site.



SITE GEOLOGIC MAP
NOCKAMIXON STATE PARK DAM

NAT. ID NO. PA.00734 BUCKS COUNTY

DATA OBTAINED FROM PENNA. GEOLOGIC SURVEY BULLENTIN C9
PLATE 2, 1950 (WILLARD, et al., 1950)

PLATE F-1