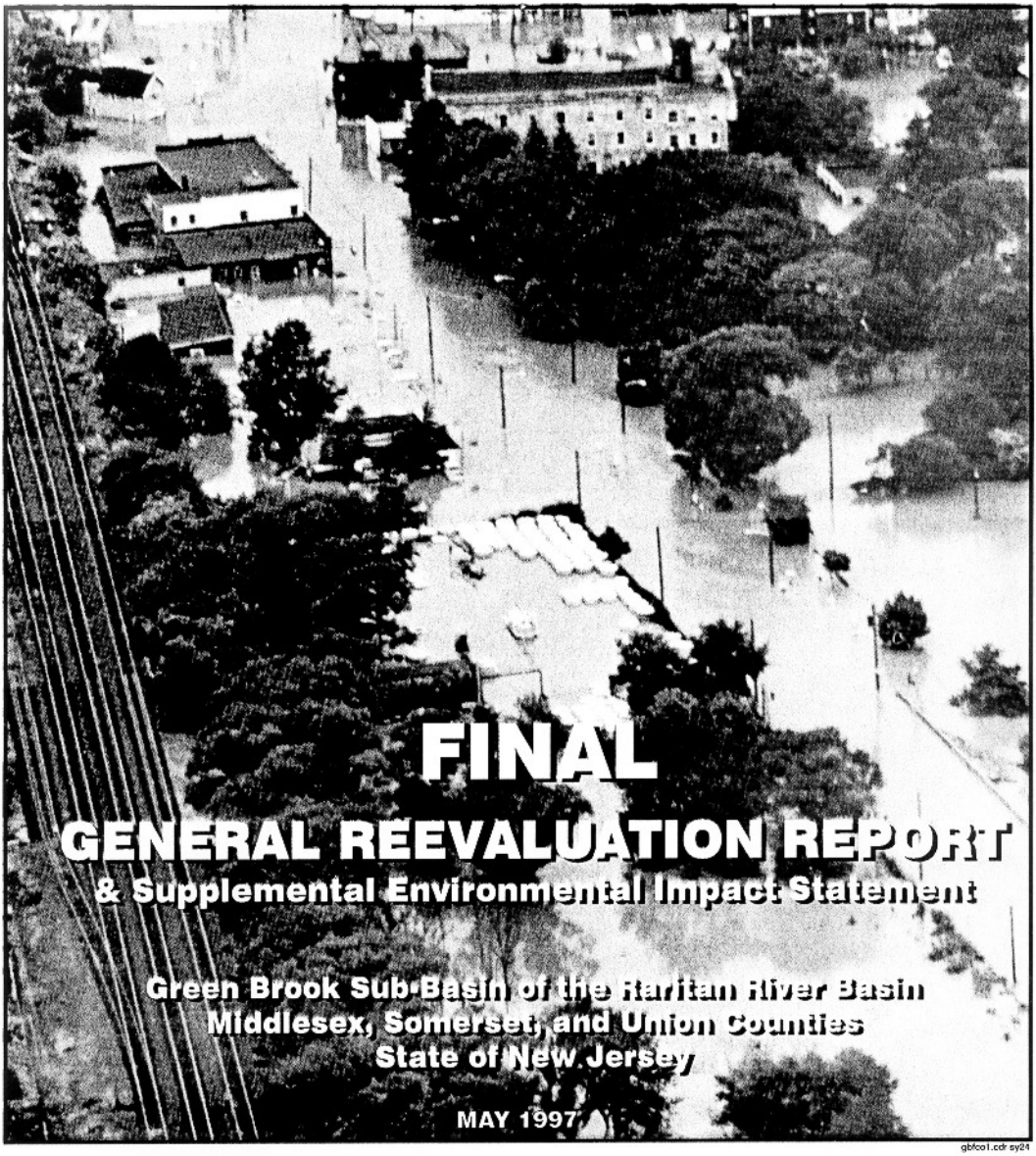

FINAL

GENERAL REEVALUATION REPORT

& Supplemental Environmental Impact Statement

Green Brook Sub-Basin of the Raritan River Basin
Middlesex, Somerset, and Union Counties
State of New Jersey

MAY 1997

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US Army Corps
of Engineers ®
New York District

Green Brook Flood Control Project

Volume 1 of 2

FINAL

GENERAL REEVALUATION REPORT

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Green Brook Sub-Basin of the Raritan River Basin
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Cover Photo: Bound Brook Borough - Main Street looking west from Middlesex Borough following Hurricane Doria August 1971
Photo Courtesy of Forbes Newspapers

ADDENDUM

to the

Final General Reevaluation Report and Supplemental Environmental Impact Statement for the Green Brook Sub-Basin of the Raritan River Basin

Middlesex, Somerset and Union Counties, State of New Jersey

July 1997

US ARMY CORPS
OF ENGINEERS
NEW YORK DISTRICT

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Introduction

This Addendum has been prepared to accompany the Final General Reevaluation Report and Supplemental Environmental Impact Statement for the Green Brook Sub-Basin of the Raritan River Basin, Middlesex, Somerset and Union Counties, State of New Jersey, dated May 1997. The addendum provides clarification on the use of the term National Economic Development Plan (NED Plan) when referring to the lower portion of the basin, provides an additional condition for the Local Cooperation Requirements, provides responses to the U.S. Fish & Wildlife Coordination Act Report and makes reference to the Post-Authorization Change Analysis which is provided as a support document.

NED Plan - Context of Terminology

Within the text of the General Reevaluation Report (GRR) and Supporting Documents, when referring to the NED Plan in the lower portion of the basin, this term refers to the plan that was formulated and approved in the August 1980 Feasibility Report and has been reaffirmed by the recent study effort documented in the May 1997 GRR as still being economically favorable. The NED Plan in the upper and Stony Brook portions of the basin have been reformulated during the recent study effort.

When referring to the basin-wide NED Plan the report is discussing the reaffirmed plan in the lower portion of the basin coupled with the reformulated plans in the upper and Stony Brook portions of the basin.

The study effort documented in the GRR consists of a limited reevaluation of the lower portion of the basin and a general reevaluation in the upper and Stony Brook portions of the basin.

Local Cooperation Requirements

The following paragraph is to be considered an additional condition of the Local Cooperation Requirements which appear on page 157, paragraph 403 of the main text:

l. Any costs incurred in clean up of hazardous materials located on project lands and covered under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) shall be considered a non-Federal responsibility for which no cost sharing credit shall be given. The project sponsor shall be required to operate, maintain, repair, replace and rehabilitate the project in a manner so that liability will not arise under CERCLA.

Response to Fish & Wildlife Coordination Act Report

The Fish and Wildlife Coordination Act Report (FWCAR) was provided just prior to printing the Final GRR. Therefore a response could not be worked into the Final GRR. The New York District has since prepared a response to the comments raised in the FWCAR. Those responses to comments are now included in the Final Supplemental Environment Impact Statement (FSEIS) as FSEIS Appendix C-1 entitled U.S Army Corps of Engineers Response to U.S. Fish & Wildlife Services Coordination Act Report.

The Fish and Wildlife Coordination Act, Section 2(b) Report is included in the Final Supplemental Environmental Impact Statement as FSEIS Appendix -C, refer to this document for the Conclusions and Recommendations of the U.S. Fish and Wildlife Service (USF&WS).

In summary the Corps shares with the USF&WS a desire and commitment to avoid or minimize any adverse impacts as much as possible, and appreciates comments and assistance in developing an environmentally sound plan. The District will continue to work with the USF&WS

during the detailed plans and specifications stage for the lower and Stony Brook portions of the basin, as well as the reevaluation of the upper portion of the basin, to further minimize project impacts and improve our mitigation outputs, within the constraints of project's purpose. Towards that end we have responded to the USF&WS specific recommendations which are included in the FSEIS as noted above.

Post-Authorization Change Analysis

The Green Brook Flood Control Project, as described in the General Reevaluation Report, is within the scope of the project authorized for construction by Congress in Section 401(a) of the Water Resources Development Act of 1986, as amended. The changes in the authorized project are within the approval authority delegated by the Chief of Engineers to the Director of Civil Works. Therefore, reauthorization of the project described in the General Reevaluation Report is not required by Congress. Refer to Support Document M: Post-Authorization Change Analysis, for detailed comparison of the 1986 Authorized Plan and the currently recommended plan.

SYLLABUS

This General Reevaluation Report is a major step in the implementation of the Green Brook Flood Control Project. Construction of a flood control project for the Green Brook sub-basin was authorized by Congress in the Water Resources Development Act of 1986. This report affirms that this authorization remains appropriate for the Green Brook sub-basin based on today's problems, needs, and planning and design criteria.

This final report is the result of extensive coordination and review by many interested parties. A draft report was released for public review from January 6, 1997 through March 7, 1997. This review period included four formal public meetings and numerous informal information sessions with various groups. The public coordination process confirmed the general desire for the Corps and New Jersey Department of Environmental Protection (NJDEP), the non-Federal Sponsor, to continue engineering, design and construction of the project. However, the coordination also magnified concerns with the project features recommended for the upper portion of the basin in the Boroughs of Berkeley Heights, Watchung, Scotch Plains, North Plainfield and the City of Plainfield, in Union and Somerset Counties. In order to further consider all views on this portion of the project, the NJDEP has asked the Corps to defer construction of the upper portion features of the project at this time, and to continue to work with the NJDEP and other interested parties in evaluating additional information in an effort to seek a greater balance between flood protection and preservation of environmental resources. It must be emphasized that any reconsideration of the features in the upper basin will not affect the Stony Brook and lower basin plans. Accordingly, this final document is considered a decision document for construction implementation of the lower and Stony Brook portions of the basin, with continued planning and engineering of the separable upper portion of the basin. The decision to construct the upper portion features will be deferred until such time that evaluations of additional information and views are completed and local interests have the opportunity to review findings.

This document presents the rationale which supports this conclusion, describes the anticipated environmental impacts of implementing the project, and outlines the responsibilities for Federal and non-Federal interests. The accomplishment of this milestone is attributed to the strong partnership of the New Jersey Department of Environmental Protection (the non-Federal sponsor) and the New York District. This partnership is reinforced by many interested and active participants, particularly the Green Brook Flood Control Commission.

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EXECUTIVE SUMMARY

Objectives of the General Reevaluation Report

1. The General Reevaluation Report is a decision document that presents all of the relevant engineering, economic and environmental factors necessary for determining the appropriateness of constructing the Green Brook Flood Control Project. It was prepared to meet the following objectives:

- Affirm the project authorized by the Water Resources Development Act of 1986.
- Support the decision process for construction budgeting.

2. The report reviews the decision process leading to authorization, affirms the viability and feasibility of the project, as newly scaled and updated, describes its components, provides the cost estimate, specifies the responsibilities of the Federal government and the non-Federal sponsor, and outlines the remaining steps in the implementation process.

Authorizing Legislation

3. A feasibility report was issued in August 1980. The review process resulted in administration support of a project designated as Plan E in the report, which would protect a 150 year level of flood protection in the lower portion of the basin only. However, subsequent legislative action in the form of the Water Resources Development Act of 1986 "adopted and authorized to be prosecuted by the Secretary (of the Army) ..." a project providing basin wide flood protection with a 500 year level of protection in the lower portion of the basin and 150 year level of protection in the upper and Stony Brook portions of the basin. This construction authorization set in motion a reevaluation process leading to the affirmation of the authorized project.

Project Status

4. Preconstruction engineering and design was initiated after project authorization. These studies encountered delays related to the apparent divergence between the needs and desires of

the non-Federal sponsor and national economic objectives. Federal participation is limited to the construction of projects that meet the national economic development (NED) objective. It is significant that Plan A (the locally preferred plan) as presented in the Feasibility Report was not economically feasible and thus did not meet the NED objective. Plan A provided basin wide 150 year level of protection and most nearly resembles the plan authorized for construction.

5. The Plan authorized for construction cannot proceed to construction with full Federal participation until the NED objective is adequately addressed and the non-Federal sponsor agrees to meet the responsibilities prescribed by national water resource laws and policies.

6. The General Reevaluation Report describes the affirmation study that addressed these matters. If the project as described in this General Reevaluation Report is accepted as consistent with Federal laws and policies, it will be eligible for inclusion in the civil works construction budget of the Corps of Engineers.

Affirmation Study

7. The affirmation study performed for the General Reevaluation Report resolves the differences between the authorized plan and Plan E (as designated in the 1980 Feasibility Report), which was stated in the Feasibility Report to meet the NED objective. Plan A was the locally preferred plan because it provided comprehensive protection in the Lower, Upper and Stony Brook portions of the basin. However, Plan A was not economically justified in the Upper and Stony Brook portions of the basin and therefore did not meet the NED objective. Plan E was the NED plan because it provided economically justified protection. This protection was limited to the lower portion of the basin and was supported by the Administration.

8. A review and update of feasibility stage engineering, economic, and environmental studies confirmed the effectiveness of the protective measures considered at the time of the Feasibility Study. The general reevaluation study expanded on those findings in conjunction with an intensive program of coordination with the affected communities. Finally, project components in the Upper and Stony Brook portions were rescaled to yield an economically justified comprehensive plan of protection that was acceptable to the non-Federal sponsor and met national objectives.

Description of the NED Plan

9. The NED plan is the result of the re-affirmation of the authorized project, and provides comprehensive protection by combining levee/floodwall works (including closure structures and interior drainage structures), channel modifications, flood detention storage, bridge replacements and modifications, and non-structural measures. The NED plan is not significantly different from the authorized plan. Environmental mitigation measures are also included. Variable degrees of protection are provided in the three portions of the basin.

10. Flood protection in the lower portion of the basin includes 66,540 feet of levees, 11,220 feet of floodwalls, 10 bridge replacements, one bridge removal, 8 closure structures, interior drainage facilities and non-structural measures to provide a 150-year level of protection. These works are located at the following five areas.

- Raritan River-Green Brook confluence
- Green Brook-Bound Brook confluence
- Green Brook-Municipal Brook confluence
- Bound Brook-Cedar Brook confluence
- Bound Brook non-structural improvements

11. Flood protection in the upper portion of the basin includes two dry detention basins at the Sky Top and Oak Way sites, 12,400 feet of channel modifications, 6,865 feet of channel clearing and desnagging, and one bridge replacement.

12. Flood protection in the Stony Brook portion of the basin consists of 4,970 feet of channel modifications from just downstream of the Rockview Terrace bridge to the Villa Maria bridge. Stony Brook features also include the replacement of the Grove Street bridge and the underpinning of the Green Brook Road and Route 22 bridges.

13. The plan was formulated to provide flood protection while avoiding environmental and cultural impacts when possible. Unavoidable impacts are addressed by a mitigation plan that will

compensate for losses due to project implementation. A mitigation plan has been developed to identify sites that could be used to fully replace lost habitat.

Public Comment

14. On January 6, 1997, the Notice of Availability of the Draft Green Brook General Reevaluation Report was published in the Federal Register. This notice officially opened the public comment period. Subsequent to the notice, four public meetings were held in communities within the project area. These meetings were designed to relay information to the public affected by the project, and to solicit input in the form of written comments.

Recommended Plan

15. The public co-ordination process confirmed the general desire for the Corps and the NJDEP, the non-federal sponsor, to continue engineering, design, and construction of the project. However, general concern expressed by local residents and elected officials from several communities and counties within the basin, has led the Corps, in conjunction with the NJDEP, to defer action on the flood protection plan for the upper portion of the basin.

16. The features of the upper portion of basin plan generated significant interest over the level of flood protection and the related environmental and social aspects of the plan. The New York District and the local sponsor have agreed to evaluate concerns raised during the public comment sessions, and to define potential plan alternatives to further balance the environmental and social considerations. While the upper portion of the basin undergoes further evaluation, the New York District Corps of Engineers will recommend the flood protection plans for the lower and Stony Brook portions of the basin for construction.

First Cost of Construction

17. First cost includes expenditures for construction of the project, including engineering, design, supervision, administration and contingencies but excludes the previously expended pre-construction engineering and design costs. The estimated first cost of the NED plan is $309,970,000. The price level is April 1996. Allowing for inflation over the construction period, the actual full funding required for construction of the NED plan would be $367,865,000. The

first construction cost of the plan recommended by the District for construction, which includes only the lower portion of the basin and the Stony Brook portion of the basin, is estimated at $259,625,000. The fully inflated estimate which represents the actual funding required for the recommended plan construction is $307,042,000.

Feasibility

18. Federal participation requires that the annual benefits exceed the annual economic costs. Benefits are equal to the estimated annual damages that would be prevented by the project averaged over the project life. The annual benefits of the NED plan are presently estimated at $45,921,000, while benefits of the recommended plan are estimated at $37,733,000. Annual economic costs are derived by applying the prevailing discount rate of 7-3/8% over the 100-year project life to the costs of construction, and adding the annual costs of operation, maintenance and replacements. Annual costs of the NED plan are presently estimated at $34,251,000, while annual costs of the recommended plan are estimated at $28,925,000. The benefit-cost ratios of both the NED plan and the Recommended Plan are 1.3.

Legislative Cost Sharing

19. The project would be a joint undertaking of the Federal government and New Jersey Department of Environmental Protection (NJDEP), the non-Federal sponsor. Federal law requires that all costs, including $24,000,000 in prior expenditures for planning, engineering and design, be apportioned accordingly. This is based on Section 103 of the Water Resources Development Act of 1986 (WRDA 1986). The Federal share of the recommended project's cost is $210,083,000. The non-Federal costs are estimated at $73,542,000, of which lands, easements, rights-of-way, relocations and disposal areas (LERRDs) are estimated at $56,812,000.

Implementation

20. The implementation process will carry the project through the remaining preconstruction engineering and design phases, preparation of plans and specifications, and construction. Funds must be budgeted by the Federal government and non-Federal sponsor to support these activities. The non-Federal sponsor must sign a project cooperation agreement before construction can

begin. A project schedule will be established to describe the construction schedule and the year-by-year financial requirements. The first structural project feature scheduled for construction will be the Main Street bridge at the Raritan River-Green Brook confluence. Flood proofing of residential and commercial buildings in the vicinity of Prospect Place and Union Ave. in the Borough of Middlesex are the first non-structural features scheduled for construction. A Feature Design Memorandum for the first construction phase will be the basis for construction plans and specifications.

Project Cooperation Agreement

21. The Project Cooperation Agreement (PCA), will define the responsibilities of the Corps and the NJDEP for project financing, operation and maintenance. NJDEP will be required to provide a number of items of local cooperation, including the provision of all lands, easements, and rights-of-way for construction, operation and maintenance of the project.

Conclusion and Recommendation

22. This General Reevaluation Report concludes that the NED Plan meets all Federal planning objectives and is consistent with the scope and cost of the Water Resources Development Act of 1986 construction authorization.

23. The District recommends implementation of the lower and Stony Brook portions of the NED Plan while planning and engineering of the upper portion be continued to balance the need to provide flood protection and environmental preservation.

PERTINENT DESIGN DATA	
Lower Portion of the Basin (Recommended for Implementation)	
Lower Portion Basin Drainage Area	65.2 Square Miles
Level of Protection	150-Year Recurrence Interval
Length of Levees Average Height	66,540 feet 11 feet
Length of Floodwalls Average Height	11,220 feet 13 feet
Number of Closure Structures	8
Number of Bridge Replacements	10
Number of Bridge Removals	1
Number of Interior Drainage Primary Outlets	28
Number of Interior Drainage Pump Stations	16
Length of Channel Relocation	3,300 feet
Length of Riprap Channel Stabilization	8,900 feet
Non-Structural Features: Number of Flood Proofings (Incl. Raisings) Number of Buy Outs	 162 12
Stony Brook Portion of the Basin (Recommended for Implementation)	
Stony Brook Basin Drainage Area	8.1 Square Miles
Level of Protection	25-year recurrence interval
Length of Channel Modifications	4,970 feet
Number of Bridge Replacements	1
Number of Bridge Underpinnings	2
Number of Flood Proofings	4

PERTINENT DESIGN DATA

Upper Portion of the Basin (Implementation Deferred)	
Upper Portion Basin Drainage Area	10.3 Square Miles
Level of Protection	20-Year recurrence interval
Length of Channel Modifications	12,400 feet
Length of Channel Clearing and Desnagging	6,865 feet
Number of Bridge Replacements	1
Number of Bridge Wingwall Modifications	6
Sky Top Detention Structure:	
Materials of Construction	Earthen embankment, roller compacted concrete spillway, reinforced concrete primary outlet.
Maximum Height	41 feet
Overall Structure Length	1,120 feet
Spillway Length	160 feet
Primary Outlet Diameter	3 feet
Normal Pool Depth	Stream base flow
Basin Performance (2-year storm):	
peak inflow	280 cfs
peak outflow	90 cfs
volume stored	29 acre feet
Basin Performance (10-year storm):	
peak inflow	590 cfs
peak outflow	110 cfs
volume stored	145 acre feet
Basin Performance (100-year storm):	
peak inflow	1910 cfs
peak outflow	160 cfs
volume stored	605 acre feet

PERTINENT DESIGN DATA

Oak Way Detention Structure:	
Materials of Construction	Earthen embankment, roller compacted concrete spillway, reinforced concrete primary outlet.
Maximum Height	45 feet
Overall Structure Length	965 feet
Spillway Length	165 feet
Primary Outlet Diameter	4 feet
Normal Pool Depth	Stream base flow
Basin Performance (2-year storm):	
peak inflow	440 cfs
peak outflow	200 cfs
volume stored	21 acre feet
Basin Performance (10-year storm):	
peak inflow	1030 cfs
peak outflow	230 cfs
volume stored	102 acre feet
Basin Performance (100-year storm):	
peak inflow	2850 cfs
peak outflow	530 cfs
volume stored	285 acre feet

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INTRODUCTION

General

1. This General Reevaluation Report is a major step in the implementation of the Green Brook Flood Control Project authorized by Congress in the Water Resources Development Act of 1986. It updates the studies performed for the 1980 Feasibility Report and affirms the validity of the authorized project. The report:

a. Describes the planning and decision-making process which leads to this conclusion,

b. Updates and re-scales the components of the project,

c. Presents the estimates of costs and benefits,

d. Specifies the responsibilities of the Federal government and non-Federal sponsor,

e. Outlines the implementation process and the project schedule through construction, and

f. Recommends approval to construct the New York District recommended plan.

Project Authorization

2. This report was prepared under the construction authorization of the Green Brook Flood Control Project enacted as Section 401a of the Water Resources Development Act of 1986, which states:

> *The following works of improvement for the control of the destructive floodwaters are adopted and authorized to be prosecuted by the Secretary substantially in accordance with the plans subject to conditions recommended in the respective reports designated in this subsection.... "Green Brook Sub-basin, Raritan River basin, New Jersey: Report of the Chief of Engineers, dated September 4, 1981 at a total cost of $203,000,000 with an estimated first Federal cost of $151,000,000 and an estimated first non-Federal cost of $52,000,000. Such project shall include flood protection in the upper Green Brook Sub-basin and the Stony Brook tributary, as described in Plan A in the report of the District Engineer, New York, dated August 1980"*

Scope of Study

3. This report focuses on the flood damage problems in the Green Brook Basin and its tributaries. It offers a recommendation on the cooperative actions that should be taken by the Federal government and the non-Federal sponsor of the project. The recommendation is based on the following considerations, all of which are documented in this report.

a. Identification of the flood damage problems

b. Relationship of flood damage problems to the environmental and socioeconomic needs and desires of the people living and working in the drainage basin

c. Refinement of solutions in the 1980 Feasibility Report for protecting the flood prone areas and reducing flood damages

d. Determination of the costs and benefits as well as the environmental, social and economic impacts associated with implementing these measures

e. Selection of the plan that would solve the flood damage problem consistent with Federal and local planning objectives

f. Provision for protection to emergency response and other critical lifeline facilities impacting the general health and welfare of the region, as well as facilities of public congregation such as schools, municipal buildings, etc.

g. Identification of the shared responsibilities of the Federal government and non-Federal sponsor

Study Participants and Coordination

4. The considered plans of protection for the Green Brook Basin have been coordinated with interested agencies at the Federal, state and local levels. As a result of coordination with the U.S. Department of the Interior, Fish and Wildlife Service, the recommended plan incorporates measures to minimize adverse effects on the environment. Corps public meetings, monthly Green Brook Flood Control Commission meetings, the open public comment period on the Draft Report, and many informal meetings, held with local officials and citizenry, provided local input and preferences that were integrated into the development and selection of the recommended plan.

5. The non-Federal part of the extended study team is led by the project sponsor, the New Jersey Department of Environmental Protection (NJDEP) with support from the Green Brook Flood Control Commission ("Commission"). The Commission was authorized by the State of New Jersey in response to the 1971 flood. The Commission consists of volunteer representatives from the thirteen flood-affected municipalities and the three counties in the basin. Together with NJDEP, the Commission holds monthly meetings open to the public to discuss their goal for a comprehensive flood control solution for the entire basin. The Commission has held meetings on the first Wednesday of the month, ten months per year since the occurrence of the 1971 flood event. Of the two remaining months each year, one is set aside for a special legislative brunch held in May to discuss progress to date and to plan future strategy, while each August is reserved for a special memorial service in honor of the six lives lost in the 1973 flood.

6. The founder and chairman of the Commission, The Hon. Vernon A. Noble, publishes a newsletter regularly. A typical newsletter, dated September 1995, is included in Appendix A, Public Involvement and Pertinent Correspondence. This particular newsletter encapsulates the Commission's vision of "protection for all the people in the Green Brook Basin."

Format of Report

7. This General Reevaluation Report is accompanied by a Final Supplemental Environmental Impact Statement (FSEIS). Appendix A, “Public Involvement and Pertinent Correspondence,” documents the coordination effort with the local sponsor and the citizens of the flood affected municipalities. The General Reevaluation Report summarizes many detailed technical investigations. Technical support documents were prepared to describe the detailed technical studies conducted and were used for quality control and quality assurance. The following support documents are available at the office of the District Engineer:

Support Document A: Quality Assurance/Quality Control Review Plan

Support Document B: Plan Formulation

Support Document C: Economics & Problem Identification

Support Document D: Environmental

Support Document E: Real Estate

Support Document F: Hydrology

Support Document G: Hydraulics

Support Document H: Interior Drainage

Support Document I: Geotechnical

Support Document J: Structural

Support Document K: Cost Estimates

Support Document L: Electrical

8. The remaining sections of this report detail the development and analysis of the NED plan, the recommended plan, as well as the steps required for project implementation. The initial three sections are the ***Basin Description***, which presents physical, environmental and social conditions, followed by a review of the ***Project and Study History*** and a brief ***Problem Description***. The planning framework is then described in progressively greater detail, starting with a section on ***Planning Background*** which identifies general policies, guidelines, and regulations which are common to the assessment of any plan. These general principles are followed by a concise statement of ***Planning Objectives***, and a more specific description of the ***Plan Affirmation Criteria***.

9. After establishing the planning framework, the document describes the sequential analyses undertaken to identify alternatives, to select the nature and magnitude of the facilities, and to ensure that the plan is acceptable to all of the study participants. A general overview of the analysis of alternatives conducted prior to Congressional Authorization is presented under ***Feasibility Investigations***. Review of the project scaling in light of current policies, conditions, and views of NJDEP is described in the section ***Reaffirmation of the Authorized Project.*** After documenting ***Local Coordination*** efforts, which identified plan modifications to minimize social and environmental disruptions, the document provides a detailed description of ***The NED Plan.***

10. The next three sections provide details on the development, design basis, environmental impacts, and economics of the NED Plan. The section ***Design of the NED Plan*** discusses the project design as well as estimates of project costs and residual damages. A brief synopsis of the

NED Plan's impact on the natural and cultural environment is presented in the section titled ***Environmental Analyses of the NED Plan.*** This section also identifies the mitigation requirements and significant areas of concern. The ***Economic Analysis of the NED Plan*** section evaluates the project efficiency through a comparison of benefits and costs. The ***Public Review and Comment*** section describes the public input process to the Draft General Reevaluation Report during the public comment period. The ***Recommended Plan*** section discusses the plan recommended for construction which resulted from the recommendations within the draft general reevaluation report and public input. This section also evaluates the recommended plan efficiency through a comparison of annual benefits and costs. The document then explains the remaining steps for ***Project Implementation*** including the sequence of construction. Following the ***Conclusion*** and ***Recommendation*** sections, are the ***FSEIS*** , ***Support Document D - Environmental***, and ***Appendix A - Public Involvement and Pertinent Correspondence,*** which document the views of the study participants.

11. In an effort to maintain the continuity of the report, technical figures such as plans, profiles and design details, are included after the GRR text. Photographs and illustrations have been included within the text to supplement written descriptions.

12. To fully appreciate the development of the recommended flood protection plan for the Green Brook Sub-basin, a full understanding of the chronology of events including:

- The 1980 Feasibility Study results
- The Congressional authorization of WRDA 1986
- The reaffirmation of the authorized project
- The development of the NED Plan
- The outcome of the public review and comment period
- New York District's recommendation for implementation of portions of the NED Plan and deferral of the recommendation to construct the upper portion of the basin plan at this time.

13. Periodic reference to this section of the report will help to orient the reader and lead to a more clear understanding of the flood protection plan development.

BASIN DESCRIPTION

Overview

14. The flood problems of the Green Brook Basin result from hydrologic features that also dictate the formulation of alternative plans to reduce damages. In addition, the basin contains a variety of environmental resources that could be affected by flood damage reduction works. This section of the report provides descriptions of the physical, social and environmental conditions that exist in the Green Brook Basin.

General

15. The Green Brook Basin lies in central New Jersey within the counties of Somerset, Middlesex and Union and is one of the major tributaries in the Raritan River Basin. Green Brook, which originates in the Watchung Mountains, has a 65-square mile watershed, as seen on Figure 1. The bell shaped basin widens markedly as Green Brook flows southwesterly to its mouth at the Raritan River. The headwaters of Green Brook consist partially of runoff from the Watchung Reservation, undeveloped mountainous woodlands along Blue Brook in the Watchung Reservation, and runoff from the upper reaches of Green Brook itself as it passes through a mixture of residential developments and corporate campuses. As the stream plummets from the slopes of the First Watchung Mountain, the drainage area characteristics quickly change to a broad flat basin, largely suburban and industrialized. Its principal tributaries, from the mouth to the headwaters, are: Ambrose Brook, Bound Brook, Bonygutt Brook, Municipal Brook, Stony Brook and Blue Brook, as well as Cedar Brook, which is a tributary to Bound Brook. In addition, to provide closure around the Borough of Bound Brook, a short reach of the Raritan River and its tributary, Middle Brook, are included in the study. Flood damages in the tri-county basin are quite severe because of encroachments that have taken place. At some locations buildings have been constructed over the tops of various streams and open floodplains have been virtually eliminated. The Green Brook Basin consists of three component areas that each have distinctly different hydraulic characteristics. Shown on Figure 1, these areas are the lower portion of the basin, the upper portion of the basin and the Stony Brook portion of the basin. Data on Green Brook and its tributaries are displayed in Table 1.

TABLE 1

GREEN BROOK AND TRIBUTARIES DESCRIPTION DATA

Stream Name	Length (miles)	Drainage Area (sq. miles)	Average Channel Slope (ft/mile)
Lower Portion of the Basin			
Raritan River*	30.2	1105	2.1
Middle Brook	2.2	17	40.0
Green Brook	15.7	65.2	7.6
Ambrose Brook	9.1	13.6	8.7
Bound Brook	11.4	24.3	4.4
Cedar Brook	2.2	6.8	18.6
Bonygutt Brook	2.8	1.7	9.1
Municipal Brook	2.1	1.2	87.2
Upper Portion of the Basin			
Green Brook	10.7	10.3	18.5
Blue Brook	4.4	3.7	24.0
Stony Brook Portion of the Basin			
Stony Brook	5.3	8.1	88.1

*Slope: Raritan from Middle Brook to mouth of Green Brook.

Climate

16. The climate of the Raritan River Basin is characteristic of the entire Middle Atlantic seaboard. Marked changes of weather are frequent, particularly during the spring and fall. The winters are moderate with moderate snowfall and the summers are moderate with hot, sultry mid-summer weather and frequent thunderstorms. Precipitation also is moderate with about 44 inches falling annually, well distributed throughout the year.

Past Storms

17. Thunderstorms, usually occurring in the summer, are limited in extent and cause local flash flooding on streams. Cyclonic storms, due to transcontinental air mass movement with "highs" and "lows" occurring usually in the winter or early spring, are potential flood producers over large areas because of their widespread extent. Extra-tropical storms cause heavy rains

usually in the summer and fall seasons. West Indies hurricanes of tropical origin proceed northward along the coastal area, accompanied by extremely violent winds and torrential rains of several days duration. Some of the notable storms which have caused flood conditions in the basin occurred in September 1882, February 1886, July 1897, October 1903, March 1936, July 1938, September 1938, August 1955, October 1955, September 1966, May 1968, August 1971, August 1973, July 1975, September 1979 and July 1984.

Geology

18. The Green Brook Basin lies within the Piedmont Physiographic Province, or Triassic Lowlands, in north central New Jersey. The geological forces that have formed the basin include deposition of sediment by ocean waters, volcanic activity, uplift, erosion, and glaciation. The primary consolidated formation in this area is the Triassic shale sandstone and silt stone of the Brunswick formation. This formation has been highly eroded, and covered with glacial deposits in the north, but exhibits residual soil cover in the south. The result is generally low relief- mostly gently rolling hills, with some alluvial-filled lowlands, disrupted by some higher elevation glacial features in the northern portion. The prominent major feature in the area is the crescent-shaped belt of the Watchung Basalt flows that have been exposed by erosion, and are generally known as the First, Second and Third Watchung Mountains. These ridges, extending through the central portion of the province, trend in a northeast-southwest direction. With respect to the project area, Green Brook and several of its tributaries originate on The First Watchung Mountain or in the valleys between First and Second or Second and Third Mountains.

Water Supply and Quality

19. Due to the highly developed nature of the Green Brook Basin, the water quality of the surface waters is degraded in most areas. The State of New Jersey has classified the waters in the basin as one of two types of FW2, or fresh surface waters suitable for the maintenance, migration, and propagation of the natural established biota. In addition, such waters are suitable for primary contact recreation, industrial and agricultural water supply, and any other reasonable uses except public potable water supply. A number of natural and man-made lakes exist in the basin. Most of these lakes are shallow and in advanced stages of eutrophication.

20. No sewage treatment plants or Combined Sewer Overflows (CSO) release effluent to streams in the basin. No known point sources of pollution exist in the basin. Non-Point sources of pollution occurring in the study area are typical of urban or suburban development and include: septic leaching, storm water and urban run-offs contaminated with oils, antifreeze, lawn fertilizer, etc.. Such pollutants are carried downstream through the normal flow of water. Therefore, the quality of the water becomes degraded as these pollutants become concentrated in the downstream portions of the streams in the study area. Runoffs and their associated erosion also contribute to water quality degradation through increased turbidity and sedimentation. The effects of such pollution becomes more evident in the lower basin due to the level of development in the region. The upper basin and Stony Brook basin portions of the study area maintain a higher level of water quality as these areas are not as developed.

21. Vegetative stream cover is relatively consistent throughout the study area. The shading of stream waters by overhanging vegetation helps to maintain a consistent and cooler water temperature. The consistency of the water temperature is critical in the support of the aquatic vegetation and wildlife. Dissolved oxygen is carried more readily by cooler water temperatures. A greater diversity in fish and benthic species can be found in cool water streams as these species are dependent on dissolved oxygen levels for survival. Rapid changes in water temperature also adversely effect aquatic species and water quality. Some portions of Middle Brook, Green Brook (in the lower basin) and Stony Brook have been altered and stream side vegetation has been removed. Sunlight which hits the stream bed and surrounding rocky material sometimes causes rapid increases in water temperature. As a result, the ambient water temperature is greater, the frequency and range of temperature changes in the water temperature have increased, and the dissolved oxygen levels in the waters of the lower basin are lower than the levels found in the upper basin of the Green Brook.

22. NJDEP further classifies the basin waters by their ability to support trout. These ratings are based on dissolved oxygen (DO) content, range of temperature fluctuation in a 24 hour period and concentration of un-ionized ammonia in the stream channel. In the Green Brook Basin; Blue Brook, Middle Brook and portions of Green Brook located below N.J. Route 22 are classified by NJDEP as FW2-NT (Non-Trout). Green Brook waters upstream of N.J. Route 22 are classified as FW2-TM (Trout Maintenance). Trout maintenance waters are capable of supporting

stocked trout but do not have water quality conditions suitable for trout reproduction. These waters may be effected by the addition of a large detention structure.

23. Local water supply is obtained from wells. Therefore, there will be no impact on public water supply sources with respect to the project.

Air Quality and Noise Environment

24. The project area is predominantly located within a populated urban and suburban setting which contains sections of several major highways. These roads are a part of the most heavily traveled commuting and transportation corridor within the United States. The volume of traffic using this network impacts significantly on the air quality and noise level of the project area.

25. Data going back 20 - 25 years show that violations of the Federal And N.J. State air quality standards are not uncommon in the vicinity of the project area. NJDEP reports that the 1995 data is part of a 5 year improvement trend.

26. An Air Quality monitoring program was conducted in the Watchung Valley, Union County, New Jersey to determine existing (1974, 1975) background levels of carbon monoxide (CO) and associated meteorological conditions. The monitoring consisted of continuous measurements of wind direction, wind speed and CO concentrations. It should be noted that the National Ambient Air Quality Standard for carbon monoxide for one hour (35 parts per million} was not exceeded at any of the locations analyzed, while the 8-hour standard of 9 parts per million was exceeded at all locations. The highest concentration of the points analyzed occurred in the vicinity of the intersection of Park Avenue with Route U.S. 22, where the carbon monoxide levels are 28 parts per million and 17 parts per million for the 1-hour and 8-hour averaging periods, respectively.

27. In 1994 and 1995, NJDEP studied air quality at one station in the project area and two stations in the vicinity of the project. The station at Plainfield (within the project area) measured ozone and nitric acid. The stations at Elizabeth and New Brunswick (within five miles of project area) measured sulfur dioxide, total suspended particulates, inhalable particulates, carbon monoxide (CO) and lead .

28. In 1994 the Plainfield station measured a violation of the Federal and State primary ozone standard twice. It measured violations of the N.J. secondary ozone standard 85 times. In 1994 the Elizabeth station measured violations of the State secondary ozone standard 149 times and violations of the Federal and State primary standard for Carbon Monoxide (CO) twice. In 1994 the New Brunswick station measured violations of the Federal and State primary ozone standard four times and violations of the secondary N.J. standards for total suspended particulates three times.

29. The noise environment is similarly degraded by the presence of extensive road and rail networks throughout the basin. Five major highways and a busy commuter rail line cross through and serve the project area. The existing ambient noise level would mask all other sources of noise on a basin- wide basis.

30. The above data indicates that the current ambient air quality and noise environment are already impacted by traffic and development. Against these existing factors, the additional impacts caused by project construction activities would not be significant on a basin wide basis.

Flora and Fauna

31. Because of the highly developed nature of the Green Brook sub-basin, wildlife resources are limited, with the most diverse areas concentrated in the upper reaches of the basin where development is not as intensive. The main vegetative associations in the basin are the Mixed Oak forest and the Hemlock-Mixed Hardwoods forest. Both forest types are found in the Watchung Reservation. Scattered remnants of the Mixed Oak forest can still be found on the lowland plain, but the bulk has been destroyed by development. The floodplains are vegetated by such species as willow, sycamore, box elder, red maple, silver maple, swamp white oak, elm, ash, black gum, spicebush, witch hazel, viburnum, arrowwood, and others. Marshes and bogs are dominated by common reed, cattail, and sedges.

32. The United States Fish and Wildlife Service's Planning Aid Report (1990) prepared a list of vegetation occurring in the Green Brook Sub-basin. This vegetation list is presented in the Environmental Support Document. The main vegetative associations in the basin are the Mixed Oak forest and the Hemlock-Mixed Hardwoods forest. Both forest types are found in the

Watchung Reservation. Scattered remnants of the Mixed Oak forest can still be found on the lowland plain, but most has been destroyed by development.

33. Wetlands are found throughout the project area. The predominant type of wetlands found within the project are forested wetlands occurring adjacent to stream corridors. Vegetation dominating these areas include red maple, pin oak, elm, and green ash trees. Wetland vegetation in the upper reaches of Green Brook and Blue Brook includes a well-developed under story characterized by arrowwood and elm. Some isolated pockets of emergent marsh habitat can be found in the Blue Brook, Ambrose Brook, Stony Brook and Bound Brook drainage. Most of these areas are found within parks or man-made ponds and pools. Common reed and cattail plants are common in these areas. The project is expected to impact approximately 108 acres of wetlands habitat and 29 acres of stream habitat. Mitigation for wetlands and other wildlife habitats is detailed in the Environmental Support Document.

34. Extensive alteration of the floodplain has occurred due to development. The floodplains left undisturbed are primarily described as stream side forest. Such areas are characterized by vegetative species such as willow, sycamore, box elder, red maple, silver maple, pin oak, elm, ash, black gum, spice bush, witch hazel and arrowwood. A few marsh habitats located along Blue Brook, Bound Brook and Ambrose Brook are affected by the project. Such areas are dominated by common reed, cattail and sedges.

35. Fish habitat in the sub-basin is degraded as a result of urban development, existing stream modifications and pollution. In general, the upper portions of the basin including Blue Brook and the upper portions of the Green Brook support a wider variety of habitat than the middle and lower potions of the Basin. This greater diversity is due to the quality of water in these streams. Several streams within the project area have been surveyed for fish species by the EPA (1994), the State of New Jersey (1996), and the U.S. Fish and Wildlife Service (1989). The State of New Jersey and EPA surveys were undertaken to determine the water quality value of selected streams with respect to the aquatic community. The USFWS surveys were undertaken only to identify potential species occurring in the sampling area. The list of species identified as a result of these surveys is presented in Appendix F of the Environmental Impact Statement (EIS) accompanying this report. The upper portions of the Green Brook are stocked with trout by the

State of New Jersey Division of Fish, Game and Wildlife. However, no trout species were identified at any of the field surveys. All surveys were conducted with pulsed direct current output from electrofishing gear. Middle Brook, located in the lower basin, was also sampled for benthic invertebrates by the EPA (1994).

36. Middle Brook was sampled for fish species and benthic species by the EPA in 1994. The fish sampling station was located adjacent to Chimney Rock, north of U.S. Route 22. This station is located outside the project area. As a result of the sampling, the EPA rated the water quality as "good" for fish ecosystems. The benthic survey was conducted twice, once at Chimney Rock (same location as fish sampling station) and once within the project area, near High Street in Bound Brook. As a result of the benthic survey, the EPA deemed the Middle Brook as "moderately impacted" due to lack of diversity in benthic species and alteration of natural stream conditions. The EPA further states in the Stream Bioassessment report that the benthic rating of "moderately impacted" should be used to describe the conditions in Middle Brook as the benthic community is a more sensitive indicator of water quality conditions. Fish species identified at Middle Brook include: American eel, white sucker, longnose dace and blacknose dace. Benthic species identified during the survey include mayfly, dragonfly and caddis fly larvae.

37. The lower basin was also surveyed by the State of New Jersey (1996) in Green Brook, near Green Brook Road, downstream of the Green Brook/Bound Brook confluence. The State of New Jersey deemed the water quality as "fair" based on diversity of fish species and condition of in-stream habitats. Species identified during the State's survey include: eastern silvery minnow, American eel and tesselated darter.

38. Stony Brook was sampled for fish species by the EPA in North Plainfield, within the project area. The EPA (1994) rated Stony Brook water quality as "good" based on the fish survey. The most common fish species identified during the survey include American eel, tesselated darter, longnose dace and white sucker.

39. The U.S. Fish and Wildlife Service, in conjunction with the Corps of Engineers, sampled Blue Brook in the upper basin above Seeley's Pond, below the site of the proposed retention structure. Species most frequently identified during this survey included American eel, white sucker, tesselated darter, and blacknose dace. A yellow bullhead was also identified at this

location. Of all the surveys conducted in the basin, this was the only recorded occurrence of this species.

40. Several types of small animals inhabit the basin and are plentiful in Watchung Reservation. Wildlife species identified as potentially occurring within the project are have been identified in a Planning Aid Report developed by the USFWS in 1990. The results of this report appear in Appendix F of the SEIS.

41. Avian species are common throughout the basin. Song birds such as robins, blue jays, crows, sparrows and starlings are common throughout the project area. The upper portions of Green Brook (above U.S. route 22) and Blue Brook provide habitat for several species of game birds and a wider variety of songbirds including ring-necked pheasant, bobwhite, wrens, catbirds and thrushes. Waterfowl production is extremely limited due to the lack of suitable habitat. However, isolated marsh areas on Bound Brook and Ambrose Brook as well as secluded portions of Stony Brook, Green Brook, and Blue Brook in the Watchung Mountains do provide nesting habitat for Canadian geese, mallard and some domestic species of duck.

42. Various amphibians and reptiles can be found in the study area, however, the variety of species is limited due to lack of existing habitat. Bull frogs, painted turtles and snapping turtles are expected to occur in the isolated marsh areas. Poor water quality and extensive development have limited the occurrence of these species in Stony Brook and the lower basin to man-made pools and ponds.

43. Mammalian species inhabiting the Green Brook sub-basin include raccoon, squirrel, woodchuck, and rabbit. Muskrats potentially occur within the Bound Brook in South Plainfield, and the upper reaches of Green Brook and Blue Brook. Deer, opossum and chipmunk are common in forested areas located in the Watchung Mountains, north of U.S. Route 22.

44. **Endangered and Threatened Species.** The State of New Jersey lists several species of concern, some of which have been recorded in the study area. Appendix F depicts the results of a New Jersey Natural Heritage Database search for species of concern potentially occurring within the project area. This investigation took place in 1988. Such species include the endangered bog turtle, blue-spotted salamander, bald eagle, peregrine falcon, cooper's hawk, and

the threatened wood turtle, longtail salamander, southern gray tree frog, merlin, re-headed woodpecker, red shouldered hawk and sharp shinned hawk. The cooper's hawk has been known to nest in the Watchung Reservation. The United States Fish and Wildlife Service investigation in the project area identified two bog turtles near Lake Surprise during a field investigation in 1977. As Lake Surprise is not affected by the proposed project, habitat for this species will not be affected. More recent information (Zappalorti, 1989) suggests that the turtle has been extirpated due to habitat degradation.

45. Recent coordination with NJDEP provides more current information than reflected in the State Database report of 1988. The state has identified potential impacts to one state threatened species and one state endangered species. Sufficient habitat to support the wood turtle exists on the Blue Brook near the site of the proposed Sky Top structure and on the Stony Brook near areas of proposed channelization. During the public involvement process, residents indicated that wood turtles can be found on Stony Brook just south of the proposed channelization. The Corps will continue to coordinate with the NJDEP to determine the extent of the impact caused by the project on the wood turtle. Additional mitigation required to off-set wood turtle impacts will be paid for by the local sponsor as the wood turtle is not a federally protected species.

46. As a result of coordination efforts undertaken during the release of the Draft Supplemental Environmental Impact Statement (DSEIS), the Corps has learned that the State and individuals have identified the bog turtle as occurring on the Blue Brook near the Sky Top detention structure. As with the wood turtle, the Corps will continue to coordinate with NJDEP to determine the potential impacts to this species. Any specialized mitigation required for the bog turtle will be paid for by the local sponsor as the turtle is a state protected species.

47. **Federally Endangered Species**. Although the southern bald eagle, the goshawk and the peregrine falcon occasionally appear in the Green Brook Basin as transients, there are no known species of either plants or animals that are listed as endangered by the Department of the Interior for which the Basin provides critical habitat. The bog turtle, however, is a candidate species for listing on the Federal Endangered Species List. If the bog turtle is declared a federally endangered species prior to construction in the Upper Basin, then additional coordination with the USFWS will be initiated. Such coordination could involve endangered species surveys

and the possibility of incidental take permits. Any additional mitigation required for this turtle under the Endangered Species Act would be borne by the Corps and the local sponsor. Such mitigation costs are not reflected in this report.

Recreation and Natural Resources

48. Recreational facilities in the basin are extensive, consisting of picnicking, swimming, fishing, golf, ice skating, bird watching, and open park areas. The recreational facilities that may be affected by the proposed project are the Watchung Reservation, Green Brook Park, Green Acres Park, Spring Lake Park, and several unnamed open park areas and ball fields. The most used facility in the basin is undoubtedly the Watchung Reservation which attracts almost a million visitors annually for hiking, horseback riding, nature walks, and bird watching. The Watchung Reservation provides opportunities for wildlife observation. A series of hiking trails and horseback riding paths are maintained in the Reservation by the Union County Parks Department. Green Brook Park and Green Acres Park are also extensively utilized.

49. **Hunting and Fishing**. Sport hunting opportunities are nonexistent within the project area. The Watchung Mountains do support a deer herd and avian game species as described above. Hunting in these mountains is prohibited. The State of New Jersey stocks the upper reaches of Green Brook and Stony Brook with trout for recreational fishing. Little if any fishing takes place in the lower basin because of degraded water quality.

50. **Special Resources**. A unique feature located on Blue Brook, one of the major tributaries of Green Brook, is the Watchung Reservation. This tract of land of nearly 2,000 acres includes portions of the First and Second Watchung Mountains and the Blue Brook Valley. The reservation provides the greatest extent and variety of wildlife habitat in the study area and since it is surrounded by development, it is a limited resource. From a recreational standpoint, the area provides unique beauty and diversity for nearly one million visitors yearly. Roadways, bridle paths, and foot paths have been developed to make the Reservation accessible and useable by people for a variety of activities. A large detention basin is proposed to be constructed within the Watchung Reservation. Species and resources affected by this basin will primarily suffer from the fill material associated with the construction of the structure. Temporary pools created by this structure will cause some siltation and debris racks along the edges of the temporary pools. Some

vegetative change may take place. However, with careful mitigation and planting techniques, wildlife habitat can be restored to the areas, although it is unlikely that the quality of wildlife habitat would be restored to its present state. More detail on habitat mitigation is presented in the Environmental Support Document.

51. Several municipal parks such as the Green Brook Park (Cities of Plainfield and North Plainfield) and Spring Lake Park (South Plainfield) will be affected by the project. The construction of levees within these areas will result in a change in aesthetic quality and natural resources located in these parks. Recreational impacts can be mitigated for to some extent through the development of bike paths or jogging trails on top of levees.

52. A mosaic of shallow and deeper water, Seeley's Pond is being affected by eutrophication and siltation. As part of the basin mitigation plan, the Corps and local authorities are considering restoration of some of the deep water and emergent habitats. This would be done through dredging and replanting. The Pond will not be adversely impacted by the proposed project.

53. Several springs, known as the Blue Brook Spring Habitats, are located within the "gorge" area along Blue Brook. These springs support micro ecologies which could be lost if inundated by flood waters. Current plans do not affect this resource.

54. The project was reviewed by Department of Agriculture, Natural Resources Conservation Service for impacts on prime and unique farmland. There was a finding of no impact on farmland

55. **Future Impacts**. The basin is almost totally developed in the vicinity of streams thus the existing stream side open areas will be more extensively utilized as the population of the less developed portions of the basin grows.

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PHOTO NO. 1 - BLUE BROOK IN THE WATCHUNG RESERVATION

PHOTO NO. 2 - SPRING LAKE PARK IN PLAINFIELD, N.J.

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Aesthetics

56. Because of the extensive development along the streambanks in the lower portion of the basin, there are no outstanding aesthetic or scenic features. The Stony Brook gorge is partially developed but still scenic. Both Green Acres Park and Green Brook Park offer opportunities for aesthetic enjoyment. The Green Brook gorge is largely undeveloped and very scenic. The major aesthetic resource in the basin is the Watchung Reservation, which attracts nearly one million visitors yearly not only for its recreational opportunities but also because of the aesthetic enjoyment it affords.

Cultural Resources

57. Cultural resource surveys and investigations have been undertaken to identify historic properties in the study area, evaluate their eligibility for listing on the National Register of Historic Places (NRHP), and assess whether the proposed project will impact NRHP eligible properties. Literature review and archaeological research indicate that there was at one time considerable evidence of prehistoric occupation in the Green Brook sub-basin. Similarly, historical research documents the basin's rich local history, highlighted by a major role during the Revolutionary War. Studies undertaken for the Green Brook Flood Control Project have located several archaeological sites, with evidence of Native American occupation and the remains of historic structures, as well as standing structures eligible for listing on the NRHP. Details on cultural resources investigations and their findings are presented in the FSEIS.

Human Resources

58. The historical population for the floodprone communities within the basin flood areas is shown in Table 2. The Green Brook Basin is considered urbanized with an average density of the floodplain communities of approximately 2,450 persons per square mile (1990). Since growing rapidly between 1960 and 1970, the population has remained relatively stable from 1970 to the present.

TABLE 2
GREEN BROOK FLOOD CONTROL
POPULATION SUMMARY DATA BY MUNICIPALITY

Community	Area (sq.mi.)	Resident Population 1960-1990				Population Density 1960-1990 (Pop./Sq. Mi)			
		1960	1970	1980	1990	1960	1970	1980	1990
Middlesex County									
Dunellen Borough	1.04	6,840	7,072	6,593	6,528	6,576.9	6,800.0	6,339.4	6,276.9
Middlesex Borough	3.50	10,520	15,038	13,480	13,055	3,005.7	4,296.6	3,851.4	3,730.0
South Plainfield Borough	8.36	17,879	21,142	20,512	20,489	2,138.6	2,528.9	2,453.6	2,450.8
Piscataway Township	18.78	19,890	36,418	42,223	47,089	1,058.1	1,939.2	2,248.3	2,507.4
Subtotal Middlesex Communities	29.68	55,129	79,670	82,808	87,161	1,857.3	2,684.3	2,790.0	2,936.7
Somerset County									
Bound Brook Borough	1.70	10,263	10,450	9,710	9,487	6,037.1	6,147.1	5,711.8	5,580.6
Bridgewater Township	32.44	15,789	30,235	29,175	32,500	486.7	932.0	899.4	1,022.1
Green Brook Township	4.58	3,622	4,302	4,640	4,460	790.8	939.3	1,013.1	973.8
North Plainfield Borough	2.79	6,993	21,796	19,108	18,820	6,090.7	7,812.2	6,848.7	6,745.5
Watchung Borough	6.00	3,312	4,750	5,290	5,110	552.0	791.7	881.7	851.7
Subtotal Somerset Communities	47.51	49,979	71,533	67,923	70,377	1,052.0	1,505.6	1,429.7	1,481.3
Union County									
Berkeley Heights Township	6.26	8,721	13,078	12,549	11,980	1,393.1	2,089.1	2,044.6	1,913.7
Fanwood Borough	1.34	7,963	8,920	7,767	7,115	5,942.5	6,656.7	5,796.3	5,309.7
Plainfield City	6.04	45,330	46,862	45,555	46,567	7,505.0	7,758.6	7,542.2	7,709.8
Scotch Plains Township	9.07	18,491	22,279	20,774	21,160	2,038.7	2,456.3	2,290.4	2,333.0
Subtotal Union Communities	22.71	80,505	91,139	86,645	86,822	3,544.9	4,013.2	3,815.3	3,823.1
Total Project Area Communities	99.90	185,613	242,342	237,376	244,360	1,858.0	2,425.8	2,376.1	2,446.0

Source: Population from U.S. Decennial Census.
Area Square Miles based on 1990 Census of Population and Housing.

Land Use

59. The three counties comprising the Green Brook Basin, Middlesex, Somerset and Union, are highly developed. According to the Lower Raritan 208 Study, in 1974, 59.2% of the total land area in the Green Brook Basin was in a developed state. The greatest area is devoted to housing, primarily single family. Other categories that utilize large amount of land are industrial and commercial enterprises . Due to the historical development patterns of the basin, the areas closest to the streams are the most highly developed. The bulk of undeveloped land is to the southeast of Green Brook in South Plainfield and Piscataway, and to the northwest in the Watchung Mountains. Within the floodplains, except for a few isolated plots, such as Green Brook Park and the Watchung Reservation, the majority of the land is highly developed.

Transportation

60. The Green Brook Basin is served by a network of transportation corridors. The major roads in and around the basin are I-78, I-287, U.S. 22, N.J. 18 and N.J. 28. In addition, the Garden State Parkway, the New Jersey Turnpike and U.S. 1-9 are located a short distance outside the basin. Several railroads provide both passenger and freight service in the basin. Among them are the former Central Railroad of New Jersey, now the property of New Jersey Transit, and the former Port Reading and Lehigh Valley lines, both of which are currently part of the Conrail system.

61. There are no major airports located within the basin. However, Newark International Airport is located within 15 miles of the basin and is easily accessible to the businesses and residents of the basin through mass transportation systems and personal vehicles.

Future Conditions Without Flood Protection

62. In order to develop plans which would be responsive to both the immediate and future needs of the flood-prone communities and the overall goals of the region, future conditions were projected based on available planning data and information obtained from various Federal, state and local agencies. The most probable future for the flood-prone areas within the basin is a

basically stable level of development for the floodplain and a continuation of the present land use pattern.

63. The projection of a stable development base is valid because residential, commercial and industrial uses generally require specialized structures which have existed in the project area for a significant period. Desirable features include low transportation costs caused by easy access and close proximity to New York City. Significant changes in major infrastructure features of the project area are not anticipated. In addition, since floodplain regulations minimize new construction in areas inundated by the 100-year flood, substantial new residential, commercial and industrial development in the few remaining open areas within the floodplain is not likely. The most probable future condition is expected to be a continuation of a stable, almost fully developed floodplain with relatively few new developments. Continued development in upland areas, such as the Watchung Mountains, will contribute to an increase in future flood risk.

64. Without flood protection, the basin will continue to be susceptible to severe flooding, prone to substantial threats to the local and national economy and the general safety and well-being of the citizens living and working in the floodplain communities.

STUDY AND PROJECT HISTORY

Overview

65. Flood problems in the Green Brook Basin have been studied extensively. Numerous reports have been produced with a view toward providing flood protection as well as to accommodating existing land uses within the basin. The culmination of these studies was the August 1980 Feasibility Report that resulted in the project authorization in 1986 and the initiation of preconstruction engineering and design. This section of the report describes each of the earlier Corps' reports, in chronological order, and provides a listing of other flood studies conducted which document the damages due to past storms.

General

66. The Green Brook Flood Control Project is the result of efforts over the past two decades by the Corps of Engineers, other Federal agencies, state and local agencies, civic organizations and the general public. A summary of the significant events is provided below. A project history flow diagram is also provided to give an overview as to how the plan has evolved over the years (see Diagram 1).

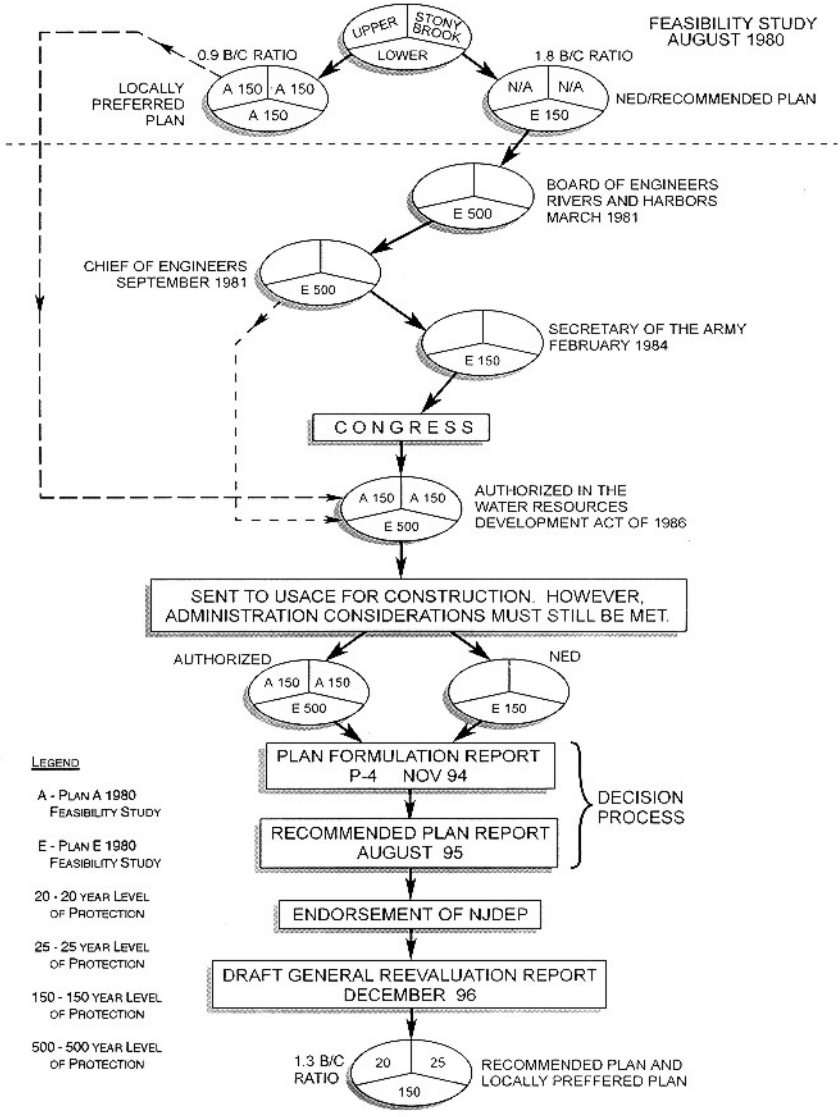
Small Project Reports

67. In 1968 a reconnaissance investigation was conducted, under the Corps of Engineers Continuing Authority Program for small projects, for Ambrose, Bound and Bonygutt Brooks. The resulting report recommended further study at all three locations. Detailed project reports concluded that individual flood protection projects were not economically feasible at any of the locations. Subsequently, record floods occurred in 1971 and again in 1973, causing catastrophic damage throughout the basin. As a result of the devastating events, the need for basin-wide studies of the entire Green Brook Basin was apparent. These efforts obviated further consideration of the aforementioned streams separate from the overall Green Brook flood problem.

Feasibility Report

68. The Corps of Engineers, North Atlantic Division issued the *Feasibility Report for Flood Control, Green Brook Sub-basin*, dated August 1980. Many of its basic principles remain valid.

DIAGRAM 1: Green Brook Study History



and are reflected in this report. As shown on Figure 1, the Feasibility Report divided the Green Brook Basin into three plan formulation areas; the lower, upper and Stony Brook portions of the basin. The formulation areas are based on distinct hydraulic characteristics, problems and needs in each area. The plan recommended in the 1980 Feasibility Report, designated as Plan E, as shown on Figure 2, consisted of a system of levees and floodwalls to provide protection against a 150-year flood in the lower portion of the Green Brook Basin only. Plan E was recommended since it was most responsive to national economic development. A more comprehensive, basin-wide solution, known as Plan A (Figure 3), would have also extended 150-year protection to the upper and Stony Brook portions of the basin. Plan A was preferred by the local sponsor but was not recommended since it was not responsive to national economic development objectives.

69. The Board of Engineers for Rivers and Harbors (BERH) reviewed the North Atlantic Division's report and issued its report on 16 March 1981 (see Appendix A --Attachment D), in which they endorsed all plan formulation decisions in the 1980 Feasibility Report. However, the BERH also stated that "the recommended 150-year level of protection is inadequate for this highly urbanized floodplain." To avoid catastrophic consequences of levee overtopping, the BERH recommended protection to the 500-year level. The Chief of Engineers Report , dated 4 September 1981(Appendix A-Attachment D), concurred with the BERH as to the 500-year level of protection. On February 1984, the Secretary of the Army expressed the administration's views in his letter transmitting the report to Congress (Appendix A-Attachment D). He stated that there was insufficient justification for deviating from the plan which maximizes net national economic benefits, and that Plan E as recommended in the August 1980 report should be authorized.

Preconstruction Engineering and Design

70. The Water Resources Development Act of 1986 authorized construction of a project, providing protection in all three portions of the Green Brook Basin. On the basis of this authorization, funds were budgeted and appropriated for preconstruction engineering and design. Surveying, mapping and other studies necessary to provide the basis for actual construction commenced toward the end of 1986. However, delays were incurred because of the perceived conflict between authorization language and national economic development considerations. This

apparent conflict between the needs and desires of the non-Federal sponsor and national economic development affected the quest for a comprehensive implementable plan.

General Reevaluation Study

71. It was decided to provide a decision-making vehicle for identifying a plan that would respond to Federal and local objectives in response to the Water Resources Development Act of 1986. A general reevaluation study was initiated in January 1994 to review prior planning decisions to resolve issues of plan selection. This effort was not a reformulation but rather a refinement and re-scaling of plausible alternatives developed during the feasibility investigation, achieved by updating the analysis to account for changes in development, environmental constraints and planning guidance. The intent of this effort was to reaffirm the viability of the project elements and, if possible, resolve all the conflicts between the national economic development considerations and the needs and desires of the non-Federal sponsor. This report is the product of that study, the results of which are detailed in subsequent sections.

72. Significant documents prepared during the conduct of this General Reevaluation Study were the Project Management Plan approved in August 1994, the P-4 Plan Formulation Document dated November 1994 and the Recommended Plan Report dated August 1995. All these reports were done in partnership with all interested parties. The New Jersey Department of Environmental Protection endorsed the Plan Formulation process, all of these reports, and the New York District's Recommended Plan in their letter of September 13, 1995 (see Appendix A).

Other Studies

73. Special post-flood reports to document the damages caused by significant floods in the basin have been issued as follows, all by the Corps of Engineers except as noted:

a. The Floods of May 1968 (May 1970)
b. Floods of August and September 1971 by the State of New Jersey
c. The Floods of August, September 1971 (Hurricane Doria) (March 1975)
d. The Flood of June 1972 (Hurricane Agnes) (April 1975)
e. The Flood of August 1973 (April 1975)

74. Flood hazard reports have been issued by the NJDEP as follows:

a. Green Brook (May 1972)
b. Bound Brook and Cedar Brook (February 1973)

c. Stony Brook and East Branch Stony Brook (January 1973)
d. Raritan River (March 1972)

75. Under the National Flood Insurance Program (NFIP) flood insurance studies have been performed for all the flood-prone communities in the Green Brook Basin.

PROBLEM DESCRIPTION

Overview

76. The flood problem must be understood in terms of the physical characteristics of its three component portions of the basin. Historical and frequent storm events have resulted in loss of life and significant economic damage.

General

77. This section describes the flooding problems addressed by the plans under consideration. It discusses the problem in terms of its causes and effects.

Causes of Flooding

78. The Green Brook Basin has been subject to frequently severe and sometimes devastating flooding from storms ranging from local thunderstorms to tropical storms. The flooding problems within the basin are as varied and unique as the storms causing the floods.

Upper Portion of the Basin

79. Runoff from the steep slopes of the First and Second Watchung Mountains is funneled into Green and Blue Brooks. At the confluence with Blue Brook, Green Brook flows through a diagonal gorge in the First Watchung Mountains. At the base of the gorge, Green Brook normally continues to flow southwestward along the foot of the Watchung Mountains. Under flood conditions, however, flows far exceed the capacity of the Green Brook Channel and overtop the divide between the Cedar Brook and Green Brook watersheds. These flows spread eastward

PHOTO NO. 3 HISTORIC FLOODING, CITY OF PLAINFIELD.

across the flat topography of Scotch Plains Township and the City of Plainfield, (see Photo 3), inundating homes, industries and commercial centers before eventually returning to Green Brook via the Cedar Brook and Bound Brook tributaries. While much of the flooding associated with the diverted flow is relatively shallow, local depressions pond far deeper and pose a significant safety hazard, a condition particularly prevalent near railroad underpasses. Flood damages in this area tend to be relatively severe in comparison to depth due to numerous businesses with at-grade entrances.

Stony Brook Portion of the Basin

80. The origin of the flood problem in the Stony Brook portion of the basin also lies in the steep slopes of the Watchung Mountains. Unlike Green Brook, however, Stony Brook flows through a gorge oriented exactly perpendicular to the mountain. High velocity flows concentrated in this narrow canyon explode into the communities of Watchung and North Plainfield causing the most ferocious and dangerous flooding in the Green Brook Basin (see Photo 4). This area was the site of five deaths and numerous injuries during the August, 1973 storm. Closer to its mouth, Stony Brook turns southwest and becomes comparatively slow moving with a wide, flat floodplain.

PHOTO NO. 4 HISTORIC FLOODING, STONY BROOK

81. Lower Portion of the Basin

82. Wide, flat floodplains are also typical of the lower portion of the Green Brook Basin, where Green Brook, Bound Brook and tributaries periodically overflow their banks causing extensive inundation of homes, businesses and industries. Near the mouth of the Green Brook Basin, where it joins the Raritan River, some of the most severe flooding in the lower portion of the basin occurs in downtown Bound Brook (see Photo 5). Flooding in this area tends to persist longer than in other portions of the basin as successive peak flows occur on Middle Brook, Green Brook, Ambrose Brook and finally the Raritan River.

Damage Centers

PHOTO NO. 5 HISTORIC FLOODING, LOWER BASIN

83. Flood damages along Green Brook are centered largely in the boroughs of Bound Brook and Middlesex, Green Brook Township, the City of Plainfield, the Borough of North Plainfield and Scotch Plains Township with lesser amounts of damage occurring in Bridgewater Township and the boroughs of Dunellen and Watchung. Losses along Ambrose Brook take place at Piscataway Township and the Borough of Middlesex. Along Bound Brook damages are centered in the Borough of Middlesex, Piscataway Township and the Borough of South Plainfield. Flood damages along Cedar Brook occur in Scotch Plains Township, the City of Plainfield and the Borough of South Plainfield, and to a lesser extent the Borough of Fanwood. Losses along Bonygutt Brook occur at the boroughs of Dunellen and Middlesex. Within the study reach, flooding from the Raritan River and Middle Brook also severely damage the Borough of Bound Brook. Flood damages in the basin affect a wide range of land use, which varies from open, undeveloped lands to highly urbanized communities. As a result, flood damage is incurred because of physical damage to property, loss of commercial, industrial and public activity and impaired vehicular traffic. In addition, damages affect the economy and general well-being of the flooded areas.

Past Flood Damage

84. For the greatest portion of this basin, the most damaging flood of record resulted from the August 2, 1973 storm. Although the entire basin was affected by this storm, Green Brook and Stony Brook were hit the hardest. Flooding was so extensive that the Governor requested and received a "Major Disaster" declaration from the President. A search of record history of the basin shows that, in addition to the August 1973 flood of record, nine major floods have occurred: September 1882, February 1896, July 1897; October 8-9, 1903, July 26, 1916, July 23, 1938, May 29, 1968, August 28, 1971, and July 1975. The August 1971 flood was severe enough for the

President to declare the entire State of New Jersey a disaster area. In fact, for reaches affected by the Raritan River backwater, the August 1971 flood was the largest recent flood. Prior to the installation of the Bound Brook gage on the Raritan River in 1903, data on major flood events were based on record searches and recorded high water marks. Subsequent to 1973, significant floods occurred in July 1975, September 1979 and July 1984 but did not approach the magnitude of the August 1973 event.

85. Six deaths were attributed to the flood of August 2, 1973. These deaths occurred in North Plainfield and Plainfield. Thirty-four persons were also injured and estimates indicate that more than 1000 people were evacuated from their residences.

Damage Estimates

86. Project feasibility is based on the prevention of flood damages expected to occur without the project. Damage estimates are categorized as; (1) physical damages to structures and their contents, (2) both physical and non-physical damages to exterior items such as lawns, landscaping, cars, and pools, and (3) personal emergency response costs such as for evacuation, additional housing, initial cleanup and reoccupation as well as the costs of public emergency response. The various streams were subdivided into reaches based on like hydraulic characteristics, level of development and municipal boundaries. Based on field inspections of more than 10,500 structures within the approximate Standard Project Floodplain, the total value of development within the study area is estimated to be nearly $3 billion. The median single family residence is valued at $149,000, while the median non-residential structure is valued at $270,000. Table 3 displays the average annual flood damages in the Green Brook Basin, which are estimated at $40,250,000. Table 4 summarizes the expected damages from various storms including a recurrence of the floods of August 1971 and August 1973. Descriptions of historic flooding in the affected areas are provided in Support Document C, Economics and Problem Identification, available at the Office of the District Engineer.

TABLE 3
SUMMARY OF DEVELOPMENT AND AVERAGE ANNUAL DAMAGES

Area	Number of Residential Structures	Number of Non-Residential Structures	Structure Value		Average Annual Damage
			Residential	Non-Residential	
Lower Portion of the Basin	5,271	724	$830,256,000	$549,967,000	$22,528,000
Upper Portion of the Basin	3,460	468	$927,388,000	$536,190,000	$14,876,000
Stony Brook Portion of the Basin	503	111	$96,142,000	$55,182,000	$1,670,000
Total	9,234	1,303	$1,853,786,000	$1,141,339,000	$39,074,000

TABLE 4
SUMMARY OF EXPECTED DAMAGES WITHIN DETAILED PROJECT AREA
(April 1996 Price Level)

Town	Estimated Damage from		Expected Damage from		
	1971	1973	50 yr	100 yr	150 yr
BOUND BROOK	$87,000,000	$36,100,000	$80,000,000	$97,000,000	$106,500,000
DUNELLEN	$2,000,000	$5,600,000	$2,700,000	$3,900,000	$5,600,000
GREEN BROOK	$2,800,000	$11,000,000	$5,300,000	$8,900,000	$15,000,000
MIDDLESEX	$21,000,000	$34,300,000	$29,800,000	$61,000,000	$80,700,000
N. PLAINFIELD	$9,700,000	$26,900,000	$11,200,000	$16,500,000	$19,800,000
PISCATAWAY	$800,000	$1,200,000	$1,100,000	$1,600,000	$3,300,000
PLAINFIELD	$95,500,000	$202,800,000	$69,700,000	$114,200,000	$178,300,000
SCOTCH PLAINS	$77,200,000	$141,900,000	$38,500,000	$78,100,000	$111,200,000
S. PLAINFIELD	$7,000,000	$10,400,000	$6,900,000	$10,000,000	$13,100,000
WATCHUNG	$1,000,000	$12,500,000	$3,100,000	$6,900,000	$10,100,000

Note: 1) Only limited flood damage in those portions of Berkeley Heights, Warren and Bridgewater which are in the study area.

2) Expected damages presented reflect only those portions of the towns which are located in the study area. Overall town damages may be significantly higher.

PLANNING BACKGROUND

Overview

87. All flood damage reduction alternatives must reflect consideration of certain common factors. Generally, these factors result from the interplay between the specific conditions in the basin's streams and adjacent areas, and the Federal policies and regulations that govern the planning and design of water resources projects.

General

88. The affirmation and updating of the authorized project were conducted in accordance with current Federal water resource planning procedures. This requires a balanced approach to engineering, environmental and economic considerations while responding to the needs and desires of the non-Federal sponsor. The relevant components of the planning background for the Green Brook reevaluation are discussed below. All of these factors are significant in the logical plan selection process discussed in subsequent sections.

Federal Planning Requirements

89. **Consistency With Project Authorization**. Implementation of any plan that exceeds the scope of the project authorized by the Water Resources Development Act of 1986 would require new authorization.

90. **Principles and Guidelines**. This report is consistent with the national objectives as stated in ER 1110-2-100, Policy and Planning Guidance for Conducting Civil Works Planning Studies and the Principles and Guidelines. In accordance with the Principles and Guidelines, plans must contribute to national economic development (NED) consistent with protecting the nation's environment. Plans to address the needs in the study area must be formulated to reasonably maximize NED benefits while providing a complete, effective, efficient, and acceptable plan of protection.

a. Completeness is defined in ER 1105-2-100 as,

" ...the extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects. This may require relating the plan to other types of public or private plans if the other plans are crucial to realization of the contributions to the objective. "

b. Effectiveness is defined as,

" ...the extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities. "

c. Efficiency is defined as,

" ...the extent to which an alternative plan is the most cost effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the Nation's environment. "

d. Acceptability is defined as,

" ...the workability and viability of the alternative plan with respect to acceptance by State and local entities and the public and compatibility with existing laws, regulations, and public policies. "

91. These objectives impose general planning constraints within any study area. For example, national objectives would preclude consideration of alternatives for flood control that would degrade the environment, induce flood damages beyond the line of protection, or place project works in a manner which creates a socially unstable environment.

92. **National Economic Development (NED) Plan**. The NED plan is the alternative that reasonably maximizes net benefits over costs and is the baseline against which other alternatives are compared. Normally, the Federal share of the NED plan is the limit of Federal expenditures on any plan that is more costly.

93. **Locally Preferred Plan**. Although the NED plan must normally be recommended, the planning process recognizes that the non-Federal sponsor may have additional desires such as protection beyond that provided by the NED plan. A locally preferred plan may be recommended provided the sponsor agrees to pay the difference in cost.

Prior Planning

94. This report builds on the prior studies identified in the Study and Project History section of the report. Conclusions reached in those studies were accepted as valid unless significant physical, economic, engineering or environmental changes dictated otherwise. The study incorporates changes that have occurred since the Feasibility Study. Analyses in the various technical disciplines reflect current conditions and procedures, providing a sound basis for decision-making.

95. **Physical Changes**. Recent development and alterations of the channel in several areas affected decisions made in regard to the choice of protection measures and their design. New topographical mapping was performed to reflect current conditions.

96. **Economic Changes**. Economic analyses were affected by new Federal policies and recent development in several areas. Damage estimates and benefits are based on current physical conditions and new damage surveys. Benefits of the recommended plan are based on risk and uncertainty principles.

97. **Engineering Changes**. Engineering analyses of flood protection and interior drainage alternatives reflects current physical conditions as well as advanced hydrologic and hydraulic modeling. Levee and floodwall top elevations are based on risk and management principles. Extensive geotechnical and structural analyses were performed to identify safe, efficient and implementable designs for the various components.

98. **Environmental Changes**. Environmental analyses reflect increased attention to adverse impacts on wetlands and streams caused by levees, floodwalls and channelization improvements. As a result, a mitigation plan has been established to compensate for impacts to wildlife habitats. Levees and floodwalls have been moved in some areas to minimize the lengths of necessary stream relocations. In addition, the assessment of environmental impacts was aided by a major habitat evaluation and mitigation investigation. The potential impacts of any regulated or hazardous material sites were investigated and appropriate response plans were identified. The Corps will continue to examine the use of construction materials and bio-engineering techniques in such a manner as to minimize impacts to wetlands and wildlife habitat.

Needs and Opportunities

99. The most critical water resources need is a long term solution to reduce the potential for loss of life and damage caused by flood events. The implementation of a flood control project, however, would also yield local benefits to the affected communities beyond damage reduction. If the flooding problem were eliminated or greatly alleviated, the central business districts of several of the communities would be revitalized. This may prove especially true for the City of Plainfield, which has recently been declared an economic redevelopment zone by the State of New Jersey. Such economic activity, in conjunction with the renovation of previously flood prone residential structures, will lead to higher land values, higher tax ratables and an overall improvement in the quality of life afforded by these communities. Also, through the implementation of a flood control project, municipal buildings, hospitals, schools and emergency response facilities could be protected from flood inundation which would improve the overall safety of the affected communities during a storm event (see Photo 6). Although local benefits which do not contribute to NED objectives are excluded from the benefit-cost analysis, they are significant.

PHOTO NO. 6 FLOODING OF EMERGENCY FACILITIES

PLANNING OBJECTIVES

100. The identification and evaluation of alternatives were based on their response to economic and environmental conditions in the basin.

101. The Green Brook Basin has unique characteristics which require definition of specific planning objectives. Such objectives have remained essentially the same as those reflected in the 1980 Feasibility Report. In summary, these objectives are:

- To reduce the flood hazard and associated urban flood damages in the Green Brook Basin;
- To preserve, maintain and, to the extent possible, enhance the resources of the existing natural and social environment in the project area;
- To preserve to the extent possible existing open space areas and associated recreational opportunities in the project area;
- To provide protection to hospitals, municipal buildings, emergency response facilities and transportation corridors and thus improve public health and safety during any future flood disasters; and
- To provide a plan that is compatible with future flood control and economic development opportunities. Any plan considered for implementation must not contravene or preclude other plans to address the needs and well-being of those who live and work in the basin.

102. In conclusion, plans were formulated to be complete, effective, efficient and acceptable and to reasonably maximize net benefits while providing comprehensive protection throughout this highly urbanized watershed.

PLAN AFFIRMATION CRITERIA

Overview

103. Specific criteria were applied to the affirmation of the authorized plan. These provided the basis for economic determinations that influenced decision-making. Significant environmental factors and changes in the planning environment were also considered. This section of the report describes the updated planning criteria used to reevaluate, refine and ultimately reaffirm the authorized plan.

General

104. Flood protection planning in the Green Brook Basin reflects the physical, economic, environmental and social conditions specific to the basin. The following paragraphs are critical to understanding how the planning process addresses the Federal objectives of completeness, effectiveness, efficiency and acceptability.

System Approach

105. As determined at the time of the formulation of the 1980 Feasibility Study, the Green Brook Basin consists of three areas which have distinctly different hydraulic characteristics. Accordingly, as shown on Figure 1, the Green Brook Basin was divided into the lower portion, upper portion and Stony Brook portion for the purposes of plan formulation. For the reasons described below, flood protection alternatives were considered independently for each portion of the basin at the time of the Feasibility Study. Since conditions have not changed since that time, the system approach remains valid and has been retained as explained in the following paragraphs.

106. **Lower Portion of the Basin**. This portion of the basin is characterized by mild stream gradients, slower, deeper flooding and backwater impacts from the Raritan River. The lower portion of the basin is defined as the part of the basin downstream of the Green Brook and Stony Brook confluence. It is comprised of the lower reaches of Green Brook and its major tributaries; Ambrose Brook, Bound Brook, Bonygutt Brook, Municipal Brook and Cedar Brook, a tributary to

Bound Brook, as well as several lesser tributaries. In addition, a small reach of the Raritan River and its tributary, Middle Brook, are included in order to assure closure of flood control improvements on Green Brook.

107. Due to the hydraulic, hydrologic, social and economic interrelationship within this portion of the watershed, it was decided early in the study process that in order to meet the planning objectives of a complete, effective, efficient and acceptable project, flood protection in the lower portion of the basin must be planned as a system, and that it is not appropriate to exclude intermediate damage areas. Some of the reasons that led to that conclusion are as follows:

a. This portion of the basin is characterized by the many emergency response facilities which serve the various communities in the basin, such as hospitals, fire houses, police stations and emergency management centers. Comprehensive planning within this portion is needed to insure that these facilities remain viable.

b. Mild stream gradients throughout the lower portion exacerbate the hydraulic and hydrologic interaction between main stem and tributaries. A system approach is needed to avoid induced damage and severance costs.

c. A system approach is needed to insure socially acceptable conditions. If local protection were provided on one side of the stream and not the other, adverse social impacts would result. Property values would also diminish and blighting of the unprotected area is possible.

d. A lack of comprehensive planning within this portion could result in a series of discontinuous segments interspersed by areas of induced flooding. This would be inconsistent with these basic planning objectives.

108. It should be noted that if the affirmation study yields a plan for the lower portion of the basin that is consistent with Plan E as supported by the Administration, it can be implemented under the existing authorization, subject only to a limited reevaluation to verify that it remains economically justified.

109. **Upper Portion of the Basin**. Generally, the stream gradient in the upper portion of the basin is steeper than in the lower portion of the basin. The upper portion of the basin is also free of significant backwater influences and major tributary confluences. It is impacted by flash flooding characterized by rapid runoff plummeting off the slopes of the Watchung Mountains. The upper portion of the basin consists of Green Brook, upstream of its confluence with Stony

Brook, and Green Brook's major tributary, Blue Brook. The steep stream gradient leaving the Watchung Mountains, meeting the milder gradient of the glacial outwash plain, combines with a poorly defined basin divide to create a flow diversion of up to 60% to 70% from Green Brook to Cedar Brook across areas of the City of Plainfield and the Township of Scotch Plains. This area is planned as a system to address this complex hydraulic problem by combining flow reduction through the use of upstream detention, in conjunction with increased channel capacity.

110. **Stony Brook**. Stony Brook is a tributary of Green Brook and a major contributor of flood flows with headwaters in the Watchung Mountains. This tributary, which includes areas of steep slopes and high velocity discharges, has also been isolated as a distinct hydrologic/hydraulic area.

Benefits

111. The benefits that would result from flood protection in the Green Brook Basin must respond to the national economic development (NED) objective. The following are the benefit categories used in original plan formulation which remain applicable in this affirmation.

a. Flood damage reduction. These benefits are equal to the average annual value of the private and public damages that would be prevented by a project.

b. Reduced Flood Insurance Administration Costs. These benefits are equal to the annual savings in the cost of administering the National Flood Insurance Program.

c. Early replacement of bridges. These benefits are equal to the annual savings in bridge reconstruction and maintenance.

d. Reduced traffic delays. These benefits are equal to the average annual value of lost time.

Interior Drainage

112. The intent of the interior drainage facility design in the General Re-evaluation Report is similar to that of the Feasibility Report design. That is, to offer the same level of protection from both sources of flooding, interior and exterior. This intent is also demonstrated by the Feasibility

Study economic analyses which claimed benefits for interior areas up to the level of protection of the exterior facilities, i.e., the 150-year flood event.

113. The methodology and technical design procedures described in EM 1110-2-1410, Interior Drainage of Leveed Urban Areas: Hydrology were used to develop interior drainage facilities in the 1980 Feasibility Study. The interior drainage analysis for the GRR utilized EM 1110-2-1413, Hydrologic Analysis of Interior Areas. Although the methodologies and technical design procedures outlined in these EM's are not very different, the resulting computational analyses using those described procedures are quite different.

114. Certain analytical procedures used for the 1980 Feasibility Study have been superseded. These superseded procedures include the use of economic computations that did not provide for a separate interior analysis. Computational procedures used in developing rainfall/runoff relationships were not consistent between the interior and exterior. Most importantly, both a correlation analysis and routing procedures were not used.

115. Current procedures use economic analyses that are performed for each interior area separately from the main line of protection. Current hydraulic analysis and routings (utilizing INTDRA and HECIFH) performed for the design of the interior areas also utilize the exterior hydrology which fully accounts for coincidence and dependence of interior and exterior flood stages. This procedure provides a continuous analysis throughout the full range of damages and frequencies. HEC-1 modeling is used to compute the runoff for both the interior areas and mainstream flows. The current analysis resulted in the development of minimum facilities which were upgraded to the recommended facilities. The recommended facilities were upgraded so as to provide an interior level of protection equal to that of the main line protection as previously supported by the administration.

116. In summary, although the physical configuration of the interior drainage facilities has changed, the current design will provide for flood relief from either source, river or interior, consistent with the level of protection contained in Plan E as supported by the administration.

Freeboard

117. The means by which hydraulic and hydrologic uncertainties are incorporated into flood control projects has changed since Green Brook Basin alternatives were originally formulated. The inclusion of an assumed specific difference, normally three feet, between the floodwater surface and the top of a levee or floodwall is no longer used. The top of such works is now

designed probabalistically incorporating risk and uncertainty of overtopping. In areas which have undergone detailed Feature Design, the recommended plan has included an overtopping and levee superiority analysis. For the remainder of the project area, the traditional freeboard level of three feet has been maintained as an appropriate risk management feature. Similarly, when formulated during the Feasibility Study, channel works were developed to contain the design storm within a prismatic channel allowing for up to two feet of freeboard before overspilling the banks. More recent guidance defines the level of protection as the point of significant damage. As a result, the formulation of channel improvements now includes overbank flow, while still providing a similar level of protection.

Degree of Protection

118. The parameter by which the effectiveness of flood protection plans are measured has changed since Green Brook Basin alternatives were originally formulated. The designation of a specific flood against which an alternative provides full protection is no longer used to define the reliability of a plan. Effectiveness is now measured probabalistically by risk assessment techniques. However decisions reached on the basis of the formerly used parameter are considered to remain valid for selecting alternatives to be considered for reevaluation under the new parameter.

Environmental Considerations

119. **Environmental Protection.** The reevaluation considered flood protection consistent with protecting the nation's environment. This includes full consideration of environmental habitat, cultural resources and hazardous, toxic and radiological waste (HTRW) in the formulation and layout of plans. Accordingly, plans for flood protection were re-formulated to first avoid environmental impacts where possible. When avoidance is not possible, minimizing impacts and providing mitigation measures for impacts is the next consideration. The impacts associated with flood control plans were an important factor in assessing consistency with overall planning objectives.

120. **Supplemental Environmental Impact Statement (SEIS)** The revisions made to the plan during this GRR resulted in a decrease in environmental impacts as compared to the original

plan A (1980). Due to these proposed revisions and the time that has lapsed since the FEIS was filed, it was deemed appropriate to prepare a supplement to the original EIS. This SEIS is subject to the same public review process as the FEIS. A Draft Supplemental Environmental Impact Statement was submitted for public and agency review on 6 January 1997. The comment period for the DSEIS ended on 7 March 1997, allowing for a 45 day comment period plus additional extensions. Revisions to the SEIS have been made reflecting public input. A copy of a Final Supplemental Environmental Impact Statement (FSEIS) is submitted with the Final GRR.

121. **Environmental Impact Revisions** Major environmental revisions that have been made since the development of the FEIS include: 1) utilizing nonstructural methods of flood control instead of levees to avoid wetland disturbances and minimizing stream relocation in the lower portion of the basin and 2) reducing the scope of channel modification from a concrete flume to a rip-rap lined channel in the Stony Brook portion. In addition, a major habitat evaluation and mitigation investigation effort has taken place since 1980 to assess environmental impacts and provide for replacement of habitat losses as required by current policy and regulation.

122. Based on comments from agencies and the public, several changes are reflected in the FSEIS. The most significant change is associated with the deferral of plans in the Upper Basin. Plans for the Upper Basin appear in the FSEIS. These plans are presented for the purposes of identifying possible cumulative impacts associated with the project. Additional documents to satisfy the NEPA process will be prepared following the examination of the Upper Basin plan.

123. The plans for the Lower and Stony Brook portions of the basin will incorporate measures to enhance in-stream habitats and will attempt to implement bio-engineering techniques into the project to the greatest extent possible.

124. **Wetland Mitigation.** In developing wetland mitigation costs and identifying appropriate land sites, conceptual sites and plans were analyzed for cost and potential increase in wildlife habitat. More information on mitigation analyses is described in the Environmental Support Document. Federal criteria for the level of mitigation required is based on the habitat value impacted. To assess this value, the USFWS in coordination with the New York District conducted a Pennsylvania Modified Habitat Evaluation Procedure (PAMHEP) study. A summary of the findings as a result of this study can also be found in the environmental support

document. The amount of mitigation conducted in association with the project will be based on the value of the area impacted, and the predicted increase in value associated with the mitigation site(s). The State of New Jersey requires mitigation on an acreage versus acreage basis. That is, the number of acres required for mitigation is related to the amount of acreage impacted. The purchase of land to satisfy State acreage requirements greater than the amount of land required to replace federally estimated habitat value would be a non-Federal cost. Mitigation sites must be acquired and mitigation plans developed prior to the initiation of project construction. Such mitigation is required under enforcement Section 404 of the Clean Water Act and New Jersey State Law.

125. **Recreational Open Space.** The Green Acres program, established by the State of New Jersey, allows municipalities to obtain funding for recreational areas in exchange for a commitment to preserve existing recreational open space within the municipality. Potential mitigation measures for impacts to parklands include constructing running tracks and bike paths on top of levees that could enhance parkland for recreational purposes. The actual acreage requirements for the Green Acres mitigation (were) will be determined based on state policy considerations and then project requirements (were) will be negotiated according to Federal cost-sharing policy.

FEASIBILITY INVESTIGATIONS

Overview

126. The Green Brook Basin was comprehensively studied to address flood problems at all damage localities. As concluded in the August 1980 feasibility report, protection was feasible only in the lower portion of the basin. However, a plan that would protect all three portions was locally preferred and authorized for construction in 1986.

General

127. As indicated by the plan formulation flow diagram shown on Figure 4, a full range of flood protection measures were considered during the feasibility investigation performed for Green Brook. These various alternatives may be divided into the broad categories of structural and non-structural measures. Structural measures include reservoirs, flow diversions, channel modifications, levees and floodwalls. Non-structural measures include floodplain zoning, flood proofing, flood warning systems, building code regulations, and permanent or temporary evacuation of floodplain areas. The following summarizes the results of those investigations and serves as the foundation upon which this most recent preconstruction engineering and design reaffirmation effort is premised. A review of the physical development in the basin, as well as a review of revisions in planning guidance, indicates the conclusions derived during the feasibility stage for the various alternatives are still valid.

Non-Structural Measures

128. Non-structural measures are so named because they focus on modifying how the buildings located within the floodplain will react to the flood events or how the floodplains are utilized rather than physically modifying the natural characteristics of the floodplain.

129. Non-structural measures can be an excellent means of flood protection in environmentally significant areas because they do not alter the natural floodplain. These measures were given full consideration to the extent practical. However, due to the somewhat limited protection afforded by this type of plan, non-structural measures needed to be fully evaluated in the context of all the planning objectives. Based on preliminary analysis, it was found that high levels of protection

using non-structural measures are impractical for broad application throughout the basin. For example, to protect against the 150-year flood, non-structural improvements would need to be effected on approximately 1,260 residential structures, 348 commercial structures, 18 industrial structures and 16 public structures. In addition, in many areas, the short warning time and extreme flood depths are such that evacuation of the floodplain through removal of the structures is the only practical non-structural solution. However, the resulting impacts on some communities would essentially eliminate their economic base because of insufficient land available to accommodate the displaced taxpayers.

130. Although a non-structural plan that would protect against a 150-year flood would be impractical, smaller non-structural plans were considered. A 10-year level of protection evacuation plan was considered. Though put forward as the Environmental Quality (EQ) plan at the time of the Feasibility Study, it was not economically justified and did not gain support from the local sponsor. A 10-year floodproofing plan was also investigated. The low level of protection combined with the high risk of failure would result in high residual damages and a significant safety risk.

Structural Measures

131. Structural measures were considered to have the highest potential for achieving effective flood protection in the Green Brook Basin. During the early stages of plan formulation, a wide array of structural measures, as shown on the formulation flow diagram on Figure 4, were investigated to provide flood control for the Green Brook Basin. Many of the alternatives were quickly eliminated, either due to economic considerations or a lack of engineering feasibility.

132. **Lower Portion of the Basin**. This portion of the basin is characterized by mild stream gradients, slower, deeper flooding and backwater impacts from the Raritan River. This portion is also characterized by the presence of hospitals, municipal buildings and emergency response facilities, of significant importance to the overall study area during times of crisis. Plan formulation proceeded on the premise that the high stages of flooding cannot be effectively reduced by increasing channel capacity or by detaining flows. Thus, the hydraulics of this portion of the basin dictated that flood protection can only be effectively achieved by levees, floodwalls, or non-structural methods (see Illustrations 1 & 2). A wide variety of structural

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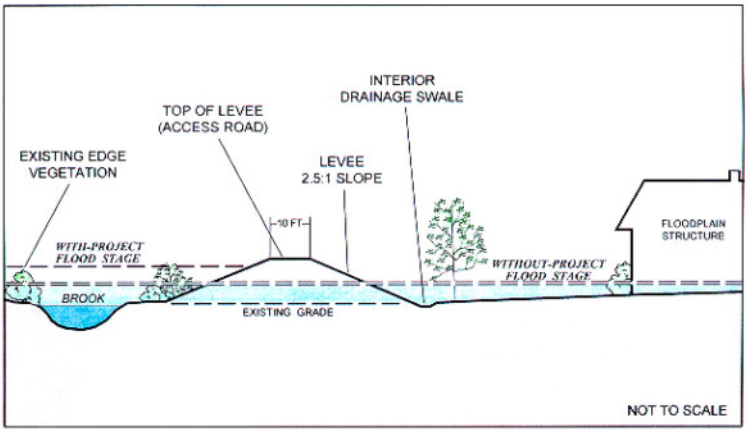

ILLUSTRATION NO. 1 - TYPICAL LEVEE APPLICATION

PHOTO NO. 7 - LEVEE PROTECTS HOMES ALONG THE ROCKAWAY RIVER IN MONTVILLE, N.J.

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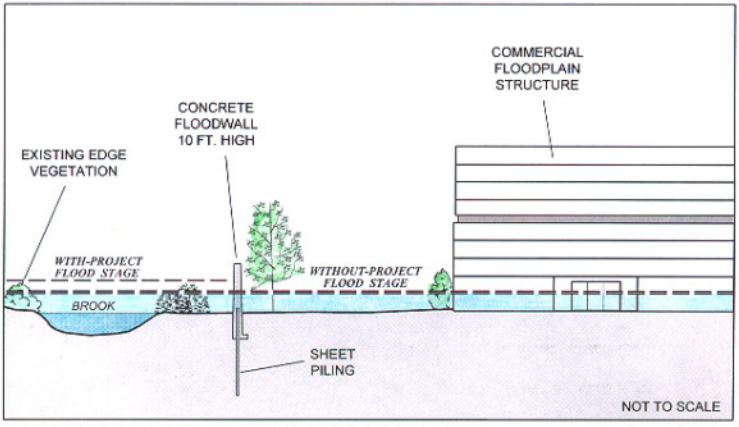

ILLUSTRATION NO. 2 - TYPICAL FLOODWALL APPLICATION

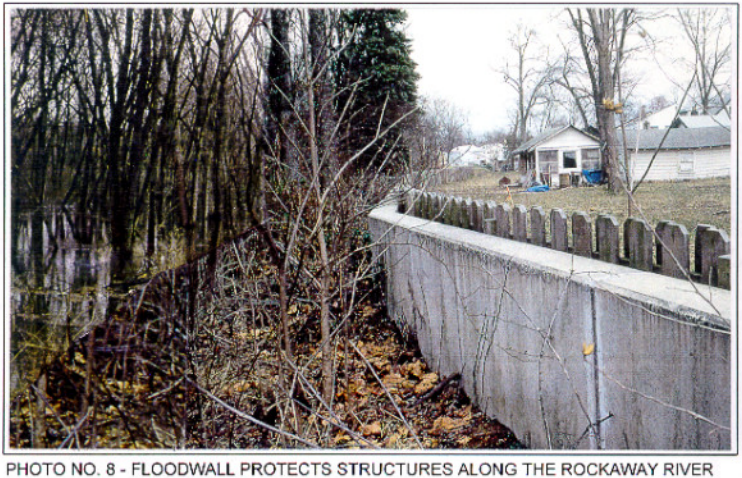

PHOTO NO. 8 - FLOODWALL PROTECTS STRUCTURES ALONG THE ROCKAWAY RIVER IN MORRIS COUNTY, N.J.

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flood control measures were examined. The result was a verification that attempts to lower the water surface elevations are ineffective and all measures except levee/floodwall and flood proofing combinations should be eliminated from further consideration.

133. Initial levee layouts were formulated to meet the planning objectives of providing comprehensive protection within this highly urbanized portion of the study area. Accordingly, emphasis was placed on protection for the significant public structures including hospitals, municipal buildings and emergency response facilities.

134. **Upper Portion of the Basin**. Improvements in the upper portion of the basin centered on elimination or reduction of the diversion of water into the Cedar Brook Basin. This can be accomplished either by reducing the rate of flow at the critical reach of stream through the use of upstream detention (see Illustration #3) or by increasing the conveyance (see Illustration #4) of Green Brook.

135. Upstream Detention. Several alternative detention basin sites were investigated for the upper portion of the basin. Included in the investigation were:

- Green Brook at the gorge in the First Watchung Mountain
- Green Brook at Oak Way
- Blue Brook above Seeley Mills Pond (Sky Top Drive), and
- Blue Brook, downstream of Surprise Lake.

136. The detention facilities on Blue Brook considered both a large, single control structure just above Sky Top Drive and a smaller control structure at that site in combination with a second structure near Surprise Lake. This two-structure alternative was later dropped from consideration due to impacts on endangered species habitats and increased cost for similar flow attenuation results.

137. Increased Conveyance. In an effort to increase the channel conveyance capacity in the critical diverting reaches of Green Brook, six alternatives were considered, including: 1) a concrete flume, 2) a trapezoidal channel modification, 3) a diversion tunnel along Route 22 to Rock Avenue, then down Rock Avenue to Green Brook, 4) a diversion tunnel along Route 22 via Rock Avenue in combination with a trapezoidal channel modification on Green Brook, 5) a

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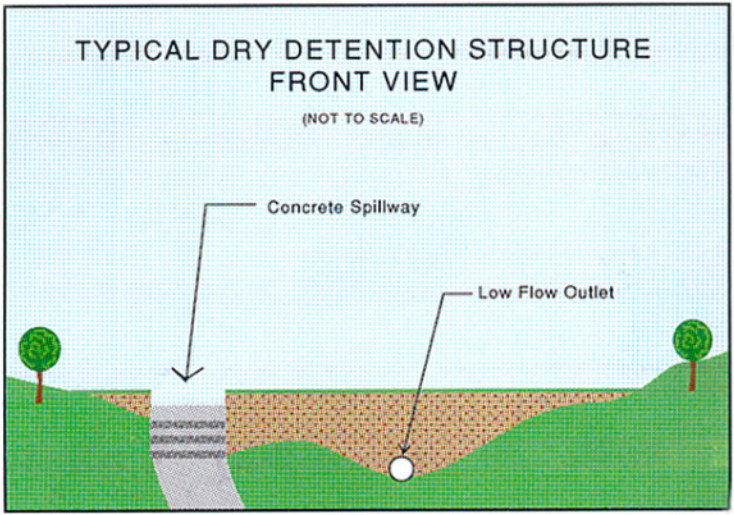

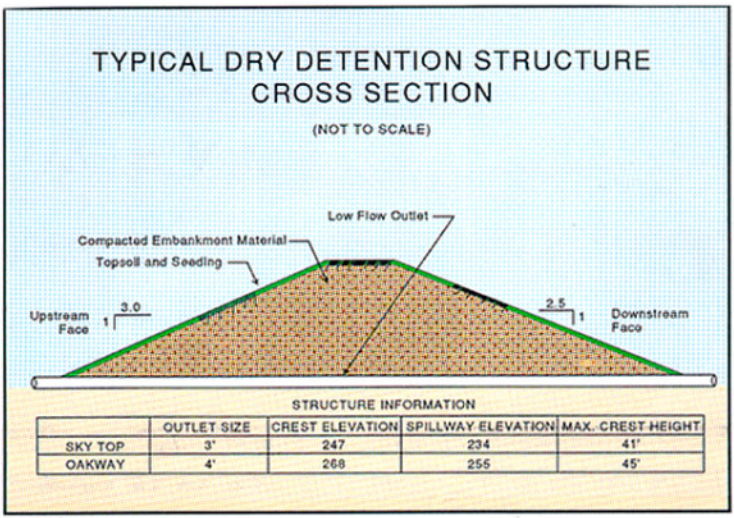

STRUCTURE INFORMATION

	OUTLET SIZE	CREST ELEVATION	SPILLWAY ELEVATION	MAX. CREST HEIGHT
SKY TOP	3'	247	234	41'
OAKWAY	4'	268	255	45'

ILLUSTRATION NO. 3 - TYPICAL DRY DETENTION STRUCTURE

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ILLUSTRATION NO. 4 - TYPICAL CHANNEL MODIFICATION APPLICATION

PHOTO NO. 9: CHANNEL MODIFICATION SITE ALONG THE STONY BROOK IN NORTH PLAINFIELD

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diversion tunnel along Route 22 to Stony Brook, then parallel to Stony Brook to Green Brook in combination with a trapezoidal channel modification on Green Brook, and 6) a diversion tunnel to Cedar Brook in combination with a trapezoidal channel improvement on Green Brook. Each of the aforementioned alternatives was considered only in combination with a detention system in the upper portion of the basin. Detention systems were necessary to minimize adverse increases in downstream flows due to the reduction in Green Brook to Cedar Brook diversion and to limit the physical size of improvements through the highly developed reaches of Scotch Plains and Plainfield.

138. The alternatives were compared on a cost basis since each was designed to provide a similar level of protection. The trapezoidal channel modification, in spite of requiring a significant number of bridge replacements, was found to be nearly 30% less costly than the next best alternative and was therefore carried forward in the planning process.

139. A plan to utilize levees and floodwalls as a means of containing the flood flows was also evaluated. It was dropped from further consideration early in the planning process because of the high degree of developed properties in close proximity to the stream, and the high costs and public disruption of raising nearly twenty bridges and approach roads throughout the reach.

140. **Stony Brook**. Two alternatives were investigated for flood protection on Stony Brook. These involved increased conveyance and detention storage.

141. Increased Conveyance. The first alternative was initially a combination flume and channel modification. The flume was utilized upstream of Rockview Terrace, because of high stream velocities, while a trapezoidal channel modification was employed downstream of Rockview Terrace. Based on a revision by USGS of gage data in the mid-1970s, a revised discharge-frequency relationship revealed that the stream below Rockview Terrace would require a significantly larger channel to contain the design flood. As a result, levees and floodwalls replaced the trapezoidal channel modification below the exit of the flume. However, this combination flume, levee and floodwall plan was not found to be economically viable.

142. Reduction of Peak Flow. The concept of utilizing stormwater detention structures in combination with flow diversion structures was considered. However, viable alternatives were

not possible due to economic and social constraints. Flow reduction measures were dropped from further consideration in the Stony Brook portion of the basin.

Summary of Findings for Components

143. **Lower Portion of the Basin**. Mild stream gradients and backwater influences from the Raritan River led to the conclusion that a comprehensive system using levees and floodwalls is the most technically and economically viable solution for the lower portion of the basin.

144. **Upper Portion of the Basin**. The flood characteristics and stream gradient lend themselves to the use of channel modifications as the most cost-effective means of reducing damages associated with flooding. Any solution that reduces flow diversions to Cedar Brook needs to be integrated with flood detention to mitigate potential increases in flood peaks within Green Brook below the diversion area. The use of detention at Oak Way and Sky Top, in conjunction with a channel modification through the upper portion of the basin, was found to be economically viable when considered in combination with local protection in the lower portion of the basin, but not as an incremental element on its own.

145. **Stony Brook**. High velocities, steep gradients and local opposition to detaining stormwater in the Stony Brook gorge, limited the alternatives providing a high level of protection to a concrete flume downstream with levees. Feasibility investigations revealed that this alternative was not economically viable and, when combined with the other portions of the project, lowered the overall Benefit-to-Cost Ratio (BCR) to below unity.

Feasibility Level Plan Selection

146. **Plans Considered**. An array of six alternative plans were studied in detail at the time of the 1980 Feasibility Study. The plans, consisting of various combinations of the most viable structural and non-structural elements described above were labeled A, C, D, E, F, and G, and are briefly described below.

- *Plan A*. This plan provides comprehensive protection to the Green Brook Basin. In the upper portion of the basin it proposed to use a dry detention basin at the headwaters of Green Brook at Oak Way, a dry detention basin on Blue Brook at the foot of Sky Top

Drive in the Watchung Reservation and channel modifications on Green Brook through Scotch Plains and Plainfield. On Stony Brook a flume, channel modification, and levee were proposed. The lower portion of the Green Brook Basin included levees and floodwalls in the plan. This plan was identified as the locally preferred plan (see Figure 3).

- *Plan C*. Essentially the same as Plan A, but instead of a single detention control structure at the Sky Top site in the Watchung Reservation, there are tandem structures on Blue Brook, a somewhat smaller control structure at the Sky Top site and a second structure approximately 1,300 feet downstream of the existing Lake Suprise dam.
- *Plan D*. Essentially the same as Plan A but no improvements are proposed on Stony Brook or reaches of Bonygutt Brook above the railroad.
- *Plan E*. Except for eliminating protection on the upper reaches of Bonygutt Brook, Plan E essentially mirrors Plan A throughout the lower portion of the basin. Through a series of levees, floodwalls, closure structures and bridge raisings, it would provide protection for the endangered reaches of the lower portion of the Green Brook Basin. Plan E was identified as the NED and the selected plan (see Figure 2).
- *Plan F*. A non-structural alternative, this plan would consist of buying out and removing the structures in the 10-year floodplain.
- *Plan G*. A non-structural alternative to the evaluation plan put forth in Plan F, Plan G would consist of the flood proofing and raising of structures located in the floodplain.

For a more detailed description of each of the aforementioned alternatives, refer to the August 1980 “Feasibility Report for Flood Control Green Brook Sub-basin”.

147. Table 5 displays the comparative data in January 1979 price levels for each of the six plans A, C, D, E, F and G as they appeared in the August 1980 Feasibility Report.

TABLE 5
COMPARISON OF FEASIBILITY STUDY PLANS
(January 1979 Prices)

Plan	Project Cost	Annual Cost (7-1/8%) 100-Year Life	Total Annual Economic Benefits	Net Excess Economic Benefits	Final B/C Ratio
A	$127,073,200	$9,231,600	$8,365,700	-	0.91
C	$133,246,300	$9,673,600	$8,365,700	-	0.86
D	$104,606,100	$7,593,600	$8,042,100	$448,500	1.06
E	$52,161,200	$3,847,300	$6,919,700	$3,072,400	1.80
F	$81,700,000	$5,827,100	$1,719,700	-	0.30
G	$7,612,000	$542,900	$1,527,200	$984,300	2.81

148. **Feasibility Study Conclusions**. Plan E, having the maximum excess of benefits over costs, was selected as the alternative to be optimized to identify the NED level of protection. Plan A, providing protection to all the major flood problem areas in the Green Brook Basin, was identified as the locally preferred plan and ultimately an up-graded version of this plan resulted in the project authorization.

149. Plan G, although providing a higher benefit cost ratio, was not pursued due to limited protection which resulted in a lower net economic return.

Legislative Action

150. The August 1980 feasibility report was reviewed by the Board of Engineers for Rivers and Harbors which concluded that the urban nature of the protected area warranted an increase in the degree of protection from 150-year to 500-year and recommended accordingly. In September 1981, the Chief of Engineers concurred. In February 1984, the Secretary of the Army expressed the Administration's views in his letter transmitting the report to Congress. He stated that there was insufficient justification for deviating from the plan which maximizes net national economic benefits, and that Plan E as recommended in the August 1980 report should be authorized. In November 1986, Congress, in the Water Resources Development Act of 1986, authorized Plan A, which provides comprehensive protection in the Green Brook Basin, but also adopted the 500-year level of protection in the lower portion of the basin as recommended by the Report of the Chief of Engineers, dated September 4, 1981. Copies of the referenced correspondence can be found in Appendix A - Attachment D.

REAFFIRMATION OF THE AUTHORIZED PROJECT

Overview

151. During the preconstruction engineering and design studies performed after project authorization, project scaling was reviewed in light of current policies, changed conditions and the views of the New Jersey Department of Environmental Protection (NJDEP). This effort permitted a balancing of objectives that yielded a feasible basin-wide plan, essentially in accord with the authorized project.

General

152. Green Brook alternative plans were considered in greater detail during the preconstruction engineering design studies performed after project authorization. Reanalysis of project viability and scaling was limited to the basic protection features found viable in the Feasibility Study. Alternatives previously found to be technically, socially or environmentally unacceptable were not considered for reanalysis. Because of the complexity of the study area and study funding constraints, the scaling and optimization of project elements took place over several years. As a result, findings are presented in January 1989, November 1992, and April 1996 price levels with the corresponding Federal discount rates. Alternatives eliminated at intermediate steps in the screening process were not updated to subsequent price levels as the interrelationship between alternatives would remain consistent.

153. In the lower portion of the basin, the design was refined to maximize the effectiveness and efficiency of providing 150-year protection as supported by the Administration. In the upper portion of the basin, the detention facilities were reevaluated in combination with several channel alternatives through Scotch Plains and Plainfield. For environmental protection and cost reduction, smaller channel modifications and lower levels of protection were also investigated in the upper and Stony Brook portions.

Changed Conditions

154. Analyses of alternatives in this report reflect changes in conditions that affect design, costs, benefits and resulting impacts. These changes are described as follows.

155. **Lower Portion of the Basin.** New survey information, hydrologic modeling and economic data revealed that the lower portion of the basin will react to plan implementation in essentially the same manner as in the earlier investigations. No major changes in development patterns that would justify reconsideration of channel work on the Raritan River were discovered. The mild gradient of the lower reaches of Green Brook still leave it subject to backwater influences. Factors that alter the planning process from earlier investigations include:

a. Improved technical procedure in the design of interior drainage works

b. Hydraulic data on tributary streams which required refinement of tie-back levee systems.

c. Environmental laws protecting wetlands

156. **Upper Portion of the Basin.** Recent commercial development near the Oak Way detention site required reformulation of detention alternatives in this portion of the basin. Though costs have escalated since the earlier investigations, it is reasonable to assume they have done so proportionately, and therefore, channel modifications are still considered the most attractive solution for increasing conveyance through the upper portion of the basin. Additionally, since the earlier formulation process, planning guidance has relaxed freeboard requirements on channel modification alternatives, making them an even more viable solution. Since the earlier investigations indicated that improvements in this portion of the basin were not economically viable by Federal criteria, the study effort centered on seeking a solution, using detention and channel modifications, that addresses the local needs and provides a Federally supportable plan.

157. **Stony Brook Portion of the Basin.** A review of new cross-section data revealed that above Route 22 the steeply sloping channel has undergone several changes since the August 1973 flood of record. The Interhaven Avenue bridge has been replaced and the channel has widened and deepened as a result of naturally occurring erosion and ongoing channel maintenance. At several locations immediately upstream of the project, bank stabilization measures have been employed to prevent undermining of Somerset Street. Immediately upstream of Route 22, it is estimated these geometric changes in the channel would result in about 0.5 to 1 foot reduction in stage during a recurrence of the August 1973 flood. In the lower reaches of the stream, the West End Avenue bridge has been replaced with a significantly larger structure, capable of

passing larger discharges. Throughout the watershed, there are no significant changes noted with respect to development patterns, and thus the potential benefit pool has not substantially changed.

Reevaluation of the Authorized Project

158. The project reevaluation effort consisted of a limited reevaluation of the lower portion of the basin to incorporate changed conditions and to re-affirm that the NED Plan supported by the Administration is still economically viable. The upper and Stony Brook portions of the basin underwent a general reevaluation to re-examine the viability of the project authorized by Congress. Where the authorized project features were not implementable or not economically justified, alternative means of providing flood protection were examined.

159. **Lower Portion of the Basin**. As previously discussed, earlier investigations concluded that the most viable solution for the lower portion of the basin consists of an integrated local protection system comprising levees and floodwalls.

160. The three significant departures from the earlier investigations consist of:

a. A backwater barrier at the mouth of Bonygutt Brook in lieu of tie back levees and floodwalls.

b. Additional hydraulic modeling on smaller tributary streams revealed the need for additional tie back systems.

c. Interior drainage facility analysis procedures which more fully consider the relationship between interior and exterior flooding.

161. Subsequent to the feasibility effort, an economic evaluation revealed that a barrier across the mouth of Bonygutt Brook to prevent high stages on Green Brook from backing water up Bonygutt Brook was a preferable alternative to a costly and environmentally disruptive tie back system of levees and floodwalls. In conjunction with this alternative, a large pumping station will be employed to discharge flood flows, emanating from Bonygutt Brook, through the line of protection and into Green Brook.

162. Additional hydraulic analysis was performed on several of the smaller tributaries to Green and Bound Brooks to assure closure of the proposed lines of protection. Additional protection

works in these smaller tributaries were not considered as they were only studied to assure the integrity of the previously proposed improvements. The additional hydraulic data on Municipal Brook revealed the tie back system must be extended several hundred feet further upstream to avoid flanking of the line of protection.

163. Economic analysis of the line of protection revealed that the 150-year design level is economically justified, as shown in Table 6.

TABLE 6
LOWER PORTION OF THE BASIN
LINE OF PROTECTION
(150-Year Level of Protection, January 1989 Price Level, 8-7/8% Interest Rate, 100-Year Project Life)

First Costs	**$151,486,000**
Annual Costs	$14,178,000
Annual Benefits	$15,371,000
Net Excess Benefits	$1,193,000
Benefit-Cost Ratio	1.1

164. The benefit cost comparison for the 150-year plan was updated to November 1992 price levels utilizing an interest rate of 8%. In addition, 50% of the benefits within the freeboard range are incorporated into the project totals. These updates are reflected in Table 7.

TABLE 7
ECONOMICS OF LOWER PORTION OF THE BASIN
LOCAL PROTECTION PLAN
(150-Year Level of Protection
November 1992 Price Level, 8% Interest Rate, 100-Year Project Life)

	Lower Portion of Basin
First Costs	$161,175,000
Annual Costs	$13,720,000
Annual Benefits	$15,795,000
Net Excess Benefits	$2,074,000
Benefit-Cost Ratio	1.1

165. **Upper Portion of the Basin**. The authorized plan for the upper portion of the basin, originally designated as a component of Plan A in the 1980 Feasibility Report, called for a 150-year level channel modification in combination with detention facilities on Green Brook at Oak Way and on Blue Brook just upstream of Sky Top Drive. As a result of the earlier investigations, the General Reevaluation effort in the upper portion of the basin has focused on an evaluation of detention facilities and channel improvements as potentially viable options.

166. Detention Facilities. Based on their ability to generate sufficient potential storage volume within a relatively uninhabited area, a total of three potential detention sites were selected for further investigation within the upper portion of the basin. The sites considered capable of providing significant flood attenuation included:

a. Sky Top site just east of Sky Top Drive on Blue Brook

b. Oak Way site 1,300 feet west of the Oak Way crossing over Green Brook

c. Gorge site within the Green Brook valley through the First Watchung Mountain, 2,000 feet north of the intersection of Diamond Hill Road and Bonnie Burn Road.

167. Project alternatives considered the use of all three sites in combination, as well as a combination of the Sky Top site with each of the other two sites independently. The Sky Top site was common to all alternatives evaluated due to the large storage capacity available on Blue Brook. At the Sky Top detention facility, the ratio of storage capacity to contributory drainage area is quite large. Sufficient storage could be provided to contain the entire 500-year flood below the height of the emergency spillway.

168. The determination of which detention facilities represent the NED alternative required a two-step process. The initial step was to determine what size facility at Sky Top was most cost-effective, and the second step was to determine which combination of detention sites were most effective. A review of costs versus alternatives of peak flood flow made it apparent that the Sky Top facility by itself did not control a significant enough portion of the watershed to effectively reduce downstream flows. Therefore, for comparative purposes, and to establish the most effective spillway elevation, the Sky Top facility was considered in combination with a detention facility at Oak Way.

169. Spillway crest elevations of 251, 234 and 221 feet National Geodetic Vertical Datum (NGVD) were considered, which essentially contain the 500-year, 100-year and 10-year floods respectively. As shown in Table 8, the Sky Top control structure with a spillway elevation of 234 feet provides the greatest net excess benefits.

TABLE 8
ECONOMIC SIZING OF SKY TOP DETENTION FACILITY
(January 1989 Price Level and 100-Year Project Life)
($000)

Alternative Control Structure in Combination with Oak Way	Project Cost	Int. & Amort.	Annual O&M	Total Annual Cost	Annual Benefits	Net Excess Benefits	B/C Ratio
Sky Top @ Elev. 251	$18,697.0	$1,659.7	$50.0	$1,709.7	$2,369.4	$659.7	1.39
Sky Top @ Elev. 234	$13,297.0	$1,180.3	$39.0	$1,219.3	$2,343.1	$1,123.8	1.92
Sky Top @ Elev. 221	$12,211.2	$1,084.0	$31.7	$1,115.7	$2,064.4	$948.7	1.85

170. Once it was established that a Sky Top spillway set at approximately the 100-year flood stage (elevation 234) was the most cost-effective, it was then necessary to consider various combinations of the detention structures, i.e., Sky Top with Oak Way, Sky Top with the Gorge and all three combined. Table 9 shows the results of that analysis.

TABLE 9
ECONOMIC COMPARISON OF DETENTION FACILITY ALTERNATIVES
(January 1989 Price Level and 100-Year Project Life)
($000)

Detention Facility Combination	Project Cost	Int. & Amort.	Annual O&M	Total Annual Cost	Annual Benefits	Net Excess Benefits	B/C Ratio
Sky Top - Oak Way	$13,297.0	$1,180.3	$39.0	$1,219.3	$2,343.1	$1,123.8	1.92
Sky Top - Gorge	$9,796.8	$869.6	$30.0	$899.6	$2,094.7	$1,195.1	2.33
Sky Top - Oak Way - Gorge	$18,173.8	$1,613.3	$47.0	$1,660.3	$2,599.9	$939.6	1.57

171. The selection of the Oak Way and Gorge NED alternatives was predicated on a qualitative/quantitative analysis. At both the Oak Way and Gorge sites, nearby development limits the maximum height of the control structure. Increasing the height or capacity of either structure

would require buyouts and roadway relocations that would escalate costs at a higher rate than the available additional benefits could increase. Therefore, the largest viable facility without extensive buyouts or relocations was considered at each site in order to maximize attenuation of peak flood flows downstream. Consideration of smaller facilities was also dismissed because reduction in detention basin control structure heights would not generate significant savings in construction costs while the available benefits would diminish rapidly. These sites are already small compared to their contributory drainage area. The NED alternatives for both the Oak Way and Gorge sites are based on this analysis.

172. Though the Sky Top-Gorge detention facility combination resulted in slightly greater net excess benefits than a combined Sky Top-Oak Way alternative, the difference was not deemed to be significant from an economic selection criteria. The Sky Top-Gorge alternative would require an extensive relocation of Diamond Hill Road, a major thoroughfare leading to Interstate 78. Relocation of the roadway would create a construction related traffic disruption, which introduces a significant degree of uncertainty into the estimate. Additionally, the Gorge facility would severely impact one of the most scenic aesthetic resources in the basin. In view of these issues and in consideration of the strong local opposition to the Gorge alternative voiced during the Feasibility Study, the Sky Top-Gorge option was deemed to be less desirable than the Sky Top-Oak Way alternative.

173. Channel Modifications. To reduce the frequency of flow diversions from Green Brook to Cedar Brook via the streets of Scotch Plains and Plainfield, channel improvements were also considered in the upper portion of the basin. Three channel alternatives were investigated in connection with the analysis. The initial channel was developed to provide an independent high (100-150-year) level of protection without the benefit of attenuation from the proposed detention facilities. The intent of the analysis was to determine if a channel modification independent of the detention facilities could be supported. This alternative required extensive bridge relocations throughout the project reach, and without the attenuation provided by the detention facilities, significantly increased flood discharges in the lower portion of the basin. Once again, it was affirmed that channel modifications in the upper portion of the basin must be combined with detention facilities to minimize downstream impacts.

174. When considered in conjunction with the detention facilities, it was apparent the initial channel alternative was over-designed, particularly in the Scotch Plains area, where the detention facilities have the greatest impact. As a consequence, a second channel used in conjunction with the detention facilities was developed to target a l50-year design level based on the point of significant damage. This alternative functioned in a manner similar to the channel developed in Plan A in the 1980 Feasibility Study. Similar to the channel in Plan A, it was found to be a non-supportable project feature with a Benefit-to-Cost ratio of 0.6. A third, significantly smaller channel was also considered. The smaller channel relied more heavily on the flood storage capacity of the detention facilities for larger, less frequent flood events, and was specially designed to minimize the extensive and costly bridge replacements required under the larger two plans. It provided a low, 10-20-year, level of protection while relying on the flood storage capacity of the detention facilities to minimize the magnitude of damages above the design level. This alternative has significantly lower construction costs due to greatly reduced bridge work and requires only desnagging efforts through sections of the commercial center of Plainfield where the existing channel capacity would yield a reasonable level of protection.

175. Coordination with the local interests prior to this current general reevaluation effort indicated this latter small channel alternative was not institutionally acceptable and thus it was not refined further. Instead, the second, larger channel alternative which most closely reflected the alternative authorized for design by Congress was chosen for further design detail and refinement.

176. **Stony Brook**. Flood protection alternatives considered on Stony Brook included two concrete channel alternatives carrying supercritical flow ending at a stilling basin just downstream of Green Brook Road. Protection was completed with a system of levees and floodwalls from Green Brook Road to the confluence with Green Brook. A levee plan was also considered upstream of Green Brook Road, but did not generate cost savings over the concrete channel alternatives and introduced unacceptable levels of risk due to inadequate time for advance warning under overtopping conditions. Keeping with the desires of the local interests to provide a basin-wide uniform level of protection, and in accordance with the Stony Brook portion of Plan A, as authorized by Congress, each of these alternatives targeted a 150-year level of protection. None of the alternatives considered were deemed to be economically viable. For the two

concrete flumes considered, the benefit-cost ratio was determined to be similar. As a result, due to the hydraulic instability of a supercritical flume and high degree of risk and possible loss of life if overtopped, the larger of the two flumes, in conjunction with the system of levees and floodwalls downstream of Green Brook Road, was selected as the most desirable alternative from an engineering perspective.

Balancing of Project Objectives.

177. A refinement of the plans of improvement for the Green Brook Basin was the subject of intensive coordination between the New York District, U.S. Army Corps of Engineers, the New Jersey Department of Environmental Protection (NJDEP) and the Green Brook Flood Control Commission. As documented in the following Section on Local Coordination, the level of formal coordination through technical and public meetings significantly intensified after September 1994, when reaffirmation results were formally presented to the local sponsor.

178. The goal and result of this coordination was the development of the New York District's Draft Plan Recommendation which reconciled differences between the NED Plan from the 1980 Feasibility Study and the Plan authorized by Congress which represented the Locally Preferred Plan (LPP) supported by the NJDEP and the Green Brook Flood Control Commission. The extended study team focused on finalizing the draft plan recommendation by balancing the following objectives:

a. Within the NED framework, avoiding environmental impacts where possible. If avoidance was not possible, then efforts to minimize impacts were chosen. Environmental mitigation measures were incorporated into the plan to compensate for unavoidable impacts.

b. The opportunity to maintain the NED objective and to provide economically viable comprehensive flood protection for a complete, effective, efficient and acceptable flood control solution.

c. Avoidance of induced flooding or adverse social conditions.

d. Provide protection to hospitals, municipal buildings, emergency response facilities and major transportation corridors resulting in a safer area adjacent to the Federal project.

e. High levels of protection which reduce the probability of catastrophic levee overtopping in the highly urbanized area.

f. Reduction of residual flood damage in the Federal Project area.

g. Adequate interior drainage facilities to reduce damages caused by floodwaters trapped behind the line of protection, thus preserving the overall integrity and quality of the Federal project.

179. **Modifications to the Lower Portion of the Basin**. The local sponsor indicated general support for the NED Plan for the lower portion of the basin as part of the LPP. As a result of coordination efforts with NJDEP and local officials, several minor alignment changes to reduce adverse social and environmental impacts were evaluated as described under local coordination.

180. **Modifications to the Upper Portion of the Basin**. The local sponsor indicated concern with the high level of costs, as well as the extent of social and environmental disruption associated with the large channel which closely reflects the plan authorized by Congress. They also indicated that a protection plan for the lower portion of the basin which has design levels based on a continued Green Brook to Cedar Brook diversion of flow would contradict the objective of providing comprehensive protection. Such a plan would, in essence, institutionalize the flooding of Scotch Plains and Plainfield. Accordingly, the sponsor requested further refinement and scaling of Plan A, with consideration of more limited channel works along Green Brook.

181. A channel modification designed to function in concert with upstream detention facilities was developed. The channel modification, which prevents diversions from Green Brook to Cedar Brook for up to a 20-year event, provides for a more equal level of protection throughout the entire diversion reach from the affluent community of Scotch Plains through the economically deprived urban center of Plainfield. The revised plan is designed to minimize bridge improvements, only requiring replacement of the Netherwood Avenue Bridge. As indicated on Figures 14, 16, and 17, the proposed channel work extends from the West End Avenue Bridge upstream to its terminus just downstream of Route 22, approximately 3,000 feet downstream of previous alternatives. Above Route 22, the detention facilities attenuate a large portion of the peak runoff. In addition, two reaches of the channel would only require clearing and desnagging.

The first and most extensive clearing and desnagging reach extends nearly 5,000 feet from Somerset Avenue upstream to Farragut Road. The second reach extends from downstream of Netherwood Avenue upstream nearly 1,800 feet to just upstream of Leland Avenue. The remainder of the project comprises prismatic trapezoidal and rectangular channel sections.

182. This channel modification was designated as the NED channel for the upper portion of the basin. A larger channel modification such as the one designated in the Authorized Plan requires extensive bridge replacements which quickly escalate costs and create an alternative which cannot be justified economically. Any reduction in the limited channel modifications would essentially diminish the project to the existing channel with the associated loss in flood protection benefits. The upstream detention facilities remain unchanged.

183. **Modification to the Stony Brook Portion of the Basin**. The local sponsor also indicated concern with extensive environmental impacts, the high cost and possible induced flooding associated with the plan authorized by Congress for Stony Brook. The development of modified plans on Stony Brook was a two-step process. Realizing there was no Federal interest in a high level channel modification for Stony Brook, but that frequent flooding would represent an unacceptable hazard, an analysis was conducted for limited channel modifications designed to avoid costly bridge replacements. A significant factor contributing to the efficiency of limited improvements on the Stony Brook portion of the basin is the apparent increase in channel conveyance capacities as a result of scour experienced during the August 1973 storm event. The channel scour caused by this storm, in conjunction with subsequent stream cleanings and the replacement of the Interhaven Avenue bridge, have increased the hydraulic conveyance capacity of the Stony Brook channel.

184. The first limited channel modification plan considered provided additional, modest increases to the existing channel capacity. The plan of improvement for this portion of the project included a trapezoidal channel having a 25 foot wide bottom width. The channel extends from Rockview Terrace to the Villa Maria bridge. This channel improvement would provide some limited flood protection over that which existed prior to the 1973 storm event.

185. A second, more extensive, channel modification along Stony Brook, starting 380 feet downstream of the Rockview Terrace bridge and extending upstream to 60 feet downstream of

the Interhaven Avenue bridge, provides somewhat more comprehensive and reliable protection. This channel modification plan provides additional modest increases in the existing channel capacity to approximately a 25-year level of protection.

186. Beginning from 380 feet downstream of Rockview Terrace, the plan of improvements incorporates prismatic trapezoidal and rectangular channel sections ranging from 25 to 50 feet in bottom width.

187. Channel improvements also include the placement of training dikes at locations with low stream banks. This includes the most upstream reach of the improvement for approximately 600 feet between the Villa Maria and Interhaven Avenue bridges, upstream of Green Brook Road, upstream of the U.S. Route 22 bridge and downstream of the Grove Street bridge.

188. This modified Stony Brook channel also includes bridge alterations. The Grove Street bridge will be replaced in order to increase hydraulic capacity. The replacement bridge has a wider opening, a higher low chord and slightly higher top of road than the existing bridge. In addition, Green Brook Road and Route 22 bridges will be underpinned allowing the stream inverts to be lowered.

189. The costs and benefits associated with the plan authorized by Congress, the limited channel modification plan, and the 25 year channel modification plan were updated and compared. The 25 year channel modification plan is the NED element of a basin-wide plan. Table 10 demonstrates that the large supercritical channel plan authorized by Congress continues to be economically unjustified having a benefit cost ratio less than unity. Both of the smaller channel modification plans provide benefit cost ratios above unity. While the limited channel modification plan does provide a higher benefit to cost ratio, it provides a relatively low level of flood protection. The 25 year channel plan provides a higher, more dependable level of flood protection and generates greater benefits in excess of cost. On this basis, the channel improvement plan providing a 25-year level of protection for Stony Brook is the NED element of a basin-wide plan.

TABLE 10 ECONOMIC COMPARISON OF STONY BROOK ALTERNATIVES (April 1996 Price Level, 7-3/8% Interest Rate, 100-Year Project Life)			
	Alternative Plans		
	Authorized Plan with 150 year level of Protection	Limited Channel Modification Plan with 5-6 year level of Protection	25-Year Channel Modification Plan
First Costs	$49,835,000	$4,582,000	$11,495,000
Annual Costs	$3,859,000	$363,000	$892,000
Annual Benefits	$1,638,000	$543,000	$1,119,000
Net Excess Benefits	($2,221,000)	$180,000	$227,000
Benefit-Cost Ratio	0.42	1.5	1.3

Optimum Plan

190. The line of protection for the lower portion of the basin, as supported by the Administration, was found to be economically justified. The flood protection plans for both the upper and Stony Brook portions of the basin were reevaluated and scaled to comply with NED planning criteria. While this approach results in different levels of protection between the lower, upper and Stony Brook portions of the basin, it provides comprehensive protection with the most efficient investment of resources.

LOCAL COORDINATION

Overview

191. Reconciliation of Federal and non-Federal objectives was essential to the selection of an acceptable plan. An intensive program of communication with local communities was undertaken to resolve differences. This section of the report describes the actions taken in the local coordination process, the issues identified through that process and the resolution of these issues and the incorporation of local ideas into the project plans.

General

192. Local interests were consulted throughout the process leading to the NED Plan. The public involvement program provided opportunities for everyone concerned to express their views on issues. Details of the plan were coordinated with the New Jersey Department of Environmental Protection (NJDEP), the Green Brook Flood Control Commission, local agencies and community members. The focus of this effort was to identify and resolve these issues, while identifying and resolving differences between project elements that respond to Federal planning objectives and those elements that are locally preferred and do not contribute to national economic development.

193. **Environmental Impacts.** Consideration was given to alternative measures to avoid, minimize, and mitigate for potential environmental impacts. In logical order, possible environmental measures included:

a. No action or nonstructural measures to avoid impacts. The 1980 analysis determined that non-structural methods such as early warning, relocation, flood proofing and buyouts did not provide a high level of protection for their costs. It was recognized flood protection based solely on flood proofing and buyouts could not provide a cost effective solution to flood relief in the basin. However, during the reevaluation process these techniques were reviewed and their use expanded at several specific sites to

avoid or reduce environmental impacts of the proposed structural flood controls.

b. Realignment of structural measures or combination of structural and non structural measures to minimize impacts. During the reevaluation process, the sponsor and New York District took advantage of changes to hydrologic engineering and environmental planning and policies. The redesigned project incorporated many changes to structure design which decrease environmental impacts. These changes included the elimination of the concrete flume, the relocation of levees and floodwalls to avoid stream relocations, and reduction in the sizes of the dry detention basin retention dikes.

c. Re-creating habitat to mitigate for adverse impacts that could neither be avoided or eliminated. This GRR needed to be in compliance with current regulations which require habitat analysis and mitigation for losses. A Habitat Evaluation Process to account for losses was necessary and a mitigation site screening study was conducted. A detailed discussion of the avoidance and treatment of environmental impacts is provided in the supplemental environmental impact statement (SEIS).

194. **Resolution of issues**. With the assistance of the New Jersey Department of Environmental Protection (NJDEP), conclusions were drawn about the fundamental components of the NED Plan which they accept and support. The resulting decisions were:

a. Non-structural measures are regarded as appropriate for avoiding wetland impacts, provided that the overall protection provided by the structural plan is not compromised.

b. Non-structural measures are unacceptable and inconsistent with planning objectives in areas of major access roads, emergency

facilities, schools and other critical public facilities in so far as egress during periods of inundation would be critical to public health and safety.

c. The general preference in environmentally impacted areas, where non-structural measures are deemed inappropriate, is to minimize realignment of existing stream channels and impacts to wetland areas where possible. This objective can be met by using a combination of levees and flood walls, with the possible use of non-structural measures at isolated locations.

195. The resulting revisions to the original plan provides some resolutions to these criteria and generally reduce basin wide environmental impacts. A detailed discussion of issue resolution is provided in the SEIS and the Environmental Support Document.

Coordination Process

196. Representatives of the New York District, the NJDEP and the Green Brook Flood Control Commission conducted a series of field, technical, and public meetings. These meetings were formalized and intensified from September 1994 to the issuance of the Draft General Re-evaluation Report in December of 1996. They represent the core of the local coordination effort and were integral to the decision process that resulted in the NED Plan.

197. **Field Meetings**. The local coordination effort was initiated by a series of field meetings held within specific project areas. These meetings provided for a physical review of the project alignment, an opportunity to focus issues, and a forum for local representatives to express their views concerning the project features. Walking tours of potential environmental mitigation sites were also conducted in March 1995 and March 1996 (see Appendix A, Attachment A "Walking Tour Memorandums").

198. **Office Meetings**. Field meetings were followed by a number of technical coordination meetings held at the offices of the U.S. Army Corps of Engineers (USACE) at the Jacob K. Javits Federal Building in New York City on January 4 and 17, and February 15, 1995. These meetings were held to discuss many of the project issues highlighted by the field meetings, to

reach conclusions concerning plan options, and to define the technical implications of alternatives to the proposed flood protection plan. Many of the technical questions concerning the project were readily resolved. However, some technical issues which were raised required additional analyses to generate data which would allow the decision process to proceed. As the results of technical studies became available, coordination meetings were held to review findings with the NJDEP. Briefings on areas of significant local responsibilities focused on HTRW, real estate, environmental and mitigation findings.

199. **Public Meetings**. In addition to the field and technical meetings, the New York District and the NJDEP initiated a number of public meetings to present the project to the citizens of the basin. These meetings allowed members of the involved municipalities to become familiar with the project features, to understand the implications of the project, and to provide a forum where views concerning the project can be expressed.

Coordination Activities

200. Following is a summary of the meetings held prior to completion of the Draft General Revaluation Report and a synopsis of the views on the various issues, as expressed by the NJDEP, municipal officials, and concerned citizens.

201. **Lower Portion of the Basin**. The various segments of the lower portion of the basin were the subject of several field meetings held by representatives of the New York District, the NJDEP, and representatives of the municipalities. These meetings were held to view the possible plan alignment, to answer questions, and to discuss local acceptability and possible alternatives to the alignment and to project features.

202. The Raritan River-Green Brook confluence area was the subject of two field meetings. The first meeting was held on September 14, 1994 in the Borough of Bound Brook. It began with a morning walking tour of the planned first structural construction area, which incorporates flood protection along the east bank of Middle Brook, the north bank of the Raritan River and the west bank of Green Brook. After the morning tour, the meeting continued at the Bound Brook Borough Hall, where project features were discussed in greater detail.

203. A second meeting was held on October 11, 1994 in the Borough of Middlesex. This meeting included visits to elements of the project within both the Raritan River-Green Brook confluence area and the Green Brook-Bound Brook confluence area. A walking tour of sections of the project within both areas was performed followed by a meeting at the Middlesex Borough Hall to allow greater discussion of project details.

204. Subsequent to the field meetings and follow-up technical meetings held at the USACE offices in New York City, a series of public meetings were held in the Borough of Middlesex to specifically discuss plan alternatives for the vicinity of Prospect Place, located east of the Green Brook channel and west of Ambrose Brook. These meetings were conducted on April 4, 1995 (Green Brook Flood Control Commission Meeting) and April 18, 1995 at the Middlesex Borough Hall. An additional meeting was held Saturday May 3, 1995 at Prospect Place to discuss specific plan options with residents in that area.

205. The Green Brook-Bound Brook confluence area was the subject of a field meeting held on October 11, 1994 with a walking tour of the project alignment conducted in the morning. The tour was followed by an afternoon meeting at the Middlesex Borough Municipal Building to discuss project features in greater detail.

206. The Green Brook-Municipal Brook confluence area was the subject of a November 2, 1994 field meeting. A walking tour of the project alignment was taken in the morning and was followed by an afternoon meeting at the Green Brook Municipal Building.

207. The Bound Brook-Cedar Brook confluence area was the subject of a field meeting held on March 16, 1995. A walking tour of the project alignment was taken in the morning and followed by an afternoon meeting at the South Plainfield Municipal Building to discuss project features in greater detail. The field visit also included a walking tour of potential environmental mitigation sites. A subsequent meeting with the South Plainfield Environmental Commission and interested parties within the Borough was held on July 24, 1995 to review the proposed project alignment in greater detail and to discuss the impacts and benefits of the flood control plan.

208. **Upper Portion of the Basin**. The upper portion of the basin encompasses the Sky Top and Oak Way dry detention basins and channel modifications to Green Brook upstream of its

confluence with Stony Brook. Both the dry detention basins and the upper Green Brook channel modifications were the subject of a field meeting held on December 7, 1994. The field visit was conducted to physically review the possible plan alignment, to answer questions, and to discuss local acceptability and possible alternatives to the project features or alignment. Additional meetings were held at the Watchung Reservation on May 10 and July 26, 1995 to further discuss the impacts and benefits of the Sky Top detention facility. An additional meeting was also held on March 16, 1994, in conjunction with the field meeting for the Bound Brook-Cedar Brook confluence area, to review the area inundated by the Green Brook to Cedar Brook flow diversion.

209. **Stony Brook** . The Stony Brook portion of the basin encompasses potential plan features from the downstream limit of Stony Brook at its confluence with Green Brook to a point just upstream of the Somerset and Watchung Avenue intersection. This portion of the basin was also the subject of a field meeting held on November 2, 1994 in conjunction with the field meeting for the Green Brook Municipal Brook confluence area in the lower portion of the basin. Representatives of the New York District, the NJDEP, and representatives of the local community attended. The field visit was conducted to physically review the possible plan alignment, to answer questions, and to discuss local acceptability and possible alternatives to the alignment or project features. Subsequent to the field visit, participants recessed to the Green Brook Town Hall to discuss project issues in greater detail.

Coordination Results

210. The decisions reached on the issues identified in the coordination process are summarized below.

211. **Lower Portion of the Basin**. Results for the lower portion of the basin have been summarized for each major confluence area.

212. Raritan River - Green Brook Confluence Area. Numerous analyses, investigations, and discussions occurred in response to the concerns raised over the project features in the Raritan River-Green Brook Confluence Area. Concurrence on these issues was achieved as follows:

a. Tea Street Area. Levees were realigned along the east bank of Middle Brook to allow the continued use of ball fields west of Tea Street. This change does not measurably impact NED costs.

b. Commercial and Local Development. The line of protection alignment was slightly altered along the upper section of Middle Brook to preserve open areas for potential commercial development and to better accommodate existing local development. This change does not measurably impact NED costs.

c. Bridge Raising Options. Discussions were held regarding the elimination of the closure structure at the Talmage Avenue-Tea Street intersection, and replacement with a roadway and bridge raising. All parties ultimately concurred that the closure structure is the most viable option at this location. However, subsequent feature design efforts have revealed that this closure structure could be eliminated. The line of protection at Talmage Avenue is completed by raising the upstream and downstream bridge parapets.

d. Brook Industrial Park. Minimization of disturbances caused by the Flood Control Project construction between the Brook Industrial Park and the Conrail railroad embankment due to possible hazardous waste in the vicinity of Brook Industrial Park were investigated. Possible types of flood protection were discussed including levees, reinforced concrete T-walls, and sheet-pile concrete encased floodwalls. T-walls were determined to be the most viable option. Levees would cause greater disturbances and would be difficult to fit into the constrained area which is available for construction. Sheet pile floodwalls were dismissed because the height requirement of the flood protection exceeds the maximum structural height allowed for sheet pile driven floodwalls.

e. Municipal Park. The alignment of the proposed levees along the west bank of Green Brook in the area of the proposed municipal park were

shifted toward the stream to the maximum extent possible without impacting freshwater wetlands.

f. Protection Alternatives just south of Union Avenue. Additional analyses of the interior drainage pump station and the levee closure along the west bank of Green Brook just south of Union Ave. were performed and indicated that the pump station capacity and the cost of this segment of the project can be reduced by revising the location of the levee closure. The revised levee closure will tie-off into high ground just west of East Street instead of tieing off into the raised roadway embankment along Union Avenue as originally envisioned. This alternative has been incorporated into the Plan and is an example of how a coordinated evaluation of interior drainage facility and the line of protection alignment results in the most efficient plan.

g. Minimize Wetland Disturbances in the vicinity of Prospect Place. As part of the plan formulation process to avoid, minimize and mitigate environmental impacts, and in response to concerns expressed by the NJDEP over the potential wetlands disturbances, the study team performed a preliminary analysis of potential alternatives to the proposed levee system. This analysis demonstrated that a sheet pile driven concrete encased floodwall could be used in lieu of the levee system originally proposed. The floodwall would be located at the top of the natural slope along the rear yard line of homes along Prospect Place. In contrast, the levee alternative would be located at the bottom of the slope causing the associated disruption of forested wetlands. Additional alternatives explored at this location include a non-structural flood proofing plan and a buy out plan. The flood protection alternatives for this area were the subject of number of public meetings held to discuss the details, merits, and disadvantages of each alternative. After two night meetings and a weekend meeting held at Prospect Place, there appeared to be a general consensus that the non-structural plan was the locally

preferred alternative for this section of the project. Since a non-structural plan in this area will not compromise the function of major access roads or public facilities during a storm event, it was determined that non-structural measures successfully avoid environmental impacts and still meet the planning objectives for flood protection. Therefore, the non-structural alternative has been incorporated as an element of the NED Plan.

213. Green Brook - Bound Brook Confluence Area. Project alignment issues were discussed at length and have been analyzed further to determine if alignment alternatives desired by local representatives are, in fact, consistent with NED criteria. In accordance with the decision process approach, the ordered preference of avoidance, minimization, and mitigation encompasses the attempts made to address environmental disturbances. Following is a synopsis of the project issues discussed for this confluence area, and the conclusions reached concerning the applicability of alternatives to the NED Plan.

a. Raising of the Sebrings Mill Road Bridge. This bridge is currently scheduled to be replaced and raised approximately 5 feet under the NED Plan. In response to the concerns regarding the higher undesirable road profile, the option of maintaining the existing road profile and providing a swing gate closure structure across Sebrings Mills Road was examined in greater detail.

   Analyses indicated that if the existing bridge were to remain, additional hydraulic losses would require increased height on upstream levees, thereby greatly increasing project costs beyond the savings realized by the elimination of bridge work. All parties agreed to dismiss the closure structure option and to retain the bridge replacement as a feature of the flood protection plan.

b. Green Brook and Bound Brook Stream Relocations. Two areas within this section of the project require streambed relocations to provide sufficient area for the construction of levees. The NJDEP expressed concern that the extensive loss of natural streambed would cause an

unacceptable degree of environmental disturbance. The NJDEP requested that the New York District examine potential alignment alternatives to the proposed stream relocations along the south bank of Green and Bound Brooks from Sebrings Mills Road to Union Avenue and along the north bank of Bound Brook between Lincoln Avenue and the N.J. Transit railroad crossing. Four potential alternatives were analyzed at each of the locations. The alternatives were: 1) the originally proposed alignment incorporating the streambed relocations and environmental mitigation in the newly created channel, 2) maintenance of the existing stream alignment with non-structural flood protection (flood proofing) provided throughout the reach, 3) maintenance of the existing stream alignment with flood protection provided by a levee/floodwall alternative including property and structure acquisitions as needed, and 4) a hybrid combination plan that would utilize levees and floodwalls with minimal stream relocations.

The preferred flood protection alternative from an environmental perspective would utilize non-structural measures to avoid disturbances caused by the implementation of the structural plan. However, the implementation of a non-structural plan for this area would be inconsistent with the planning objectives, leaving major access roads and emergency facilities inaccessible during a flood event. Therefore, the hybrid combination plan which minimizes environmental disturbance and retains a level of cost efficiency required to maximize the net excess benefits of the flood protection plan has been incorporated as an element of the NED Plan.

c. Bonygutt Brook Relocation. A section of Bonygutt Brook is subject to relocation to an area along the northeast side of Warrenville Road. The relocated channel would direct flows to a proposed interior drainage pump station. The NJDEP expressed concern over the loss of natural streambed within the lower reach of Bonygutt Brook just upstream of its confluence with Green Brook on the southwest side of Warrenville Road.

All parties agreed that the existing Bonygutt Brook alignment can be readily incorporated into the project and that a separate overflow channel can be utilized to direct flood flows to the interior pump station. Preservation of the existing Bonygutt Brook channel has been incorporated into the NED Plan.

214. Green Brook - Municipal Brook Confluence Area. Project alignment issues were discussed at length and have been analyzed further to determine if alignment alternatives desired by the NJDEP or the community can be incorporated into the NED Plan. Since the primary concern raised by the NJDEP focuses on environmental disturbances, the ordered preference of avoidance, minimization, and mitigation defined in the decision process was applied. Following is a synopsis of the conclusions reached concerning the applicability of alternatives for inclusion in the NED Plan.

a. Relocation of The Lower Reach of Municipal Brook. The originally proposed flood control plan incorporates tie back levees up both banks of Municipal Brook. These levees primarily guard against backwater flooding caused by high flood stages in Green Brook. Construction of the proposed Municipal Brook levees would require relocation of a portion of the existing Municipal Brook streambed and would also disturb wetlands along Municipal Brook between Green Brook Road and the Green Brook channel. As an alternative, a levee closure across the mouth of Municipal Brook was considered. This levee, which would run parallel to Green Brook from Jefferson Avenue to Washington Avenue, would create an interior drainage area within the lower reach of Municipal Brook.

Analyses of this alternative indicated that the remaining interior area behind such a levee closure would not provide sufficient flood storage to contain Municipal Brook flows. The lack of available flood storage is primarily due to the relatively low damage threshold associated with the low elevations of residences surrounding the Green Brook / Municipal Brook confluence area. Due to the lack of flood storage, the required pump station capacity for this levee closure across

the mouth of Municipal Brook would exceed the capacity of the largest pump station currently contemplated for the project by a factor of 3 to 4. Based on the excessive pump station requirements and associated costs, this alternative was dismissed from further consideration for the NED Plan.

b. Green Brook Stream Relocation. Construction of the current levee alignment along the south bank of Green Brook would require a streambed relocation to provide sufficient area for construction. Four potential alternatives were analyzed to address the NJDEP concerns regarding the loss of natural streambed habitat. The alternatives were: 1) the originally proposed alignment incorporating the streambed relocations and environmental mitigation in the newly created channel, 2) maintenance of the existing stream alignment with non-structural flood protection (flood proofing) provided throughout the reach, 3) maintenance of the existing stream alignment with flood protection provided by a levee / floodwall alternative including property and structure acquisitions as needed, and 4) a hybrid combination plan that would utilize levees and floodwalls with minimal stream relocations.

The preferred flood protection alternative, from an environmental perspective, would utilize non-structural measures to avoid disturbances caused by the implementation of the structural plan. However, the implementation of a non-structural plan for this area would be inconsistent with the planning objectives, leaving a major access road inaccessible during a flood event. Therefore, the NED Plan has incorporated the hybrid combination plan which minimizes environmental disturbance and retains a level of cost efficiency required to maximize the net excess benefits of the flood protection plan.

215. Bound Brook-Cedar Brook Confluence Area. Project alignment issues discussed are the subject of ongoing analyses as follows:

a. Highland Woods Nature Reserve. The current project alignment proposes the construction of a tie back levee along both sides of Bound

Brook Tributary #3. The proposed tie back levee along the east bank of the tributary is currently located in this nature reserve area. Two possible alternatives discussed included an alteration to the alignment of the proposed levee relocating it to the fringe of the proposed nature reserve area, or a levee closure across the mouth of the tributary with an integral pump station to pump tributary flows during a storm event. The closure across the mouth of the tributary would eliminate the need for the tie back levees south of New Market Ave. Both of these alternatives will be considered when this element of the project proceeds into the feature design stage of development.

b. Spring Lake Park. The originally proposed levee alignment has been refined to eliminate the disturbances to the parking area and basketball courts. Incorporation of the levee into the park facility will require further detailed assessments which will be accomplished when this project area proceeds into design.

216. Bound Brook - Non-structural Reach. Since there were no significant concerns presented by the NJDEP, it was agreed by all parties that a non-structural plan through this reach is included in the NED Plan.

217. **Upper Portion of the Basin**.

218. Dry Detention Basins. As part of the original alignment investigations and in response to local concerns, the New York District has examined potential alternative locations for the currently proposed detention facilities. Moving the Sky Top detention structure upstream is not a viable alternate due to the loss of adequate inflow sources to achieve the flood control mission. Moving the detention structure downstream was also examined and coordinated with the Union County Parks Department. Union County Parks and the New York District concurred that moving the Sky Top detention structure downstream would cause greater environmental impacts to upland forested areas. Therefore, this option was not considered a viable alignment alternative.

219. Local representatives also requested that the New York District explore the possibility of utilizing the quarry southeast of Valley Road as a possible site for floodwater storage. Subsequent to the initial field meeting, contacts with the quarry owner revealed that the quarry has a life

expectancy of greater than 30 years, and is also the site of active asphalt and concrete plants. Based on the current active status of the quarry, it was dropped from further consideration as a flood detention site.

220. As a result of the concerns expressed by local representatives, refinements to minimize environmental and aesthetic disturbances which would be created by the Sky Top detention structure are the subject of ongoing coordination.

221. Channel Modifications. As outlined previously, a comprehensive channel plan preventing flow diversions for events up to the 150-year level storm was initially examined. However, an economic analysis of this alternative demonstrated that it did not generate benefits beyond its costs, and therefore, could not be supported as part of the NED plan. In addition, there are more severe environmental impacts associated with a large scale channel improvement. Although the NJDEP has expressed a desire to provide a 150-year level of flood protection from the Green Brook to Cedar Brook flow diversion, it recognizes that there is a substantial increase in cost of this alternative over the small channel improvement which is the NED plan element. NJDEP would bear 100% of the costs in excess of the Federally supported element. At the request of the NJDEP, a smaller channel improvement meeting NED criteria was developed and incorporated into the plan, as discussed. This portion of the basin will be the subject of further evaluation to balance the need for flood protection with environmental and social considerations.

222. **Stony Brook**. The NJDEP has expressed a desire to provide a 150-year level of flood protection through the Stony Brook portion of the basin, but recognizes that the substantial increase in cost of this alternative over the limited channel modification would also be considered a local responsibility that would require that the NJDEP bear 100% of the costs in excess of the Federally supported element. The channel would also severely impact one of the few viable fish habitats in the project area. The New York District initiated additional investigations to determine if a lower level of channel modification could be economically justified and incorporated into the NED plan. As previously stated, these investigations revealed that a limited channel modification along Stony Brook from just downstream of the Rockview Terrace bridge to the Interhaven Avenue bridge can be incorporated as an NED plan element. This plan would provide increases to the capacity of the Stony Brook channel to approximately a 25-year level of protection.

223. **Summary of Results**. As a result of past local coordination activities, certain justifiable modifications and refinements of project features have been incorporated into the plan. Other areas of local concern, such as Highland Woods Nature Reserve, and Spring Lake Park will be

the subject of ongoing public coordination efforts and plan refinements during the feature design phase. As described in subsequent sections of this document, additional social and environmental concerns regarding improvements in the upper basin warrant continued evaluation of flood protection alternatives. It should be noted that these project features as currently designed represent NED plan elements. Future locally preferred modifications that result in substantial costs increases will be viewed as project improvements and the additional costs will be 100% non-Federal sponsor responsibility.

THE NED PLAN

Overview

224. The selected NED plan provides for extensive improvements throughout the three portions of the basin, including levee-floodwall systems, closure structures, pump stations, interior drainage structures, channel modifications, bridge replacements, and non-structural measures.

General

225. The National Economic Development Plan was selected based on the objectives of contributing to National Economic Development through the reduction of flood hazards and associated flood damages, while protecting the Nation's natural and social resources. This plan provides a complete, effective, efficient, and acceptable flood control that reasonably maximizes net excess benefits while providing comprehensive protection throughout this urbanized watershed. The NED Plan includes the base line project features that are used to establish the financial limits of Federal participation. Based on plan formulation, project scaling, environmental assessments and local coordination, the following NED Plan components have been identified for the three portions of the basin.

Lower Portion of the Basin

226. **Plan Overview**. The August 1980 Feasibility Report identified Plan E, protecting only the lower portion of the basin, as the NED plan for the flood control project. This plan was ultimately endorsed by the Administration and forwarded to Congress by the Assistant Secretary of the Army in his correspondence of February 1984. Though Congress chose to authorize a plan which raised the lower portion of the basin flood protection to the 500 year level, the NED plan remains the 150 year level of protection plan endorsed by the Administration. The plan proposed for the lower portion of the basin in this report is consistent with the Administration Plan and

includes levees, floodwalls, bridge raisings, closure structures and non-structural measures to provide protection from exterior flooding. A 150-year design level was chosen for the line of protection, with consistent interior drainage protection, as described previously.

227. **Basin Reaches**. The NED Plan features in the lower portion of the Green Brook Basin are described for the four major confluence areas and one area of non-structural improvements as follows:

a. Raritan River - Green Brook Confluence

b. Green Brook - Bound Brook Confluence

c. Green Brook - Municipal Brook Confluence

d. Bound Brook - Cedar Brook Confluence

e. Bound Brook - Non-structural Improvements

228. **Raritan River - Green Brook Confluence Area** . This area of the project incorporates protection works along Middle Brook, Raritan River, Green Brook and Ambrose Brook. As described from west to east, flood protection is provided by levees and floodwalls on the east bank of Middle Brook from U.S. Route 22 in Bridgewater Township through Bound Brook Borough to the Middle Brook-Raritan River confluence. Additional line of protection features run along the north bank of the Raritan River from the Middle Brook-Raritan River confluence to a point just west of the interchange track between NJ Transit rail lines and Conrail facilities, just west of the Bound Brook Railroad Station along the NJ Transit Railroad. Levees and floodwalls continue along the west bank of Green Brook from the railroad embankment across Lincoln Boulevard, upstream to Vosseller Brook (locally recognized as Windsor Brook). At this point the levee / floodwall system turns west along the south bank of Vosseller Brook and ties off just west of East St., completing the system which provides flood protection to the Borough of Bound Brook Business District.

229. Areas within the Borough of Middlesex in the confluence area are also protected by a floodwall and levee system along the east bank of Green Brook. A floodwall extends from just east of River Road and continues north to Lincoln Boulevard. North of Lincoln Boulevard, a levee and floodwall system runs along the east bank of Green Brook and then Ambrose Brook to tie off at a high point in Raritan Avenue.

230. Throughout these levee and floodwall systems, the railroad embankments typically provide flood protection. The flood protection in this confluence area is completed by non-structural features protecting buildings in; the vicinity of Prospect Place located just upstream of the Green Brook - Ambrose Brook confluence; and along a Green Brook tributary near Mountain Avenue; and at the west bank of Green Brook at Shepard Avenue.

231. In addition, this area of the project also includes a number of closure structures and bridge modifications or replacements. Closure structures are utilized at roadways and railroads where regrading for closure cannot be achieved and traffic must be maintained between flood events. The closure structures within the lower portion of the basin consist of swing gates or roller gates. Bridge replacements or modifications are performed at stream crossings which do not have sufficient hydraulic capacity to convey flood discharges, or do not have sufficient structural integrity to withstand the hydraulic loadings experienced during a flood event.

232. See Table 11 for a summary of the NED Plan elements within this confluence area. See Figures 6 through 9 for the proposed flood protection plan in this area.

233. **Green Brook - Bound Brook Confluence Area**. Flooding within this area impacts the municipalities of Dunellen, Green Brook, Middlesex, and Piscataway.

234. In the area of the Green Brook-Bound Brook confluence, Bound Brook turns from its generally east to west flow pattern towards the northwest to flow into Green Brook. The proposed protection within this portion of the basin includes levee and floodwall systems beginning on the south bank of Green Brook at a tie-off point just northeast of the Barbara Place and Lynn Avenue intersection, and runs eastward to the Sebrings Mill Road bridge over Green Brook. The levee / floodwall system continues from Sebrings Mill Road along the south bank of Green Brook and then in a southeasterly direction along the southwest bank of Bound Brook to Union Avenue (Bound Brook Road). Completing this system, which provides flood protection to the predominantly residential areas southwest of the Green Brook-Bound Brook confluence, is a series of levees and floodwalls which run from Union Avenue Bound Brook Road along Bound Brook upstream to a tie-off just east of the Mountain Avenue and Hancock Street intersection near the Middlesex Municipal Complex. A second levee and floodwall system to protect the southwest bank of Bound Brook begins near the intersection of Pershing and Sheridan Ave. and extends through Lincoln Avenue to high ground near the end of Lincoln Boulevard.

235. Residential, industrial and municipal properties located east of Bound Brook and south of Green Brook are protected by a horseshoe shaped levee-floodwall system which begins at the

TABLE 11
DESCRIPTION OF NED PLAN ELEMENTS AT THE
RARITAN RIVER - GREEN BROOK CONFLUENCE AREA
150-Year Level of Protection

Stream	Bank	Type of Protection	Location	Pertinent Dimensions	Bridge Alterations
Middle Brook/ Raritan River	East / North	Levees, Floodwalls, and Closure Structures	Along the east bank of Middle Brook from the Route 22 bridge downstream to the Raritan River along the north bank of the Raritan River to the Conrail / N.J. Transit Interchange Line.	Length: 10,430 feet Height range: 4 - 17 feet Closure Structures: - N.J. Transit RR Track - Main Street	Talmage Avenue (Structural Modifications)
Green Brook	West	Levees, Floodwalls, Closure Structures and Non-structural	Extend from N.J. Transit R.R. across Lincoln Blvd. upstream to Vosseller Brook, along the south bank of Vosseller Brook to high ground west of East St. Six flood proofs in this area as well as an additional six flood proofs at the Green Brook tributary and a flood proof at Shepard Ave.	Length: 2,460 feet Height range: 5 - 9 feet Closure Structure: - East Street	Main St./Lincoln Blvd. (Replace) East Street Culvert (Replace)
Green Brook/ Ambrose Brook	East / West	Non-structural	Non-structural plan incorporating flood proofs for approximately 22 structures.	None	None
Green Brook/ Ambrose Brook	East/ East	Levees, Floodwalls & Closure Structure	From north side of NJ Transit R.R. embankment along east bank of Green Brook to north of Lincoln Blvd then along Ambrose Brook to high ground 375' north of intersection of Raritan Ave. and Walnut St.	Length: 2,280 feet Height range: 8 - 16 feet Closure Structure: - River Road	Main St./ Lincoln Blvd. (Replace)

N.J. Transit railroad embankment on the east bank of Bound Brook, just downstream of the N.J. Transit culvert over Bound Brook. From this point, a levee / floodwall system extends along the east bank of Bound Brook to Lincoln Avenue. From Lincoln Avenue, the alignment continues along the east bank of Bound Brook to Bound Brook Road (Union Avenue). From this location, the levee creates a loop around the Middlesex County Park and heads along the south bank of Green Brook, crossing the mouth of Bonygutt Brook and tying into the Warrenville Road bridge approach road. The levee continues northeast of Warrenville Road for approximately 1,600 feet to high ground just north of Mountain View Terrace.

236. A significant feature of this area's flood protection system is the levee closure at the mouth of Bonygutt Brook. The current alignment is a deviation from the original protection plan presented in the 1980 Feasibility Report. The original plan for Bonygutt Brook included a system of levees and floodwalls from the Bonygutt-Green Brook confluence upstream along either bank of Bonygutt Brook to the NJ Transit (formerly Central Railroad) culvert. These levees and floodwalls provided flood protection from backwater flooding generated by high flood stages along Green Brook. Subsequent to the development of the Feasibility Study, hydraulic and economic analyses resulted in the determination that protection from Green Brook backwater would be better provided by a closure levee across the mouth of the Bonygutt Brook. This levee closure plan is completed by the inclusion of an interior area pump station to discharge Bonygutt flows over the levee during flood events.

237. The north bank of Green Brook in this area is also protected by a levee system which begins at Green Brook Road, just west of the Muhlenberg Medical Center and loops south of the Medical Center and continues along the north bank of Green Brook to Warrenville Road. The levee continues east from Warrenville Road for approximately 1,000 feet to a tie-off point into high ground just south of Green Brook Road, completing the line of protection within the Green Brook-Bound Brook confluence area.

238. This area of the Flood Control Project also includes a number of closure structures and bridge modifications.

239. Table 12 presents a summary of the NED Plan elements within this confluence area. See Figures 10, 11, and 22 for a schematic of the proposed flood protection plan in this area.

TABLE 12
DESCRIPTION OF NED PLAN ELEMENTS AT THE
GREEN BROOK - BOUND BROOK CONFLUENCE AREA
150-Year Level of Protection

Stream	Bank	Type of Protection	Location	Pertinent Dimensions	Bridge Alterations
Bound Brook/ Green Brook	West / South	Levees and Floodwall	From high ground 100' north of the Barbara Pl. & Lynn Ave. intersection along Green Brook south bank upstream to Bound Brook then along Bound Brook upstream to approx. 400' east of intersection of Hancock St. & Mountain Ave.	Length: 6,130 feet Height range: 10-21ft Closure Structure: - Union Ave (Bound Brook Rd.)	Sebrings Mills Rd.. (Replace)
Bound Brook	South	Levees & Floodwall	From Pershing Ave., about 1,600' downstream of the South Lincoln Ave. bridge to high ground 800' upstream of the South Lincoln Ave. bridge	Length: 2,840 feet Height range: 10-15 ft	South Lincoln Ave. (Replace)
Bound Brook/ Green Brook	North & East / South	Levees & Floodwall	From N.J. Transit R.R. downstream along the north and east bank of Bound Brook to the confluence with Green Brook. From confluence, upstream along south bank of Green Brook to a point 100' northwest of Mountain View Terr. (approximately 1,600' northeast of Warrenville Road bridge). One flood proofing in this area.	Length: 16,050 feet Height range: 8-21 ft Closure Structure: - Bound Brook Rd. (Union Ave)	None
Green Brook	North	Levees & Floodwall and Non-structural	Levees and floodwall from high ground 200' east of Muhlenberg Medical Center approx. 1,500' upstream of the Bound Brook confluence to a point 1,300' north of the Warrenville Rd.. bridge. Non-structural plan extends approximately 1,400' downstream of Sebrings Mill Rd.. and continues just upstream of Bound Brook confluence, 15 structures are to be flood proofed.	Length: 6,410 feet Height range: 6-15 ft	None

240. **Green Brook - Municipal Brook Confluence Area**. Flooding within this area impacts the municipalities of Dunellen and Green Brook.

241. The flood control features in the Green Brook-Municipal Brook confluence area consist primarily of levees and floodwalls along the north and south banks of Green Brook with tie-back levees up Municipal Brook. The flood protection system begins at a tie-off point on the north bank of Green Brook, approximately 600 feet west of the Madison Avenue bridge, continues along the north bank of Green Brook to Madison Avenue where a closure structure will be employed as part of the line of protection. From here the line of protection continues eastward across the existing mouth of Municipal Brook onto the Washington Avenue bridge approach road. Municipal Brook will be cut off from its existing channel and will be relocated to the east. The proposed Municipal Brook channel will enter Green Brook just upstream of the Washington Avenue bridge.

242. Levees extend north on either side of the relocated Municipal Brook channel from Washington and Jefferson Avenues and tie into Green Brook Road either side of its crossing over Municipal Brook. A floodwall along the west side of Municipal Brook continues to high ground an estimated 250 feet upstream of Green Brook Road. A levee and floodwall system extends along the east and south side of Municipal Brook through rear yards of a residential area along Green Brook Road. This levee continues eastward to a tie-off point at an access drive approximately 500 feet west of the Green Brook Road-Rock Avenue intersection.

243. Flood protection along Green Brook upstream of the Municipal Brook confluence is provided by a levee which is a continuation of the tie back levee up Municipal Brook and extends along the north bank of Green Brook, to Rock Avenue, onto Clinton Avenue, and eventually to a tie-off point along the northeast bank of Stony Brook, approximately 500 feet upstream of the Stony Brook-Green Brook confluence. Additional protection is provided along the south bank of Green Brook by a levee/floodwall system which begins at a tie-off point approximately 500 feet west of Washington Avenue and continues east through Washington Avenue and across Jefferson Avenue. The Jefferson Avenue bridge is to be permanently removed. Approximately 300 feet upstream of Jefferson Avenue, the levee turns southward and ties off into high ground at a point just north of First Street, approximately 500 feet north of the First Street-Jefferson Avenue intersection. The levee/floodwall system on the south bank completes the line of protection within the Green Brook-Municipal Brook confluence area.

244. The flood protection plan in this area also includes one swing gate closure structure across Madison Avenue on the north bank of Green Brook. In addition, the following bridges will be replaced:

a. Washington Avenue over Green Brook;

b. Green Brook Road over Municipal Brook; and,

c. Clinton Avenue over Green Brook.

245. As noted previously, the Jefferson Avenue bridge over Green Brook will be removed as part of the Flood Control Project, but will not be replaced at the expressed desire of the local interests. Rock Avenue bridge will not be altered. See Table 13 for a summary of the NED Plan elements within this confluence area. See Figures 12 and 13 for a schematic of the proposed flood protection plan in this area.

246. **Bound Brook-Cedar Brook Confluence Area**. Flooding within this area impacts the municipality of South Plainfield.

247. The flood control elements can be described in two distinct sections. Levees and floodwalls along the north bank of Cedar Brook and levees and floodwalls along the east and west banks of a Bound Brook tributary (hereinafter referred to as Bound Brook Tributary #3) which drains into Bound Brook from the south, approximately 1,200 feet downstream of the Cedar Brook-Bound Brook confluence.

248. The flood protection system along the north bank of Cedar Brook begins approximately 100 feet east of the foot of Dunham Avenue and extends southeast around the foot of Oakmoor Avenue where the alignment turns eastward to tie into the raised approach road of Plainfield Avenue. At Plainfield Avenue, the levee again runs eastward along the north shore of Spring Lake and ultimately ties into high ground at the southeast corner of the South Plainfield High School. In addition to the structural elements in this area, approximately 32 structures along Allen Drive, Norway Lane, and Sampton Avenue near the intersection with Clinton Avenue require flood proofing. The levee and floodwall system along Bound Brook Tributary #3 begins as a floodwall along the south bank of Bound Brook at a point approximately 300 feet west of

TABLE 13
DESCRIPTION OF NED PLAN ELEMENTS AT THE
GREEN BROOK MUNICIPAL BROOK CONFLUENCE AREA
150-Year Level of Protection

Stream	Bank	Type of Protection	Location	Pertinent Dimensions	Bridge Alterations
Green Brook/ Municipal Brook	North/ West	Levees & Floodwalls	From a point 600' west and downstream of Madison Ave. bridge to point 250' northwest of Green Brook Rd. bridge on Municipal Brook. One flood proofing, several hundred feet downstream of levee segment.	Length: 5,010 feet Height range: 7 - 13feet Closure Structure: - Madison Avenue	N. Washington Ave. (Replace) Green Brook Rd. (Replace)
Green Brook/ Municipal Brook	North/ East	Levees & Floodwalls	From 500' downstream of the Rock Ave. bridge along east bank of Municipal Brook to north bank Green Brook upstream to high ground at Stony Brook confluence with Green Brook.	Length: 10,850 feet Height range: 4 - 12 feet	Green Brook Rd. (Replace) Jefferson Ave. (Remove) Rock Ave. (Remain) Clinton Ave. (Replace)
Green Brook	South	Levees	From a point 500' downstream of the N. Washington Ave. bridge to approx. 500' north of First St.-Jefferson Ave. intersection. One flood proofing near Madison Ave. bridge.	Length: 3,880 feet Height range: 9 - 12 feet	N. Washington Ave. (Replace) Jefferson Ave. (Remove)

Clinton Ave. and extends east to Clinton Ave. where a roller gate closure structure is incorporated. From this point a levee continues along the south side of the Conrail railroad embankment on the south bank of Bound Brook. At the tributary's confluence with Bound Brook, the levee turns south along the west bank of Tributary #3 across New Market Ave. and continues another 550 feet south before turning to a tie-off point in high ground approximately 500 feet to the east.

249. The levee on the opposite bank of Tributary #3 originates at a tie-off point in a raised section of New Market Ave. just west of the New Market Ave. and Pulaski Street intersection and runs westward paralleling New Market Ave. The levee then turns south across the New Market Ave. bridge approach road. From this location, the levee continues southward along the east bank of the tributary to a point along Carmine Avenue, approximately 500 feet south of the intersection of Carmine and Amboy Avenues.

250. The flood protection plan in this area includes one roller gate closure structure and two bridge replacements. Table 14 displays a summary of the NED Plan elements within this confluence area. See Figures 26 and 27 for a schematic of the proposed flood protection plan in this area.

251. **Bound Brook - Non-structural Reach**. Flooding within this area impacts the municipality of Piscataway.

252. The flood control features along this portion of the Bound Brook channel consist of non-structural measures extending from the NJ Transit lines at the Piscataway - Middlesex boundary upstream to just beyond Brunswick Avenue. Approximately 58 structures are to be flood proofed within this reach; 50 along the north bank and 8 along the south bank.

253. See Table 15 for a summary of the NED Plan elements within this confluence area. See Figures 23, 24, and 25 for a schematic of the flood protection plan in this reach.

Upper Portion of the Basin

254. **Plan Overview**. The NED Plan identified for the upper portion of the basin includes two dry detention basins and channel modifications along the upper portion of Green Brook, reducing the frequency and severity of the diversion of flow from Green Brook into the streets of

TABLE 14
DESCRIPTION OF NED PLAN ELEMENTS AT THE
BOUND BROOK CEDAR BROOK CONFLUENCE AREA
150-Year Level of Protection

Stream	Bank	Type of Protection	Location	Pertinent Dimensions	Bridge Alterations
Cedar Brook	North	Levees	From high ground at a point 100' east of Dunham Ave. (approx. 1,150' north of the confluence of Cedar Brook and Bound Brook) upstream to point south of the intersection of Cromwell Pl. and Stratford Ave.	Length: 5,490 feet Height range: 5-14 feet	Plainfield Ave. (Replace)
Bound Brook	North	Non-structural	From Norway Lane area downstream to point 300' west of Clinton Avenue, approximately 32 flood proofs	-	None
Bound Brook/Bound Brook Tributary #3	South/ West	Levees & Floodwalls	From point 300' west of Clinton Ave. bridge west along south side of railroad embankment to confluence then over New Market Ave. bridge along Tributary #3 to high ground 1000' southwest of the New Market Ave.	Length: 3,510 feet Height range: 5-10 feet Closure Structure: - Clinton Avenue	New Market Ave. (Replace)
Bound Brook / Bound Brook Tributary #3	South/ East	Levee	From a point 250' east of the intersection of Pulaski St. and New Market Ave. west to the New Market Ave. Bridge and upstream along the right bank of Tributary #3 to a point 650' south of Amboy Ave. between Elsie Ave. & Carmine Ave.	Length: 4,250 feet Height range: 5-13 feet	New Market Ave. (Replace)

TABLE 15
DESCRIPTION OF NED PLAN ELEMENTS AT THE
BOUND BROOK NON-STRUCTURAL REACH

Stream	Bank	Type of Protection	Location	Pertinent Data	Bridge Alterations
Bound Brook	North	Non-structural Plan	NJ Central RR upstream to just beyond New Brunswick Avenue	50 structures flood proofed	None
Bound Brook	South	Non-structural Plan	NJ Central RR upstream to just beyond New Brunswick Avenue	8 structures flood proofed	None

Scotch Plains and Plainfield. Diversion flooding will continue to impact the municipalities of Plainfield and Scotch Plains during storms with an exceedance interval of approximately 20 years. Larger scale designs were rejected as inconsistent with NED criteria.

255. **Dry Detention Basins**. The dry detention basin elements of the NED Plan for flood control in the upper portions of the Green Brook are located in the valley between First and Second Watchung Mountains. A reduction in flood flows has been identified as an essential element of any plan to reduce the magnitude of diversion out of Green Brook without substantially increasing downstream flood peaks.

256. The Sky Top dry detention basin is situated on Blue Brook, a tributary to Green Brook. The containment structure is located approximately 2,100 feet upstream of the confluence with Green Brook, in the Watchung Reservation (a Union County Park). The earthen embankment for the dry basin extends approximately 1,100 feet across the Blue Brook Valley, just north of the intersection of Valley Road, Glenside Drive and Sky Top Drive.

257. The Oak Way dry detention basin is located on Green Brook, approximately 3,400 feet upstream of its confluence with Blue Brook, in the boroughs of Watchung and Berkeley Heights. The earthen embankment extends across the Green Brook Valley (about 950 feet), cutting across Valley Road. Approximately 2,550 feet of Valley Road would be raised and slightly relocated south to avoid the embankment. See Table 16 for a summary of the NED Plan elements for this segment of the upper portion of the basin. See Figures 19 and 21 for the proposed flood protection plan in this area.

258. **Upper Green Brook Channel Modifications**. In order to maximize the effectiveness of the Oak Way and Sky Top detention facilities, modifications to the Green Brook channel through Plainfield, North Plainfield and Scotch Plains have been incorporated into the NED Plan. The NED channel modifications are intended to provide a limited increase in the hydraulic capacity of the stream to extend the effectiveness of the detention facilities throughout the area of potential diversion, to offset the impact of any increase in flow and to improve channel stability. This plan would prevent flow diversions to Cedar Brook for storms having recurrence intervals of up to approximately the 20-year event. The proposed modifications consist primarily of trapezoidal and rectangular channels lined with riprap. Areas that will not undergo physical

TABLE 16
DESCRIPTION OF NED ELEMENTS
DRY DETENTION BASINS WITHIN THE
UPPER PORTION OF THE BASIN

Stream	Bank	Type of Protection	Location	Pertinent Dimensions	Bridge/Road Alterations
Blue Brook	N/A	Dry detention basin ("Sky Top")	On Blue Brook, 2,100 feet upstream of Green Brook / Blue Brook confluence.	Type: Earthfill Length: 1,120' Max Hgt: 41' Crest Elevation: 247.0 Spillway: Type: Roller Compacted Concrete (RCC) Stairstep Length: 160' Crest Elevation: 234.0 Outlet Works: 3' Dia. PMF Pool Elev.: 242.0	None
Green Brook	N/A	Dry detention basin ("Oak Way")	On Green Brook , 3,400 feet upstream of Green Brook / Blue Brook confluence.	Type: Earthfill Length: 965' Max Hgt: 45' Crest Elevation: 268.0 Spillway: Type: RCC Stairstep Length: 165' Crest Elevation: 255.0 Outlet Works: 4' Dia. PMF Pool Elev.: 263.0	Valley Road (2,550' raised and slightly relocated south)

channel improvements will be cleared and desnagged to increase the hydraulic efficiency of the existing channel.

259. Beginning at the downstream end of the proposed channel modifications, a series of trapezoidal and rectangular channels will be constructed from approximately 350 feet downstream of the West End Avenue bridge through commercial areas in Plainfield, extending to just upstream of the Somerset Street / Park Avenue bridge. The next section of channel modification is a trapezoidal channel beginning at the Farragut Avenue bridge and extending to approximately 600 feet downstream of the Netherwood Avenue bridge. The most upstream reach of the channel improvement is a trapezoidal channel approximately 5,600 feet in length running from about 500 feet upstream of the Leland Avenue bridge to the U.S. Route. 22 bridge.

260. To complete the proposed hydraulic improvements to the channel, clearing and desnagging of the reaches between the areas of proposed channel modifications will be undertaken. Clearing and desnagging will not alter the dimensions of the channel, but will remove brush, trees, minor sand/gravel bars and other debris which currently obstruct flow.

261. In addition to the channel modifications and clearing, the Netherwood Ave. bridge will be replaced in order to increase hydraulic capacity and lessen backwater effects which contribute to the diversion of flow. The replacement bridge at Netherwood Avenue will have a slightly wider opening and a low chord which will be two feet higher than the existing bridge. Other minor bridge modifications, consisting primarily of newly constructed wingwalls, will be performed at a number of bridges to increase hydraulic efficiency. See Table 17 for a summary of the NED channel modification in the upper portion of the basin. See Figures 14, 16, and 17 for a schematic of the proposed flood protection feature in this area.

Stony Brook

262. **Plan Overview**. Flooding within this portion of the project area affects the municipality of North Plainfield with lesser damages occurring in Green Brook and Watchung. The NED Plan identified for this area controls flooding from storms with an exceedance frequency of approximately 25 years. Larger scale improvements in this area do not meet NED criteria.

TABLE 17
DESCRIPTION OF NED PLAN ELEMENTS IN THE
UPPER GREEN BROOK CHANNEL MODIFICATION WITHIN THE
UPPER PORTION OF THE BASIN

Stream	Bank	Type of Protection	Location	Pertinent Dimensions	Bridge/Road Alterations
Green Brook	East/ West	Channel Modification	a. From 140' downstream of West End Ave. bridge to 65' upstream of Somerset St. bridge.	a. Trapezoidal channel Bottom width: 30' Side slopes: 2.5:1(H:V) Riprap lining length: 3,680' and, Rectangular channel Bottom width: 42'-54' (depending on locations) Concrete retaining walls; Riprap bottom length: 995' and, Regrade bottom Riprap lining length: 740'	a. Somerset St. (Add wingwalls to upstream face, west bank only) Washington Ave. (Add wingwalls to upstream face) Sycamore Ave. (Add wingwalls to upstream face) West End Ave. (Add wingwalls to upstream face)
			b. From 65' upstream of Somerset St. bridge to upstream face of Farragut Ave. bridge	b. Clearing & desnagging only Length: 5,385'	b. None
			c. From upstream face of Farragut Ave. bridge to 580' downstream of Netherwood Ave. bridge.	c. Trapezoidal channel Bottom width: 25' Side slopes: 2.5:1 (H:V) Riprap lining length: 1,390'	c. None
			d. From 580' downstream of Netherwood Ave. bridge to 560' upstream of Leland Ave. bridge.	d. Clearing & desnagging only Length: 1,480' Riprap lining length: 415'	d. Leland Ave. (Add wingwalls to upstream side) Netherwood Ave. (Replace)
			e. From 560' upstream of Leland Ave. bridge to 270' downstream of U.S. Rt. 22 bridge.	e. Trapezoidal channel Bottom width: 20' Side slopes: 2.5:1 (H:V) Riprap lining length: 5,180'	e. Raymond Ave. (Add wingwalls to upstream side)

263. **Stony Brook Channel Modifications**. A limited channel modification along Stony Brook from just downstream of the Rockview Terrace bridge to the Interhaven Ave. bridge has been incorporated as an NED plan element. A significant factor which affects the selection of the NED plan element for the Stony Brook portion of the basin is the apparent increase in channel conveyance capacities as a result of scour experienced during the August 1973 storm event.

264. The plan of improvement for this portion of the project will extend from the Rockview Terrace bridge upstream to Interhaven Ave. and will incorporate a trapezoidal channel ranging in bottom width from 25 to 45 feet, a limited area of rectangular channel having a 50 foot bottom width, a bridge replacement at Grove Street, and two bridge underpinnings at Route 22 and Green Brook Road to allow the lowering of the stream invert at those locations. The plan of protection will be completed by the addition of training dikes on the south bank of the stream just upstream of Green Brook Road and along the north bank of the stream just downstream of Grove Street, just upstream of Route 22 and between the Villa Maria driveway bridge and Interhaven Ave.

265. See Table 18 for a summary of the NED Plan Features in the Stony Brook portion of the basin. See Figures 14 and 15 for a schematic plan of the flood protection features in this area.

TABLE 18
DESCRIPTION OF NED PLAN ELEMENTS IN THE STONY BROOK PORTION OF THE BASIN

Stream	Type of Protection	Location	Pertinent Dimensions	Bridge/Road Alterations
Stony Brook	Channel Modification	a. From 300' downstream to 60' upstream of Rockview Terrace bridge.	a. Regrade bottom Riprap lining length: 730'	a. None
		b. From 60' upstream of Rockview Terrace bridge to 600' upstream of Green Brook Road bridge.	b. Trapezoidal channel Bottom Width:25'-45' Side slopes: 2.5:1 (H:V) Riprap lining length: 2180' and, Training Dike South Bank Top width: 10' Height: 1.5' Side slopes: 2.5:1 (H:V) Length: 350'	b. Green Brook Road (Underpin)
		c. From 600' upstream of Green Brook Road bridge to Grove Street bridge.	c. Rectangular channel Bottom Width: 50' Concrete retaining walls Riprap bottom length: 500' and, Rectangular/Trapezoidal channel Bottom width: 45' West Bank: Concrete retaining walls East Bank: Trapezoidal Side slopes: 2.5:1 (H:V) Riprap bottom length: 300' and, Training Dike, East Bank Top width: 10' Height: 2' Side Slopes: 2.5:1 (H:V) Length: 60'	c. Grove Street (Replace)

TABLE 18
DESCRIPTION OF NED PLAN ELEMENTS IN THE STONY BROOK PORTION OF THE BASIN

Stream	Type of Protection	Location	Pertinent Dimensions	Bridge/Road Alterations
Stony Brook (Continued)	Channel Modification	d. From Grove Street bridge to 100' upstream of U.S. Route 22 bridge.	d. Trapezoidal channel Bottom width: 25'-45' Side slopes: 2.5:1 (H:V) Riprap lining length: 630' and, Training Dike, East Bank Top width: 10' Height: 1' Side slopes: 2.5:1 (H:V) Length: 170'	d. U.S. Route 22 (Underpin)
		e. From 100' upstream of U.S. Route 22 to the downstream side of Villa Marie bridge.	e. Regrade Bottom Riprap lining length: 640'	e. None.
		f. From 50' upstream of Villa Marie bridge to 60' downstream of Interhaven Avenue bridge.	f. Training Dike, East Bank Top width: 10' Height: 1'-1.5' Side slopes: 2.5:1 (H:V) Length: 600'	f. None.

DESIGN OF THE NED PLAN

Overview

266. Development of the NED plan necessitated detailed engineering design, environmental studies and real estate investigations and appraisals. A cost estimate has been developed and, operation and maintenance requirements and residual flooding effects are also described. This section of the report describes the engineering criteria and methods of design utilized to arrive at the conclusions that support the NED plan.

Description

267. The NED plan consists of levees and floodwalls in the lower portion of the basin, channel modifications and dry detention basins in the upper portion of the basin, and a limited channel modification in the Stony Brook portion of the basin. This plan is the result of efforts undertaken in accordance with the Corps' Principles and Guidelines, and an extensive local coordination effort. For reference purposes, Tables 19, 20 and 21 display the differences among the NED plan, the plan supported by the Administration, and the plan authorized by Congress.

268. **Lower Portion of the Basin**. Structural flood protection consists of a system of levees and floodwalls required to meet the planning objectives for the majority of the lower portion of the basin. Bridge modifications, replacements and closure gates are provided as necessary to complete the line of protection. Non-structural flood protection elements were added to minimize environmental disturbances in areas where planning objectives can be met without structural flood protection. Drainage structures, detention ponds and stormwater pump stations are provided to ensure project performance.

TABLE 19
PLAN COMPARISON
LOWER PORTION OF THE BASIN

Plan Feature	Administration Plan	Authorized Plan (WRDA 86)	NED Plan (GRR 1996)	Explanation
Level of Protection	150-year	500-year	150-year	Varying levels of protection, NED Plan realigned levees and floodwalls to avoid streambed relocations.
Levees/Floodwalls	78,310 Lin. Ft.	90,000 Lin. Ft.	77,760 Lin. Ft.	Levees/floodwalls realigned to accommodate existing streambeds. NED Plan eliminated Bonygutt Brook tie-back levees.
Bridge/Road Modifications	13	14	11	Bridge replacements vary due to recent bridge reconstructions and changes in levee and floodwall alignments.
Closure Structures	10	18	8	The higher level of protection associated with the Authorized Plan requires more extensive levees, floodwalls, and roadway closures. The NED Plan includes refined project alignments which eliminated closure structures.
Channel Modifications	14,100 Lin. Ft.	14,100 Lin. Ft.	3,300 Lin. Ft.	Reduced channel realignments.
Modified Flume	650 Lin. Ft.	650 Lin. Ft.	None	NED Plan eliminated flume in efforts to minimize channel disturbances.
Pump Stations	7 (300 CFS max.)	8 (300 CFS max.)	16 (640 CFS max.)	Refined hydrology reflected coincident peak river and interior flood states negating the usefulness of gravity drains and required more pumps.
Flood Proofs	161	174	162	A higher level of protection requires more flood proofing.
Benefit:Cost Ratio	1.8	1.5	1.3	

TABLE 20
PLAN COMPARISON
UPPER PORTION OF THE BASIN

Plan Feature	Administration Plan	Authorized Plan (WRDA 86)		NED Plan (GRR 1996)		Explanation
Level of Protection		150-year		Approx. 20 Yr.		Project optimized at lower level of protection.
Levees/Floodwalls	N/A	4,300 Lin. Ft.		None		Elimination of levees/floodwalls.
Bridge/Road Modifications	N/A	14 Replacements 3 Underpinnings		1 Replacement 6 Wingwall Additions		The new plan was designed to minimize bridge modifications.
Closure Structures	N/A	None		None		
Channel Modifications	N/A	24,400 Lin. Ft.		12,400 Lin. Ft.		50% reduction in channel modification.
Modified Flume	650 Lin. Ft.	650 Lin. Ft.		None		NED Plan eliminated flume in efforts to minimize channel disturbances.
Detention Structures	N/A	2		2		Skytop optimized at a smaller structure. New development limited the size of Oak Way.
		Skytop	Oak Way	Skytop	Oak Way	
Length	N/A	1,350'	1,160'	1,120'	965'	
Height	N/A	55'	53'	41'	42'	
Flood Proofs	N/A	None		None		
Benefit:Cost Ratio	N/A	0.30		1.5		New design is cost effective.

TABLE 21
PLAN COMPARISON
STONY BROOK PORTION OF THE BASIN

Plan Feature	Administration Plan	Authorized Plan (WRDA 86)	NED Plan (GRR 1996)	Explanation
Level of Protection	N/A	150-year	Approx. 25-year	Project optimized at a lower level of protection.
Levees/Floodwalls	N/A	7,500 Lin. Ft.	None	Elimination of levees/floodwalls.
Bridge/Road Modifications	N/A	3 Replacements	1 Replacement 2 Underpinnings	The new plan was designed to minimize bridge modifications.
Closure Structures	N/A	None	None	
Channel Modifications	N/A	None	4,970 Lin. Ft.	Riprap channel used instead of concrete flume.
Concrete Flume	N/A	5,100 Lin. Ft.	None	Eliminated flume.
Flood Proofs	N/A	None	4	Building previously protected by levees flood proofed to 25-year level of protection.
Benefit:Cost Ratio	N/A	0.30	1.3	New design is cost effective.

269. **Upper Portion of Basin**. Flood protection for the upper portion of the basin is provided by a system of dry detention basins and channel modifications.

270. **Stony Brook**. Moderate flood relief for this portion of the basin is provided through the incorporation of a limited channel modification plan.

Basis of Design

271. **General**. The plans of protection for the Green Brook Basin have been developed in accordance with the Corps of Engineers guidance using the latest Engineering Regulations, circulars, manuals, and technical letters. Bridge replacements have been analyzed using American Association of State Highway and Transportation Officials (AASHTO) design criteria as modified by New Jersey Department of Transportation (NJDOT). Designs are preliminary, and will require future detailing as additional features move into the final design stage. As of the release of this report, feature level designs have been performed for Middle Brook, Raritan River and west bank of Green Brook at its confluence with the Raritan River. The level of design for these feature areas has been advanced to facilitate the preparation of construction plans and specifications.

272. The design in remaining areas is based on geotechnical and structural analyses of selected sections for typical features such as levees, floodwalls, channels and pump stations. Special features, such as bridges, closure gates and spillways were considered on an individual basis.

273. The purpose of this level of design is to provide a sound basis for project costing to determine if a Federal interest in the project exists, and to provide the local sponsor with preliminary cost sharing apportionments.

274. **Surveying and Mapping**. The alignment of project features was initially established from topographic maps developed at a scale accuracy of 1 inch = 200 feet with a 2-foot contour interval. The maps were based on aerial photographs taken in October 1986 with several critical areas updated using aerial photographs taken in April 1993. In areas that have undergone detailed feature design, i.e., the project element along Middle Brook, the Raritan River and the western bank of the initial line of protection along Green Brook, the alignment has been premised

on one-foot contour interval mapping at a scale accuracy of 1 inch = 30 feet based on 1986 aerial photographs and field-editing in 1995 and 1996 as necessary.

275. **Hydrology and Hydraulics**. Discharges for the GRR analysis are based on a HEC-1 computer model of the entire 65-square mile drainage basin subdivided into 56 basins. A detailed discussion of the Hydrologic Analysis is contained in Support Document F, Hydrology, available at the Office of the District Engineer.

276. The hydraulic analysis used the Hydraulic Engineering Center (HEC-2) Standard Step Backwater Program. Channel cross-sections were field surveyed in 1986 with overbanks obtained from digitized aerial data. Sections were generally spaced every 300 to 500 feet, and all flow controls such as bridges, culverts and dams were measured and included in the hydraulic model. Additional stream cross-sections were obtained for Vosseller Brook in 1995 when it was determined that a tie-off system extending up Vosseller Brook would be more desirable than extending the line of protection across Vosseller Brook and having to handle the drainage trapped behind the line of protection.

277. The hydraulic model was calibrated against reported flood marks for the 1971 hurricane named Doria and the August 1973 floods. Flood profiles were then developed for hypothetical storms of various exceedance frequencies.

278. The design elevation of the top of levee and floodwall protection systems were set by adding an increment of height above the design water surface elevation. This additional height was added as a risk management feature to ensure the reliability of passing the design storm without overtopping the structures. Water surface profile stability was evaluated to determine the anticipated range of water surface elevation fluctuations. Detailed overtopping analyses, performed on the feature design area levees and floodwalls, established that the top of protection must be 2.5 to 3.3 feet above the mean design water surface to reasonably assure project performance. Based on these detailed analyses, the levee and floodwall top elevations in the remaining project areas are anticipated to average 3.0 feet above the design water surface elevations. Water surface and structure design elevations are presented in Figures 31 through 48. Overtopping analysis will be performed to set final structure heights during subsequent feature design efforts.

279. A detailed discussion of the hydraulic analysis is contained in Support Document G, Hydraulics, available at the Office of the District Engineer.

280. The amount of runoff behind the levees and floodwalls was calculated using HEC-1 models for each interior area. The Interior Drainage Analysis computer program (INTDRA), was used to calculate flood stages for a variety of standard rainfall distributions, as well as selected historical events dating back to 1882. Results of the hypothetical and historic storm analyses were combined using joint probability procedures to establish interior stage vs. frequency relationships. Following more detailed feature design efforts, performance routings were conducted using the HEC Interior Flood Hazard (HECIFH) computer program. Details on interior drainage analyses are contained in Support Document H, Interior Drainage, available at the Office of the District Engineer. Although the relative extents of outlet structures and pumping stations have changed substantially, the interior drainage plan is consistent with the level of protection contained in Plan E as supported by the Administration. A comparison is displayed in Table 22.

281. In the upper portion of the basin, its was necessary to model the diversion of flow from Green Brook, through the streets of Plainfield and Scotch Plains, into the Cedar Brook Basin. From a hydraulic model of the diversion area, a stage-diversion relationship was developed. Through a stage-discharge and discharge-frequency relationship on Green Brook, a diversion frequency relationship was developed. This relationship was incorporated into the HEC-1 hydrologic model to assess the impact of diversions on downstream discharges.

282. **Geotechnical**. The geotechnical analysis is premised on an extensive subsurface exploration program.

283. In the lower portion of the basin, 110 geotechnical borings were taken between 1992 and 1995; of these, 87 were obtained in those areas along Middle Brook, Raritan River and the mouth of Green Brook which have undergone feature design. There were an additional 23 borings taken in the non-FDM areas of the lower portion of the basin. In the upper portion of the basin, an additional 39 geotechnical borings were obtained, 35 of which were distributed across the two dry detention sites. On Stony Brook, five more geotechnical borings were obtained along the course of the proposed channel improvement.

TABLE 22
DESCRIPTION OF ADMINISTRATION PLAN INTERIOR DRAINAGE FACILITIES VS. THE NED PLAN

Administration Plan				NED Plan				
Interior Drainage Area Designation	Drainage Area Size (acres)	Primary Outlet Size	Pump Station Capacity (cfs)	Interior Drainage Area Designation	Drainage Area Size (acres)	Primary Outlet Size	Pump Station Capacity (cfs)	Explanation
ML3	119	(2)-4' dia. (1)-2' dia.	N/A	ML3	92	(1)-5' dia.	N/A	Updated topo resulted in D.A. change
ML2	46	(2)-4' dia.	N/A	1ML2	29	(1)-4' dia.	N/A	ML1 and ML2 interior D.A.'s have been re-configured
ML1	99	(1)-4' dia. (2)-4'x4' box (1)-3'x4' box	N/A	2ML2	27	(1)-5' dia.	N/A	The portion of ML1 south of the railroad has been shifted to RL1
RL1	29	(1)-27" dia.	114	RL1	226	(1)-4' dia.	180	The D.A. to RL1 has been increased
GR1 GR2	18 613	(1)-4' dia. (3)-4'x5' box	8 102	GR1 GR1VOS	69 20	(1)-4'x4' box (1)-4' dia.	60 N/A	GR1&2 has been reconfigured to allow Vosseller Brook to flow directly into Green Brook
GL1	84	(1)-4'x5' box (1)-4'x4' box (1)-42" dia.	61	GL1	72	(1)-4' dia.	80	
GR3	342	(5)-4'x4' box	301	GR3 GR4	168 349	(1)-8'x8' box (2)-4' dia. (1)-3'x10' box	640 N/A	GR3&4 function as one ponding area

TABLE 22
DESCRIPTION OF ADMINISTRATION PLAN INTERIOR DRAINAGE FACILITIES VS. THE NED PLAN

Administration Plan				NED Plan				
Interior Drainage Area Designation	**Drainage Area Size (acres)**	**Primary Outlet Size**	**Pump Station Capacity (cfs)**	**Interior Drainage Area Designation**	**Drainage Area Size (acres)**	**Primary Outlet Size**	**Pump Station Capacity (cfs)**	**Explanation**
GL4	50	(2)-4' dia.	N/A	GL4	73	(1)-3' dia.	46	More detailed hydrology indicated blocked conditions requiring a pump station
GL5	100	(2)-4'x4' box (1)-4'x5' box	N/A	GL5	120	(1)-3' dia.	135	More detailed hydrology indicated blocked conditions requiring a pump station
GL6	27	(2)-4'x4' box (1)-4'x3' box	N/A	GL6	22	(1)-3' dia.	N/A	
GL7	28	(1)-2' dia. (1)-4' dia.	N/A	GL7	47	(1)-3' dia.	N/A	GL7 & Bonygutt function as one pond. The NED Plan includes a levee closure across the mouth of Bonygutt Brook and utilizes a pump station in lieu of tie back levees
GL8	75	(2)-4'x4' box	N/A	Bonygutt	281	(4)-4' dia. (1)-7'x7' box @ Pump Sta.	640	
BGL1	33	(1)-42" dia.	N/A	Eliminated				Eliminated by Bonygutt closure
BGR1	252	(2)-4'x5'	210	Eliminated				Eliminated by Bonygutt closure

TABLE 22
DESCRIPTION OF ADMINISTRATION PLAN INTERIOR DRAINAGE FACILITIES VS. THE NED PLAN

Administration Plan				NED Plan				
Interior Drainage Area Designation	Drainage Area Size (acres)	Primary Outlet Size	Pump Station Capacity (cfs)	Interior Drainage Area Designation	Drainage Area Size (acres)	Primary Outlet Size	Pump Station Capacity (cfs)	Explanation
BDR1	55	(1)-3' dia. (2)-4' dia.N/A	N/A	BDR1	95	(1)-2' dia.	N/A	
BDR2	69	(2)-4'x4' box (2)-4'x3' box	N/A	BDR2	90	(1)-2' dia.	105	More detailed hydrology indicated blocked conditions requiring a pump station
BDR3	78	(1)-3' dia. (1)-4'x5' box	N/A	BDR3 BDR4	38 61	(1)-2' dia. (2)-4' dia.	54 50	More detailed hydrology indicated blocked conditions requiring a pump station
BDL1	51	(1)-2' dia. (1)-4' dia.	N/A	BDL1	69	(1)-4' dia.	N/A	
GR4	106	(1)-4'x5' box (1)-4'x4' box (1)-42" dia.	N/A	GR5	143	(1)-4' dia.	143	GR5&6 function as one ponding area & include diversion
GR5	58	(1)-4'x4' box (1)-4'x5' box	N/A	GR6	124	(1)-4' dia.	N/A	

TABLE 22
DESCRIPTION OF ADMINISTRATION PLAN INTERIOR DRAINAGE FACILITIES VS. THE NED PLAN

Administration Plan				NED Plan				
Interior Drainage Area Designation	Drainage Area Size (acres)	Primary Outlet Size	Pump Station Capacity (cfs)	Interior Drainage Area Designation	Drainage Area Size (acres)	Primary Outlet Size	Pump Station Capacity (cfs)	Explanation
GR6	33	(2)-4' dia. (1)-2' dia.	N/A	GR7	65	(1)-3' dia.	N/A	GR7&8 function as one ponding area. More detailed hydrology indicated blocked conditions requiring a pump station
GR7	374	(1)-4'x5' box (4)-4'x4' box	N/A	GR8	175	(10-3' dia.	225	
SYR1	29	(1)-4' dia.	N/A	GR9	74	(2)-4' dia.	N/A	
GL9	156	(3)-4'x5' box (1)-3' dia.	N/A	GL9	109	(1)-3' dia.	135	More detailed hydrology indicated blocked conditions requiring a pump station
BDR4	156	(3)-4'x5' box (1)-30" dia.	N/A	BDR5	245	(1)-4' dia.	264	
BDL2	88	(1)-3' dia. (2)-4' dia.	N/A	BDL2	79	(1)-2' dia.	38	
BDL3	--	(1)-3' dia. (2)-4' dia.	N/A	BTR1	122	(1)-2' dia.	210	

284. Prior to these more recent explorations, the New York District had conducted a subsurface exploration program in 1976 in which 38 borings were taken. Data were also obtained from an additional 29 borings taken by Foundation Systems, Inc. in 1981 as part of the Spring Lake Park project along Cedar Brook. In addition, this information was supplemented by data collected from borings collected in connection with the hazardous waste investigations.

285. Locations of the various borings are shown in Support Document I, Geotechnical, available at the Office of the District Engineer. These borings ranged from 11 to 55 feet in depth, with a typical depth of 25 feet.

286. The laboratory testing program consisted of identification and physical property testing. Identification testing included grain size with hydrometer (American Society for Testing and Materials (ASTM D422)), moisture content (ASTM D2216), Atterberg Limits (ASTM D4318), unit weight, and specific gravity (ASTM D854).

287. Physical testing included triaxial (ASTM D4767) and unconfined (ASTM D2166) compressive tests on undisturbed soil, and compressive tests (ASTM D2938) on rock core samples.

288. For the 12.5 miles of floodwalls and levees proposed for the non-feature design portions of the project, 69 combinations of levee height and stratigraphy were evaluated. Each of the levee and floodwall sections were analyzed for settlement, stability and seepage. A typical levee detail is provided on Figure 49. The closure structures located within this portion of the basin were evaluated for settlement and stability, with a sheetpile cutoff included in the design to minimize seepage.

289. In the upper and Stony Brook portions of the basin, where channel modifications are proposed, four typical sections were analyzed for stability using PCSTABL5M, a slope-stability software package developed by Purdue University.

290. A geotechnical analysis was also performed for the proposed Oak Way and Sky Top detention control structures. Each structure was analyzed for settlement, slope stability and seepage.

291. A total of three typical sections were evaluated at each control structure, two embankment sections and one spillway section. The embankment sections were selected to represent the maximum and the average cross-sectional height. The spillway section was selected to be representative. The earthen embankment sections evaluated assumed a common field-type

material such as a silty sand or clayey sand consisting of a 20-foot wide crest and a 3H:1V upstream slope and a 2.5H:1V downstream slope. Figure 50 provides details of the proposed section. In addition, for the Oak Way site a roller-compacted concrete (RCC) embankment was also considered. Though not recommended at this time, the RCC section was determined to be both technically and economically viable. Because of the rural nature of the Watchung Reservation, an RCC embankment was not considered for the Sky Top site. For both sites, the analysis included the RCC spillway section.

292. Foundation requirements for bridge replacements were evaluated. The Plainfield Avenue bridge over Cedar Brook and the wingwalls for the New Market Ave. bridge over Tributary #3 of Bound Brook, as well as the Clinton Avenue and the East Main Street/Lincoln Avenue bridges over Green Brook, require pile foundations. The South Lincoln Avenue bridge over Bound Brook will be founded on shallow bedrock. Sebrings Mills Road, North Washington Avenue and Netherwood Avenue over Green Brook, as well as East Street over Vosseller Brook, the New Market Ave. culvert and Grove Street over Stony Brook, can all be founded on spread foundations.

293. The final project elements which were the focus of the geotechnical investigations were the stormwater pump stations proposed to pass drainage captured behind the line of protection through to the stream. A total of 16 pump station facilities ranging from 10 cubic feet per second (cfs) to 640 cfs are planned as part of the NED plan. For this level of study, four typical stations were evaluated in detail:

- GR1 @ 60 cfs
- RL1 @ 180 cfs
- Bonygutt @ 450 cfs
- GR3 @ 640 cfs

294. Subsurface data were based on the limited boring program discussed above and no site-specific borings were obtained for each station. Based on this information, the analysis indicated that the spread footing foundations would be applicable for each of the facilities.

295. **Structural**. The structural analysis for this stage of investigation is preliminary in nature and requires additional detailing for feature designs. All flood control components, such as floodwalls, retaining walls, pump stations, etc., have been designed in accordance with Corps of Engineers criteria. Bridge replacements have been developed in accordance with AASHTO criteria as modified by NJDOT.

296. Typical floodwalls were essentially stratified into three types based on height. Generally, for floodwalls 10 feet or more above grade, a reinforced concrete inverted T-wall (Type A) section was used. For floodwalls ranging between 5 and 10 feet above grade, a reinforced concrete inverted I-wall with sheetpile foundation (Type B) was employed. Where the height dropped below 5 feet, a reinforced concrete inverted I-wall on a spread footing (Type C) was applicable. The reinforced concrete components were designed in accordance with Building Code Requirements for Reinforced Concrete, American Concrete Institute (ACI) 318, EM 1110-20-2501, EM 1110-2-2502, and ETL 1110-2-265. The steel sheeting, where applicable, conforms to ASTM A328. Figure 51presents typical floodwall sections.

297. As shown in Table 23, the NED plan includes eight closure structures varying in span, height and type.

TABLE 23
CLOSURE STRUCTURES

Location	Gate Type	Clear Opening (ft)	Height (ft)	Top Elevation (ft NGVD)
FDM Area				
C Railroad Line (for location, see Figure 9)	Swing	64	2.5	41.6
C Main St. Underpass (see Figure 9)	Swing	40	16.5	39.5
CEast St. (see Figure 9)	Roller	55	8.5	39.5
NON-FDM AREA				
C River Rd. (see Figure 9)	Miter	40	14.5	37.5
C Union Ave. (see Figure 10)	Roller	62	10.0	50.0
C Bound Brook Rd. (see Figure 10)	Roller	62	10.0	50.0
C Madison Ave. (see Figure12)	Miter	40	7.0	55.8
C Clinton Ave. (see Figure 26)	Roller	60	5.5	67.5

298. The type of gate and clear span for each gate was selected based on specific constraints including sight distance, grading and required clearances. The major components for each structure were analyzed in accordance with criteria set forth in EM 1110-2-2705, "Structural Design of Closure Structures for Local Flood Control Projects." Foundation designs typically utilized steel H-piles to resist settlement, and for the larger gates, ground anchors to resist uplift forces. Figures 52 and 53 present a typical roller gate, and mitre gate.

299. Within the upper and Stony Brook portions of the basin, vertical retaining walls are included in the proposed channel improvements. The preliminary designs, conducted in accordance with EM 1110-2-2502 "Retaining and Floodwalls," included analysis of stability uplift pressure. Figure 49 shows vertical channel wall sections.

300. Structural design of the spillways, stilling basin and spillway sidewalls of the two detention control structures were based on critical sections and load combinations. The RCC spillways were designed in accordance with EM 1110-2-2200 "Gravity Dam Design." The design assumes the RCC is placed in 12-inch lifts, with the upstream face formed by precast sections tied to the

RCC section. The foundation, spillway crest and energy-dissipating steps will be constructed using a "rich" mix concrete. The stilling basin and sidewalls will also be constructed using a traditional concrete mix. The resulting sections are shown on Figure 50.

301. The horizontal alignment and width of replacement bridges is essentially the same as the existing bridges. Due to the relatively short spans, the bridge superstructures consist of adjacent box beams with composite concrete deck slabs. The superstructures are supported by reinforced concrete abutments, and where necessary, a reinforced concrete center pier. Wingwall and headwall requirements were also considered in the preliminary design. Figures 54 and 55 presents a typical bridge design.

302. Preliminary structural designs have been completed for four of the 16 pump stations. Each of the four structures, ranging in size from 60 to 640 cfs, was evaluated under usual, unusual and extreme conditions in accordance with EM 1110-2-3104, “Structural and Architectural Design of Pumping Stations." Uplift forces were completed in accordance with EM 1110-2-2200, "Gravity Dam Design," and sliding stability was evaluated in accordance with ETL 1110-2-256. Figure 56 shows the plans and sections for a typical pump station.

303. Numerous outlet structures are required to pass drainage through the line of protection to the receiving stream. Each structure comprises an inlet structure including debris racks on the protected side, an outlet structure including a flap valve at the channel side, and a central manhole chamber including a sluice gate adjacent to the top of the levee embankment. A typical outlet structure was analyzed based on a critical condition whereby the sluice gate is closed and high river stages occur , resulting in an empty vessel between the sluice and flap gates. A typical outlet structure is presented on Figure 57.

304. For a more detailed discussion of the structural analysis and sample calculations, please refer to Support Document J, Structural, maintained at the New York District Corps of Engineers' office.

305. **Non-Structural**. In order to complete the protection system and to ensure the effectiveness of the structural measures, several non-structural components are included in the plan.

306. Flood Proofing. There are a number of methods that can be used to flood proof a property, a building, and its contents. The options that are available are dependent on a number of things such as the depth of the flood; the type of building being flood proofed; the presence of a basement or a crawl space; soil conditions; and the layout of a property.

307. Flood proofing measures range from very radical ones to those which require minimal physical changes. Flood proofing measures considered for design of the recommended plan include the following:

- Evacuating buildings from the floodplain;
- Elevating the structure;
- Constructing various types of barriers to stop floodwaters from entering a building;
- Using techniques known as “dry flood proofing”; and, or,
- Protect major utilities while allowing the basement to flood, “wet flood proofing”.

308. The NED plan includes flood proofing 166 buildings to protect against a 150-year storm. Excluding areas of feature design, the analyses of non-structural alternatives is preliminary in nature and requires detailed architectural and engineering assessments of individual buildings to identify specific design features. Figure 58 presents typical flood proofing sections.

309. Flood Warning Systems. In conjunction with other means of protection, flood warning systems are to be implemented as part of the recommended plan. A flood warning system is currently in effect in Somerset County and will be extended to incorporate the remainder of the basin. These systems are necessary to provide advance warning to ensure that pump stations and closure gates function as planned, and to provide adequate time and direction for evacuation of hazardous areas.

310. The flood warning systems will also provide additional protection in the areas of lower levels of protection. A recurrence of the 1973 flood in the Stony Brook Portion of the Basin would result in the channel being overtopped. The flood warning system will provide advanced warning for preparedness and evacuation in this area thus minimizing the potential for loss of life.

311. **Hazardous, Toxic and Radioactive Waste**. In accordance with USACE Civil Works Regulation ER 1165-2-132, a hazardous, toxic and radioactive waste (HTRW) evaluation for the

proposed project was performed. Reconnaissance and intrusive investigations were conducted throughout the project area to determine the potential impacts of HTRW on project features and, conversely, the effects of project implementation on existing HTRW.

312. Reconnaissance phase records searches were conducted in November 1994 and January 1996. The results of the records searches identified known and potential HTRW sites where subsequent intrusive investigations were slated. In April 1995 Chemical Data Acquisition Plans (CDAPs) and Site Specific Health and Safety Plans (SSHPs) were developed for use in the intrusive investigation phase. And finally, in April 1996 completion of the final HTRW Data Interpretation/Response Plan was completed summarizing the analytical data, their effect on proposed project feature alternatives, a health risk analysis, and response alternative cost estimates. All sampling, analyses and data evaluation were conducted in accordance with Federal, state and local regulatory policy.

313. Of those project sites where intrusive analyses were performed, select sites are identified by the NJDEP (1994) as known contaminated sites. Known contaminated sites are those classified as either *active*, where the site is assigned to a specific remedial program area, or *pending*, where the site is awaiting assignment to a specific remedial program area. Sites where a no further action (NFA) designation has been given are excluded from the "known contaminated" classification. Those sites within the project area identified by the NJDEP as known contaminated sites are:

a. Brook Industrial Park (NJDEP Identifier-NJD078251675)
   100 W. Main Street
   Bound Brook Borough, NJ
b. Middlesex Municipal Landfill (NJDEP Identifier-NJD980505499)
   Mountain Avenue
   Middlesex Borough, NJ
c. Borden Incorporated (NJDEP Identifier- NJD002170439)
   930 Lincoln Blvd.
   Middlesex Borough, NJ

314. In addition to the existing known contaminated sites, six supplementary sites were also investigated for the presence of contaminants and evaluated against regulatory criteria:

a. National Guard Facility
   Bound Brook Borough, NJ
b. Amoco Station
   Rt 28 and 287
   Bound Brook Borough, NJ
c. American Cyanamid
   Bound Brook Borough, NJ
d. Bolmer/NJCR Site
   Bound Brook Borough, NJ
e. Rotary Park
   E. Main St. and Union Avenue
   Bound Brook Borough, NJ

315. The intrusive analytical data obtained at the above mentioned sites was used to develop HTRW remedial actions and their associated costs, as presented in the HTRW Data Interpretation/Response Plan, April 1996. The estimated regulatory costs were developed using an array of project feature alternatives for each site, consisting of (1) floodwalls, (2) levees and (3) avoidance through project realignment. For example, HTRW regulatory costs for a levee would differ from that of a floodwall structure based upon quantity of regulated media disturbed. Additionally the cost of realigning the line of protection and the increased costs attributed to longer levee/floodwall segments to avoid HTRW sites were also investigated. These alternative regulatory costs may be used to determine site-specific project features which minimize response costs. Furthermore, the analytical data was obtained at specific project feature locations and were primarily assumed to be homogeneous in their areal extent. Additional sampling at select locations would further define the limits of regulatory classified media, thus reducing the range of costs associated with the respective sites. In addition, cost contingencies were included to account for these data limitations.

316. In summary, there are several project features which may be impacted by the presence of HTRW regulated soil and groundwater. Estimated costs associated with HTRW regulated media range from approximately $826,000 to $9,078,000 depending upon its classification and ultimate disposition. The New Jersey Department of Environmental Protection, the non-Federal sponsor for the Green Brook Flood Control Project, has been notified of its responsibility to incur HTRW-related regulatory costs associated with the project.

Real Estate Requirements

317. **Requirements**. The Green Brook Flood Control Project, located in central New Jersey and spans three counties and thirteen municipalities, and occupies a strong diverse real estate market. Serious consideration was given to studying these communities and the project impact upon their land. After consideration, estates were assigned to the real estate interests needed for the construction of the Flood Control Project. When the design for flood protection would permit, the project was placed where the minimum real estate impact would affect the local community and special care continued as the acquisition of the minimum estate needs were planned. A gross appraisal was completed by U.S. Army Corps of Engineers, Baltimore District, Real Estate Division, to estimate the costs for acquiring the lands and easements for each construction feature at fair market value. These figures, along with market surveys and inquiries for current administrative costs, were used to estimate the real estate costs of this project. When possible, cost factors of other disciplines (i.e. environmental) and real estate estimates were analyzed together to choose land most beneficial for the least cost.

318. The real estate assigned to the Green Brook Flood Control Project consists of minimum interest in land and/or structures that would provide the construction feature with its needs. Fee simple, which signifies ownership of all rights to the land, is being used for mitigation sites, buy outs and the dry detention basin structures. Permanent easements (channels, floodwalls/levees, drainage ditches, and detention basin flowage), which are being used extensively throughout this project, will remain with owners on their property as long as it does not interfere with the project's needs. Temporary easements allow the needed construction to be done and are used for staging areas and transportation of supplies and equipment while the construction is occurring. The rights for the land return to the owner when the term is completed.

319. The estates estimated for this project including mitigation are 311.26 acres in fee simple, 272.48 acres in permanent easements and 149.16 acres in temporary work areas.

Cost Estimates

320. **General**. The project cost estimate includes all features necessary to completely implement the recommended plan of protection. This includes continued engineering and design; acquisition of the required real estate; relocations of roadways, bridges and utilities, construction of all project features including natural and cultural resource mitigation; and the supervision, inspection and administration of all construction activities.

321. The project cost estimate does not include any costs required to remediate existing hazardous, toxic and radioactive waste.

322. **First Cost**. Cost estimates were prepared using a computerized system known as MCACES and include appropriate contingencies for each item. Quantity estimates incorporate geotechnical recommendations regarding the reuse of excavated material to construct earthen embankments. The complete MCACES estimates as well as documentation of material quantities, unit prices, and the assumed construction procedures, are presented in Support Document K, Cost Estimates, available at the Office of the District Engineer. Table 24 provides a summary of project costs in standard code-of-accounts format.

323. **Comparison with Previously Approved Estimate**. A comparison by feature accounts between the first cost of the NED plan and the prior budget contained in estimate form PB-3 is presented in Table 25.

TABLE 24
SUMMARY OF NED PLAN FIRST COSTS
(April 1996 Price Level)

Account	Lower Portion of the Basin	Upper [1] Portion of the Basin	Stony Brook Portion of the Basin	Project Total
01 Lands and Damages	$22,355,000	$6,142,000	$427,000	$28,924,000
02 Relocations	$2,657,000	$282,000	$0	$2,939,000
04 Dams	$0	$12,582,000	$0	$12,582,000
06 Fish & Wildlife Mitigation	$12,296,000	$4,549,000	$213,000	$17,058,000
08 Roads & Bridges	$27,705,000	$5,900,000	$1,272,000	$34,877,000
09 Channels	$7,908,000	$11,642,000	$7,244,000	$26,794,000
11 Levees & Floodwalls	$71,274,000	$0	$0	$71,274,000
13 Pumping Plants	$29,761,000	$0	$0	$29,761,000
15 Floodway/Diversion Control Structures	$16,208,000	$0	$0	$16,208,000
18 Cultural Resource Preservation	$1,846,000	$471,000	$95,000	$2,412,000
19.01 Non-Structural	$11,712,000	$0	$282,000	$11,994,000
19.02 Landscaping	$3,698,000	$943,000	$191,000	$4,832,000
20 Permanent Operating Equipment	$115,000	$0	$0	$115,000
30 Planning, Engineering & Design	$24,261,000	$4,681,000	$1,058,000	$30,000,000
31 Construction Management	$16,334,000	$3,153,000	$713,000	$20,200,000
TOTAL [2]	$248,130,000	$50,345,000	$11,495,000	$309,970,000

Note:

1) The recommendation to construct the upper portion of the basin is deferred pending further evaluation.

2) Does not include $24,000,000 in prior expenditure for Preconstruction, Engineering, and Design.

TABLE 25
COMPARISON WITH APPROVED PB-3 ESTIMATE
(Cost in Thousands of Dollars, April 1996 Price Level)

Account	Item	Approved PB3	Current Design	Difference	Remarks
01	Lands & Damages	$17,500	$24,510	$7,010	Updated appraisal
02	Relocations	$3,300	$2,556	($744)	Design changes reduced scope
04	Dams	$0	$10,941	$10,941	Formerly part of account 15
06	Fish & Wildlife Facilities	$0	$14,215	$14,215	Not accounted for in PB3
08	Roads & Bridges	$41,400	$30,328	($11,072)	Design changes reduced scope
09	Channels & Canals	$40,800	$23,299	($17,501)	Design changes reduced scope
11	Levees & Floodwalls	$51,100	$61,977	$10,877	Design changes increased scope
13	Pumping Plants	$0	$25,879	$25,879	Design changes increased scope
15	Floodway Control & Diversion Structures	$34,000	$14,094	($19,906)	Formerly included account 04, scope reduced
18	Cultural Resource Protection	$0	$2,097	$2,097	Formerly part of account 59
19.01	Buildings, Non-Structural	$0	$10,430	$10,430	Design changes increased scope
19.05	Grounds & Landscaping	$0	$4,202	$4,202	Formerly part of account 59
20	Permanent Operating Equipment	$0	$100	$100	Formerly part of account 59
30	Planning, Engineering & Design [1]	$24,000	$54,000	$30,000	Eng. & Des. during const. was not accounted for in PB3
31	Construction Management	$20,200	$20,200	$0	
59	Contingencies	$47,100	$35,142	($11,958)	Formerly included accounts 18,19.05 & 20
	TOTAL	**$279,400**	**$333,970**	**$54,570**	

Notes:
1) Current design estimate of $54,000,000 includes $24,000,000 in Preconstruction, Engineering, and Design and $30,000,000 in Planning, Engineering, and Design during construction.

Value Engineering Study

324. In accordance with U.S. Army Corps of Engineers policy for all projects costing more than $2 million, a Value Engineering (VE) study was conducted for the Green Brook Flood Control Project. The study was based on the review version of the Draft General Reevaluation Report, dated June 1996. The VE Team was comprised of personnel from North Atlantic Division, New York District and URS / Kupper Joint Venture and was led by three representatives from the Office of the Chief of Engineers Value Engineering Study Team (OVEST). Study efforts commenced during the week of 16-20 September 1996.

325. The project was studied using standard VE methodology, consisting of six phases: Information, Speculation, Analysis, Development, Presentation and Implementation. Each phase is explained as follows:

- Information Phase - learn about the project, what it is and how it is supposed to work. This includes conducting a site visit and reviewing project information.
- Speculation Phase - a brainstorming session to identify ways to reduce life cycle project costs or improve quality of the proposed project.
- Analysis Phase - review and critique the ideas generated in the Speculation Phase.
- Development Phase - proposal development of ideas that have been identified during the Analysis Phase.
- Presentation Phase - developed proposals and comments contained in the study report are discussed.
- Implementation Phase - proposals and comments accepted during the Presentation Phase are incorporated into the plans and specifications.

326. During the Information Phase, the VE Team studied the drawings, figures, descriptions of the project work, and cost estimates to fully understand the work to be performed and the functions to be achieved. The VE Team conducted a site tour on 16 September 1996 to see the existing site conditions and relationships of constructability issues. Cost Models were prepared to determine areas of relative high cost to ensure that the Team focused on those parts of the project which offered the greatest potential for cost savings.

327. The VE Team performed the Speculation Phase by conducting a brain storming session to generate alternative ideas for consideration. All VE Team members were encouraged to contribute ideas which resulted in a total of seventy-eight items being identified as ways of potentially reducing the life cycle cost of the project.

328. Following the Speculation Phase, the VE Team analyzed these ideas, identifying items for development. Ideas which did not survive critical analysis were deleted. The Analysis Phase reduced the number to fifty-five items, which led to twenty-five proposals being developed.

329. The surviving ideas were brought forward into the Development Phase where quantity and cost estimates were determined to establish what the magnitude of the potential cost savings of each proposal could be to the overall project. A maximum cumulative savings in excess of $38,000,000 was identified. These proposals were offered for acceptance during the Presentation Phase.

330. A formal presentation of the VE study recommendations was made at the New York District office on 24 October 1996. Many of the original VE Study Team members attended the Presentation Phase. The non-Federal sponsor was also in attendance and was given the opportunity to comment on the possible project modifications.

331. The intention of the presentation held on 24 October 96 was to discuss each proposal and to reach consensus regarding acceptability for incorporation into the project plans and specifications. A number of items were identified as either acceptable or not, with other items being noted as possible or probable. Acceptability of the probable and possible items will require either additional study or more information. As a result of the formal presentation, the twenty five proposals brought forward from the Development Phase, were further qualified by the group as follows:

- Acceptable for project incorporation: **6 Items** (noted as Proposals C1, C2, C3, C8, C9 [18" only], S1 [18" width] in the Value Engineering Report)
- Not Acceptable for project incorporation: **6 Items** (noted as Proposals C4, C5, C10, C15, C19, C20 in the Value Engineering Report)
- Items that appear probable for acceptance [need further investigation]: **7 Items** (noted as Proposals C6, C11, C17, C21, S2, S3, S4 in the Value Engineering Report)

- Items that appear possible for acceptance [need further investigation]: **6 Items** (noted as Proposals C7, C12, C13, C14, C16, C18 in the Value Engineering Report)

332. The implementation of the cost saving proposals, identified in the VE study, will occur during the detailed design phases of the project. The detailed designs will be further developed during the preparation of the Feature Design Memorandums (FDM) and Plans and Specifications.

333. The potential cost savings identified in the VE study are not accounted for in the current project cost estimates, therefore through the implementation of the Value Engineering proposals the total project cost can only be reduced, thereby increasing the project benefit cost ratio. The Value Engineering Report is available for review in the office of the District Engineer.

Operation, Maintenance and Replacement Considerations

334. The local sponsor has the responsibility for performing operation, maintenance, and replacement activities. The Corps of Engineers prepares operation and maintenance manuals during the construction of the project and provides these manuals to the local sponsor. The operation and maintenance activities include the regular mowing of earthen embankments to sustain a grass-covered surface and to keep larger vegetation from becoming established. Regular mowing curtails burrowing animals and allows for easy inspection during periodic examinations or during a flood event. Mowing should occur three to five times a year.

335. Periodic removal and disposal of accumulated sediment and debris along the channel improvement areas is required to maintain hydraulic capacity of the overall project. Inspection and repair of the detention structures along Green Brook and Blue Brook should also be undertaken on a regular basis to assure that their capacity for reducing downstream flood flows is not impaired.

336. Closure structures should be checked annually to assure that watertight closures can be made.

337. Environmental mitigation areas should be inspected and maintained until they become permanently established. Thereafter, they should be periodically inspected to ensure that the established areas are not destroyed. Interior ponding areas should be checked yearly to ensure

that no physical encroachments have occurred. Pump stations, standby generators, flap gates and vertical slide gates should be operated periodically to ensure that they function properly.

338. Damaged or missing riprap along channels and the river side of the levees and flood-walls should be replaced after each flood event. Likewise, new bridges should be inspected periodically to assure that floods, traffic, and weather have not adversely affected them. Appropriate repair measures should be undertaken immediately if defects are noted. Such inspection practices should also extend to existing bridges, that are not being replaced as part of the project.

339. The flood warning system should be reviewed regularly and if necessary updated to take advantage of the latest technological flood forecasting capabilities. Remote transmitters should be checked to assure that they are providing reliable information. Periodic flood fighting drills should be conducted to practice timely information dissemination and closure implementation.

340. Corps of Engineers personnel and NJDEP representatives will make an inspection of the Federal project every year following construction completion. The local sponsor would have the responsibility to correct operation and maintenance deficiencies identified during the joint inspection.

Residual Flooding

341. Even with the implementation of the NED plan the project area would remain subject to potential residual flooding. Sources of flooding in the lower portion of the basin are ponding of drainage trapped behind the levee system, and the floodwaters overtopping the levee and floodwall line of protection. While ponded drainage will periodically spill out of interior ditches and pipes, the probability of significant flood damage at any interior drainage facility is estimated to be less than 1% in any given year. Residual damage due to interior flooding is expected to average $57,000 per year.

342. A more hazardous condition will occur if the levee and floodwall system were overtopped by a major flood event. Although the line of protection system will provide superior protection at the most hazardous locations, the damage in case of overtopping would be extreme.

343. There is a 0.67% chance that the selected 150-year storm design level will be exceeded in any year, which equates to a 50% chance that the design will be exceeded over the 100-year project life. Risk management measures to account for uncertainty in the design water surface will reduce the probability of overtopping the structures. Based on risk simulations, the effective probability of overtopping will vary between 0.35% and 0.56% in any year. This equates to a risk of levee overtopping at least once during the 100-year project life of between 30% and 43%. The average annual with project damage due to river flooding in the lower portion of the basin is estimated to be $2,052,000.

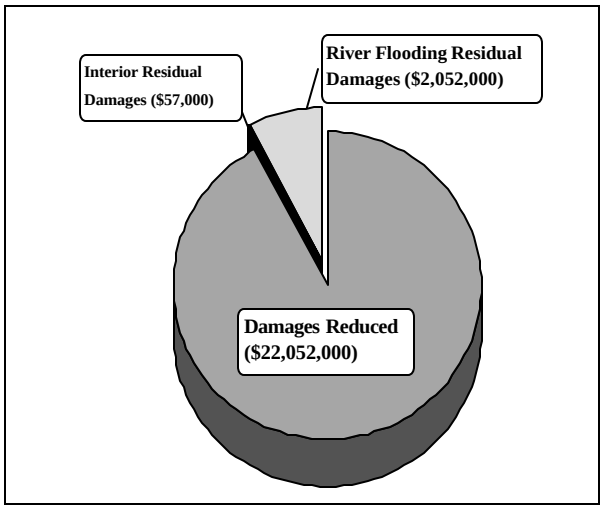

ILLUSTRATION NO. 5 - LOWER PORTION OF THE BASIN DAMAGE SUMMARY

344. The combined average annual project damage due to riverine flooding and due to interior drainage flooding is $2,109,000. This represents a 91% reduction in flood damages.

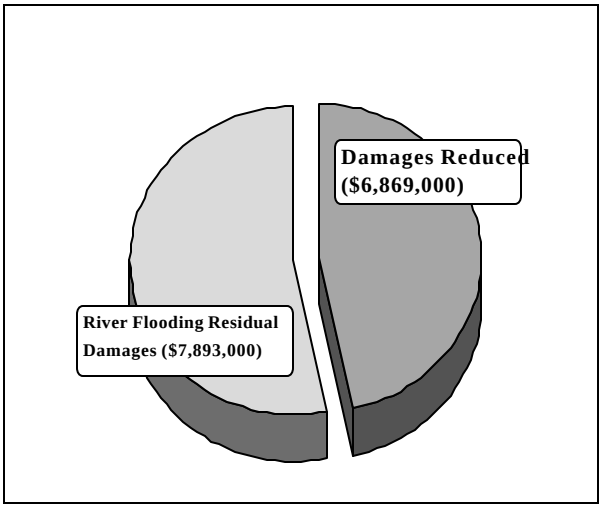

ILLUSTRATION NO. 6 - UPPER PORTION OF THE BASIN DAMAGE SUMMARY

345. In the upper portion of Green Brook, the combined effects of the channel and detention structures would reduce the probability of diversion from Green Brook, through the city of Plainfield into Cedar Brook, from approximately 15% per year to approximately 5% per year. For any 10-year period this reduces the probability of at least one diversion from 80% under existing conditions, to approximately 40% with the project. Although

the project would substantially reduce the frequency and severity of diverting flows, the upper portion of the basin would still be subject to average annual damage of $7,893,000. This high level of residual damage is a reflection of the limited scale of the channel improvements. The NED Plan results in a 47% reduction in flood damages.

346. Based on the capacity of the Stony Brook channel improvement, there is a 4% chance of flooding in any year, which is equivalent to a 34% chance of at least one flood in any 10-year period. Residual flood damage along Stony Brook is expected to average $513,000 per year. This 25-year level of protection channel improvement reduces the expected annual flood damage by approximately 67%.

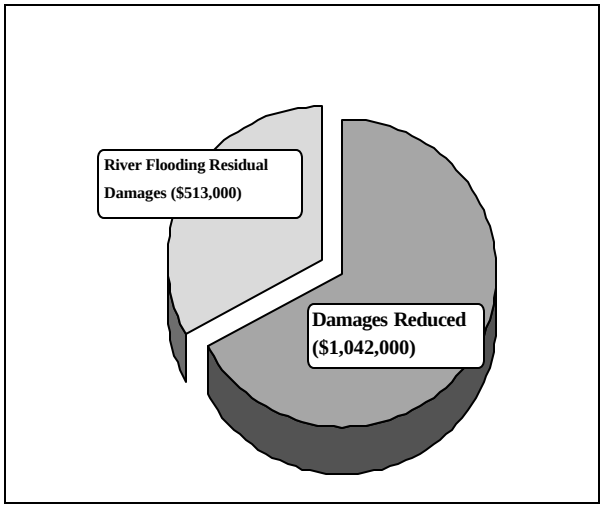

ILLUSTRATION NO. 7 - STONY BROOK PORTION OF THE BASIN DAMAGE SUMMARY

347. A detailed discussion of residual flood hazards is included in Support Document F, Hydrology, available at the Office of the District Engineer.

ENVIRONMENTAL ANALYSES OF THE NED PLAN

Overview

348. The environmental impacts of the plan are essentially confined to the areas directly affected by the project works. Impacts are addressed in detail in the Supplemental Environmental Impact Statement portion of this report.

Environmental Effects

349. The direct environmental affects from the project based on the revised plan will be concentrated in the stream beds and banks, floodplain areas and the head waters of Green Brook in the Watching Mountains. Approximately 168 acres of habitat will be adversely impacted by the proposed project. The majority of those impacts would occur in forested wetland (97 acres), upland forest (28 acres), gravel-bottomed stream (20 acres), emergent wetland (11 acres), and mud-bottomed stream (9 acres). Construction of levees will result in the filling of floodplain areas affecting habitat and the hydrologic setting. Channel modifications will affect stream habitat and water quality. Other project structures include two dry detention basin facilities in the Watching Mountains to create flood water detention basins. The two proposed dry detention basins would maintain stream base flow and begin ponding when flooding occurs. Construction of the Sky Top dry detention basin in the Watching Reservation would affect approximately 15 acres of forest land and 50 acres would be subject to flooding due to a 150 year storm event. The Oakway dry detention basin would be built across the Green Brook through approximately 4.5 acres of woodland from a corporate office complex to a major highway and 75 acres will be flooded from a 150 year storm. These inundation areas (50 acres and 75 acres respectively) are based on standing water which would take approximately 40 hours to drain.

Mitigation

350. Environmental and cultural impacts are addressed by mitigation plans which compensate for losses associated with project implementation. The District has worked closely with the U.S. Fish and Wildlife Service to appropriately mitigate for environmental impacts that result from the project. A Pennsylvania Modified Habitat Evaluation Procedure (PAMHEP) has been used to assign habitat values to the area impacted by the project. A conceptual mitigation plan has been developed to identify sites which could be used to fully replace habitat, value for value within existing project area or on offsite mitigation sites as needed. This conceptual plan forms the basis of the mitigation component of the NED costs.

351. **Mitigation Site Screening**. The New York District of the Corps of Engineers has screened the Green Brook basin and adjacent areas for suitable mitigation sites. The corps has identified more than 30 suitable sites for potential habitat mitigation. NJDEP is in the process of reviewing these sites for potential mitigation usage to satisfy the requirements of the wetlands permitting process. Specific mitigation plans and the completion of permitting requirements will take place prior to construction activities. Criteria used to evaluate potential mitigation sites include :proximity to project area, surrounding land use, availability of suitable hydrologic source for wetland creation, size of property, and existing vegetative cover.

352. **Conceptual Mitigation Actions.** Potential mitigation actions under consideration at this time include planting hydrophytic tree and shrub species; excavation to maintain viable sources of hydrology; and grading and seeding plans for emergent vegetation. In general, the plans will seek to replace habitat based on cover type impacts on a greater than 1 to 1 ratio. For example, the Corps expects to create and/or enhance more than 97 acres of forested wetland. The exact amount of acreage to be used for mitigation will depend on the sites available and the ability to restore suitable wildlife habitat to these sites.

Areas of Controversy

353. **Bound Brook**. Within the Town of Bound Brook a levee/flood wall system is designed to enter the boundary of an EPA designated superfund site. The design is proceeding under the assumption that the EPA, as scheduled, will complete the clean-up of the site prior to construction. Further details can be found in the HTRW Appendix.

354. **Sky Top detention basin:** The environmental and aesthetic impacts caused by the structure are a concern of the NJDEP and the Union County Parks Department. The facility would impact a significant area of the Watchung Reservation, an integral component of the Union County Park system. This area will be re-examined by the Corps prior to implementation.

Issues To Be Resolved

355. In the Bound Brook - Cedar Brook confluence area of the lower portion of the basin, the current project alignment includes a levee located in the Highland Woods Nature Reserve. Alternatives will be considered when this element of the project proceeds into the design stage of development.

356. Mitigation for the project will be required due to wetland and habitat impacts. The exact mitigation sites have yet to be determined as construction for the project will not be initiated until 1998. The mitigation sites will be purchased and subsequent mitigation plans approved for the project by the State of New Jersey Department of Environmental Protection prior to construction of the project. The State has assumed responsibility for regulatory permits formerly under Corps jurisdiction under Section 404 of the Clean Water Act. Mitigation sites must be acquired and plans for mitigation finalized prior to initiation of project construction. Such cannot take place until after the State signs the PCA.

357. The Corps will continue to coordinate with the NJDEP to evaluate the effects of the project on New Jersey threatened and endangered species. Costs for developing mitigation for these species, if necessary, will be paid for by the local sponsor.

358. The bog turtle is a candidate for protection under the Federal Endangered Species Act. If the turtle becomes a federally endangered species prior to construction on Blue Brook, the Corps is required to follow procedures required under Section 7 of the Endangered Species Act. Monies for such potential requirements are not included in the project cost estimate at this time.

359. The Corps of Engineers and the local sponsor have agreed to defer implementation of the plan for the upper portion of the basin following an evaluation of this portion of the project.

360. The Corps will add measures to enhance stream habitat in the Lower Basin. The Corps will also work to utilize bio-engineering techniques on the project to the greatest extent practical. These issues developed during coordination with NJDEP as part of the NEPA process. Such measures will be studied and implemented during the Feature Design phase of the project.

Cultural Resource Considerations

361. As required by the National Historic Preservation Act of 1966, the New York District and New Jersey Historic Preservation Office (HPO) are engaged in a consultation process to identify design alternatives which will avoid project-related impacts to historic properties eligible for listing on the National Register of Historic Places (NRHP). The prehistoric archaeological resources identified to date are in areas prone to flood-induced erosion or in locations where in-place preservation might render them susceptible to vandalism. The New Jersey HPO has concurred that mitigation is the appropriate preservation strategy for the two NRHP archaeological sites located in the lower portion of the basin (see FSEIS Appendix D, New Jersey HPO letter dated March 19, 1996). Impacts to identified NRHP eligible historic structures, with the exception of bridges, have been avoided or minimized. The District is currently coordinating with the HPO to develop an appropriate strategy for mitigating for unavoidable impacts to NRHP bridges. For the Lincoln Boulevard Bridge, a removal item in the FDM area, the District has proposed modifying the design of the replacement structure to include features which reflect the historical significance of the existing structure.

362. Cultural resource evaluation and consultation is ongoing and will be continued throughout project planning as specified in a draft Programmatic Memorandum of Agreement (PMOA) developed through consultation with the HPO, Advisory Council on Historic Preservation, and interested parties. Through the implementation of the PMOA, the District will continue to develop alternatives which avoid or minimize impacts to NRHP eligible cultural resources whenever feasible. Mitigation plans for unavoidable impacts will be developed. The PMOA will stipulate that mitigative data recovery plans be coordinated with the New Jersey HPO for the two NRHP eligible archaeological sites in the lower portion of the basin. Pending completion of the additional coordination on the deferred portion of the project, further cultural resource investigations may be undertaken. On the basis of the Recommended Plan, the PMOA will require the District to develop a monitoring program, contingency plan and an interpretive program for the NRHP listed Deserted Village of Feltville Historic District. These conditions have been coordinated with the Union County Bureau of Park Operations (see FSEIS Appendix D, New York District letter dated April 15, 1996).

363. Additional discussion of cultural resources is provided in the FSEIS. The draft PMOA and pertinent correspondence are provided in FSEIS Appendix D.

ECONOMIC ANALYSIS OF THE NED PLAN

Overview

364. Federal participation in the project requires a demonstration of economic feasibility, which is established by determining whether the benefits to the national economy exceed the annual economic costs. Benefits were determined from the results of a detailed investigation of the economic impacts of flooding in the basin. Annual charges were based on the application of economic principles to all the costs of constructing, operating and maintaining the project. The economic analysis is discussed in detail in Support Document C, Economics, maintained at the office of the District Engineer.

General

365. All benefits and costs for the NED plan are at April 1996 price levels. Average annual benefits and costs have been amortized over a 100-year period of analysis beginning at the anticipated base year of 2009. Computations used the fiscal year 1997 Federal discount rate of 7-3/8%.

Annual Charges

366. The detailed cost basis and summary cost tables of various improvement alternatives are presented in Support Document K, Cost Estimates. Costs presented are NED costs and do not necessarily reflect the financial costs. Contingencies, Engineering & Design and Supervision & Administration are included in the cost analysis. However, since the costs analysis assesses the viability of future project investments, sunk costs of $24,000,000 expended in the Preconstruction Engineering and Design phase are not included in the benefit-cost-ratio calculation.

367. **Interest During Construction**. Interest during construction is the value of construction money invested before completion of the project. It is added to the construction cost to determine the total investment in the project and is calculated by computing interest at the applicable project discount rate on the monthly construction expenditures from the start of construction to the completion of the project. The project is currently estimated to take 10½

years to complete. Total interest during construction is therefore calculated to be $136,019,000. This cost is simply an economic time value adjustment and does not require monetary expenditures.

368. **Operation, Maintenance and Replacements**. Charges attributable to the operation and maintenance (O&M) of the project consist of annualized replacement costs, anticipated energy charges, and the costs of routine maintenance. Project components requiring routine care include detention structures, channels, levees, floodwalls, and the interior drainage ponds, outlets, closure structures and pump stations.

369. The major mechanical equipment within interior drainage pump stations have anticipated life expectancies of 30 years. The cost of periodic equipment replacement has been estimated, annualized over the 100-year life and incorporated into the O&M estimate. In addition, electric power requirements based on the anticipated frequency of pump station operation have been added to the project's annual operation charge.

370. **Rehabilitations**. Significant portions of the overall project's components such as levees are subject to damage from storms exceeding the design levels. The cost of repair after various flood events was weighted by their expected probability of occurrence to determine average annual major rehabilitation costs.

371. **Summary of Annual Costs**. Table 26 provides a summary of annual costs required to implement and operate the project.

TABLE 26
NED PLAN
SUMMARY OF ANNUAL COSTS
(April 1996 Price Level, 7-3/8% Discount Rate, 100-Year Period)

Costs	Lower Portion of the Basin	Upper Portion* of the Basin	Stony Brook Portion of the Basin	Total
First Cost	$248,130,000	$50,345,000	$11,495,000	$309,970,000
Interest During Construction	$116,259,000	$19,436,000	$324,000	$136,019,000
Total Investment Cost	$364,389,000	$69,781,000	$11,819,000	$445,989,000
Interest and Amortization	$26,896,000	$5,151,000	$872,000	$32,919,000
Operation, Maintenance, and Replacements	$1,013,000	$175,000	$20,000	$1,208,000
Rehabilitation	$124,000	$0	$0	$124,000
Total Annual Cost	**$28,033,000**	**$5,326,000**	**$892,000**	**$34,251,000**

Note* The recommendation to construct the upper portion of the basin is deferred pending further evaluation

Benefits

372. **General**. Project benefits are equal to the gains to the National Economic Development (NED) as determined by the difference between conditions with- and without-project. Flood control benefits are based primarily on the damages that will be prevented by the project and averaged over the 100-year project life. Damage reduction estimates were based on historical floods, current development of the floodplain, and statistical analyses to account for risk and uncertainty in major damage variables.

373. Interviews were conducted to obtain first-hand information on damages resulting from flood events. This effort provided site specific data for major floodplain structures and verified that general flood damage relationships established for the nearby Passaic River Basin are also applicable to the Green Brook Basin. These "damage functions" established specific relationships between the depth of flooding and the resulting damage for various types of buildings.

Assessments of the value and flood vulnerability of every floodplain structure were used to develop aggregate relationships between flood conditions and damages.

374. Flood risks under both the with- and without-project conditions were evaluated. For the lower portion of the basin, average annual damages were calculated by weighting the cost of damage from various storms by the probability of occurrence. Benefits were calculated as the value of damage prevented below the 150-year design level, plus 50% of the damage from storms exceeding the design level but not overtopping the protective structure. For the Stony Brook and upper portion of the basin the annual cost of damage for both the with- and without-project conditions was calculated using risk and uncertainty simulation techniques. This approach to calculating annual damages allows the analysis to reflect uncertainty in various parameters, such as flood stage or the associated damage. The calculation used the annual probability of any flood stage to randomly select a storm event for each year of the analysis. A Latin Hypercube sampling protocol was employed to ensure adequate consideration of extreme events. The damage associated with that storm event was then determined and the process repeated up to 20,000 times. The results of each calculation iteration were collected and analyzed, with the mean value representing average annual damage.

375. Additional benefits attributable to the project are a reduction in Flood Insurance Administrative costs, a reduction in flood-related traffic delays, and a reduction in future bridge replacement costs.

376. Table 27 provides a summary of average annual benefits expected upon completion of the overall project.

TABLE 27
NED PLAN
SUMMARY OF ANNUAL BENEFITS
(April 1996 Price Level, 7-3/8% Discount Rate, 100-Year Period)

Benefit Category	Lower Portion of the Basin	Upper Portion* of the Basin	Stony Brook Portion of the Basin	Total
Reduction in Building Damages	$22,052,000	$6,869,000	$1,042,000	$29,963,000
Residual Intrior Flooding	($57,000)	$0	$0	($57,000)
Total Flood Damage Reduction	$21,995,000	$6,869,000	$1,042,000	$29,906,000
Pre-Base Year Benefits	$13,169,000	$1,118,000	$0	$14,287,000
Reduced Public Emergency Costs	$706,000	$67,000	$77,000	$850,000
Reduced FIA Administrative Costs	$141,000	$58,000	$0	$199,000
Early Replacement of Bridges	$583,000	$75,000	$0	$658,000
Reduced Traffic Delays	$19,000	$1,000	$1,000	$21,000
TOTAL	$36,613,000	$8,188,000	$1,120,000	$45,921,000

Note* The recommendation to construct the upper portion of the basin is deferred pending further evaluation.

Benefits During Construction. As soon as individual portions of the overall project are completed they begin preventing flood damage. To account for these benefits, compound interest is added to these pre-base year benefits in the same manner that interest was applied to construction costs. The total annualized value of these pre-base year benefits is calculated to be $14,287,000, and was added to the overall project benefit stream.

Feasibility

377. Project feasibility is based on comparisons between benefits and costs. As seen in Table 28, project benefits outweigh the project cost for each portion of the project. The benefit to cost ratio is estimated to be 1.3 to 1.

TABLE 28
NED PLAN
SUMMARY OF ANNUAL BENEFITS AND COSTS
(April 1996 Price Level, 7-3/8% Discount Rate, 100-Year Period)

Costs	Lower Portion of the Basin	Upper* Portion of the Basin	Stony Brook Portion of the Basin	Total
Annual Benefits	$36,613,000	$8,188,000	$1,120,000	$45,921,000
Annual Costs	$28,033,000	$5,326,000	$892,000	$34,251,000
Net Excess Benefits	$8,580,000	$2,862,000	$228,000	$11,670,000
BCR	1.3	1.5	1.3	1.3

Note* The recommendation to construct the upper portion of the basin is deferred pending further evaluation.

PUBLIC REVIEW AND COMMENT

378. The Draft General Reevaluation Report and Supplemental Environmental Impact Statement were released to the public in December of 1996. This release in conjunction with the Notice of Availability published in the Federal Register on January 6, 1997 officially opened the Public Comment period. The draft report described the basin's flooding history, reviewed past project studies, outlined planning objectives, documented local coordination efforts prior to the official comment period, presented the National Economic Development (NED) plan, and, with the support of the local sponsor, recommended the NED plan for construction. This report was widely distributed to representatives of the municipalities in the Green Brook sub-basin, public libraries, and to all individuals that requested a copy of the document.

379. Subsequent to the release of the draft document, the New York District of the Corps of Engineers and the New Jersey Department of Environmental Protection (NJDEP) sponsored a number of public information sessions. These sessions were established to inform residents of the past flooding problems and the proposed solutions for the Green Brook sub-basin; to provide an opportunity for residents to speak with the planners and engineers that designed the proposed project; and, to provide an opportunity to residents to make comments on the proposed solution. These sessions were formatted to provide numerous data stations where interested residents were able to review information on various aspects of the project from descriptions of past flooding to details of the plan recommended for construction. Each station included graphic boards to relay information. Planners and engineers involved in the development of the flood control plan were available to answer questions. Periodically during the public information sessions a graphic slide presentation was made to supplement the exhibits. At the conclusion of the slide session, questions and comments were fielded in an open forum. In total, four public information sessions were held; Public Meeting #1 in the Borough of Bound Brook on January 14, 1997, Public Meeting #2 in the Township of North Plainfield on January 18, 1997, Public Meeting #3 in Berkeley Heights on January 28, 1997, and Public Meeting #4 in the Township of Scotch Plains on February 24, 2997.

380. To further disseminate information on the project the New York District, the NJDEP, and the Green Brook Flood Control Commission conducted an on-site briefing for Congressman Franks on December 30, 1996. In conjunction with the Congressman's office, a media briefing was subsequently held on January 13, 1997.

381. Though members of the public expressed a number of concerns over aspects of the project proposed for construction, it quickly became evident that features of the flood control plan in the upper portion of the basin caused the greatest concerns. Specifically, the two dry detention basins located in the valley between the first and second Watchung Mountains generated concerns over safety, maintenance, environmental impacts to the Watchung Reservation, and negatives affects on corporate tax ratable. Questions concerning the proposed flood control plan in the upper portion of the basin were the subject of an additional meeting held in Scotch Plains on February 21, 1997. This meeting was attended by U.S. Congressman Franks, the New York District, the NJDEP, and local and county officials representing the communities in the upper portion of the basin.

382. The public comment period was originally scheduled to extend for a 45 day period. At the request of local representatives and the U.S. Congressman's office, the public comment period was extended 15 days to provide additional time for the affected municipalities and counties to review aspects of the proposed flood control plan. The public comment period was officially closed on March 7, 1997. At that time, Union County officials and officials of the affected municipalities in the upper portion of the basin requested additional time to review project details and explore project alternatives that may alleviate some of the concerns expressed during the public information sessions. In response to this request, the New York District and the NJDEP agreed to defer further action on the flood control plan proposed for the upper portion of the basin. The flood control plan for the upper portion of the basin will become the subject of a local task force which will examine the currently proposed plan, propose project alternatives, and seek to build a consensus for viable flood protection for the residents in this portion of the basin.

383. Flooding in the lower and Stony Brook portions of the basin continues to be a significant concern to residents within the affected municipalities. These concerns were re-emphasized by the October 1996 flood which caused approximately $23 million in flood related damages and required the evacuation of over 3,000 people. The New York District and the NJDEP have agreed that questions concerning the flood control plan in the upper portion of the basin should not delay flood control for the affected municipalities in the lower and Stony Brook portions of the Basin. Therefore, while recommendation for the construction of the NED plan in the upper portion of the basin will be deferred, the New York District and the NJDEP will continue to pursue flood protection as outlined in the NED plan for the remainder of the project area.

RECOMMENDED PLAN

Overview

384. As a result of the public comment period it became evident that the NED plan in the lower and Stony Brook portions of the basin were widely accepted and supported by the local municipalities and area residents. However, the general interest to balance flood protection with environmental and social concerns in the upper portion of the basin has led the non-Federal sponsor to request that the the Corps of Engineers defer action on the flood protection plan in the upper portion of the basin. The request for a one year deferral on recommendation for flood protection in the upper portion of the basin was made formally in an April 17, 1997 letter from the NJDEP. The letter from the NJDEP also reaffirmed their continued support for the flood protection plans in the lower and Stony Brook portions of the basin and formally requested that the Corps of Engineers to continue with the current schedule for flood protection in these areas of the project. In response to the request of the local sponsor which is supported by Congressman Bob Franks, Union County officials, and officials of the municipalities in the upper portion of the basin, the Corps of Engineers will defer recommendation for flood protection in the upper portion of the basin for a period of one year. During this time a task force will be formed to address concerns over the NED plan in the upper portion of the basins and to build consensus to provide flood protection for this area of the project.

Description

385. The NED plan described in the preceding sections for the lower and Stony Brook portions of the basin is the plan recommended for construction by the U.S. Army Corps of Engineers, New York District. By letters dated September 13, 1995 and April 17, 1997, the local sponsor, New Jersey Department of Environmental Protection (NJDEP) has indicated their support for construction of the lower and Stony Brook portions of the basin, recognizing that construction recommendations for the upper portion of the basin will be deferred, and that the plan for the lower and Stony Brook portions of the basin provide somewhat less protection than the 1986 Authorized Plan. The recommended plan consists of levees, floodwalls, and non-structural methods in the lower portion of the basin and a limited channel modification in the

Stony Brook portion of the basin. This plan is in accordance with the Corps' Principles and Guidelines and is fully described in preceding sections.

Annual Charges

386. The detailed cost basis and summary cost tables of the recommended plan are presented in Support Document K, Cost Estimates. Costs presented are NED costs and do not necessarily reflect the financial costs. Contingencies, Engineering & Design and Supervision & Administration are included in the cost analysis. However, sunk costs expended in the Preconstruction Engineering and Design phase are not included in the benefit-cost-ratio calculation. Interest during construction is added to the construction cost to determine the total investment in the project and is calculated by computing interest at the applicable project discount rate on the monthly construction expenditures from the start of construction to the completion of the project. The construction of the flood control plan in the lower and Stony Brook portions of the basin is currently estimated to take 10½ years to complete. Total interest during construction for the recommended project is therefore calculated to be $116,583,000. This cost is simply an economic time value adjustment and does not require monetary expenditures.

387. **Operation, Maintenance and Replacements**. Charges attributable to the operation and maintenance (O&M) of the recommended plan consist of annualized replacement costs, anticipated energy charges, and the costs of routine maintenance. These costs are identical to the operation and maintenance costs for the designated NED plan for the lower and Stony Brook portions of the basin. Recommended plan components requiring routine care include channels, levees, floodwalls, and the interior drainage ponds, outlets, closure structures and pump stations.

388. **Rehabilitations**. Significant portions of the overall project's components such as levees are subject to damage from storms exceeding the design levels. The cost of repair after various flood events was weighted by their expected probability of occurrence to determine average annual major rehabilitation costs.

389. **Summary of Annual Costs**. Table 29 provides a summary of annual costs required to implement and operate the recommended plan .

TABLE 29 RECOMMENDED PLAN SUMMARY OF ANNUAL COSTS (April 1996 Price Level, 7-3/8% Discount Rate, 100-Year Period)			
Costs	**Lower Portion of the Basin**	**Stony Brook Portion of the Basin**	**Total**
First Cost	$248,130,000	$11,495,000	$259,625,000
Interest During Construction	$116,259,000	$324,000	$116,583,000
Total Investment Cost	$364,389,000	$11,819,000	$376,208,000
Interest and Amortization	$26,896,000	$872,000	$27,768,000
Operation, Maintenance, and Replacements	$1,013,000	$20,000	$1,033,000
Rehabilitation	$124,000	$0	$124,000
Total Annual Cost	**$28,033,000**	**$892,000**	**$28,925,000**

Benefits

390. Recommended plan benefits are equal to the gains to the National Economic Development (NED) as determined by the difference between conditions with- and without-project. As with the NED plan, benefits are based primarily on the damages that will be prevented by the project and averaged over the 100-year project life. Damage reduction estimates were based on historical floods, current development of the floodplain, and statistical analyses to account for risk and uncertainty in major damage variables.

391. Additional benefits attributable to the recommended plan are a reduction in Flood Insurance Administrative costs, a reduction in flood-related traffic delays, and a reduction in future bridge replacement costs.

392. Table 30 provides a summary of average annual benefits expected upon completion of the recommended plan.

TABLE 30 RECOMMENDED PLAN SUMMARY OF ANNUAL BENEFITS (April 1996 Price Level, 7-3/8% Discount Rate, 100-Year Period)			
Benefit Category	**Lower Portion of the Basin**	**Stony Brook Portion of the Basin**	**Total**
Reduction in Building Damages	$22,052,000	$1,042,000	$23,094,000
Residual Interior Flooding	($57,000)	$0	($57,000)
Total Flood Damage Reduction	$21,995,000	$1,042,000	$23,037,000
Pre-Base Year Benefits	$13,169,000	$0	$13,169,000
Reduced Public Emergency Costs	$706,000	$77,000	$783,000
Reduced FIA Administrative Costs	$141,000	$0	$141,000
Early Replacement of Bridges	$583,000	$0	$583,000
Reduced Traffic Delays	$19,000	$1,000	$20,000
TOTAL	$36,613,000	$1,120,000	$37,733,000

393. **Benefits During Construction**. As soon as the lower portion of the basin sections of the recommended plan are completed they begin preventing flood damage. To account for these benefits, compound interest is added to these pre-base year benefits in the same manner that interest was applied to construction costs. The total annualized value of these pre-base year benefits is calculated to be $13,169,000, and was added to the overall project benefit stream. The Stony Brook portion of the basin is the last construction segment of the project and therefore does not accrue pre-base year benefits.

Feasibility

394. Project benefits outweigh the project cost for the lower and Stony Brook portions of the basin as demonstrated on Table 31. The benefit to cost ratio is estimated to be 1.3 to 1.

TABLE 31
RECOMMENDED PLAN
SUMMARY OF ANNUAL BENEFITS AND COSTS
(April 1996 Price Level, 7-3/8% Discount Rate, 100-Year Period)

Costs	Lower Portion of the Basin	Stony Brook Portion of the Basin	Total
Annual Benefits	$36,613,000	$1,120,000	$37,733,000
Annual Costs	$28,033,000	$892,000	$28,925,000
Net Excess Benefits	$8,580,000	$228,000	$8,808,000
BCR	1.3	1.3	1.3

PROJECT IMPLEMENTATION

Overview

395. The implementation process will carry the project through the remaining design phases, preparation of feature design memoranda for the various elements of the project, development of plans and specifications, and construction. Funds must be budgeted by the Federal government and non-Federal sponsor, NJDEP, to support these activities, which include the preparation of a final plan. A schedule will be developed to identify the steps and financial requirements.

General

396. The implementation process will carry the project through the remaining design phases, preparation of plans and specifications, and construction. Funds must be budgeted by the Federal government and NJDEP to support these activities. The NJDEP must sign a project cooperation agreement to support the Corps' budget request. A project schedule will be established based on reasonable assumptions on the construction schedule and the year-by-year financial requirements. The first project features to be constructed will be located near the Raritan River - Green Brook Confluence. A Feature Design Memorandum for the first construction phase will be the basis for construction plans and specification.

Local Cooperation Requirements

397. The Water Resources Development Act of 1986 (Public Law 99-662) sets forth specific provisions for Federal and non-Federal cost sharing on water resource projects. For a local flood protection project, the Federal government will provide a maximum contribution of 75% of the total project costs assigned to structural flood control components. The Federal contribution is dependent upon Legislative and Executive Branch funding of the project.

398. The non-Federal sponsor is required to provide a minimum contribution of 25% of the total project cost. For the structural flood control components of a project, the sponsor's share shall consist of a minimum cash contribution of five percent (5%) of the total cost assigned to flood control plus all lands, easements, rights-of-way, relocations and disposal areas (LERRD)

necessary for project construction. Cash payments are to be made during the construction period at a rate proportional to Federal expenditures. The sponsor's share of preconstruction engineering and design costs are to be repaid during the first year of construction. These costs which equal $24,000,000 were distributed over the three portions of the basin for the NED Plan. However, for the Recommended Plan, these costs will be recovered by re-apportioning the $24,000,000 over the lower and Stony Brook portions of the basin as demonstrated in Table 32. LERRD are to be furnished to the Federal government prior to the advertisement of any construction contract which involves those LERRD.

TABLE 32
SUMMARY OF RECOMMENDED PLAN FIRST COSTS
(April 1996 Price Level)

Account	Lower Portion of the Basin	Stony Brook Portion of the Basin	Project Total
01 Lands and Damages	$22,355,000	$427,000	$22,782,000
02 Relocations	$2,657,000	$0	$2,657,000
04 Dams	$0	$0	$0
06 Fish & Wildlife Mitigation	$12,296,000	$213,000	$12,509,000
08 Roads & Bridges	$27,705,000	$1,272,000	$28,977,000
09 Channels	$7,908,000	$7,244,000	$15,152,000
11 Levees & Floodwalls	$71,274,000	$0	$71,274,000
13 Pumping Plants	$29,761,000	$0	$29,761,000
15 Floodway/Diversion Control Structures	$16,208,000	$0	$16,208,000
18 Cultural Resource Preservation	$1,846,000	$95,000	$1,941,000
19.01 Non-Structural	$11,712,000	$282,000	$11,994,000
19.02 Landscaping	$3,698,000	$191,000	$3,889,000
20 Permanent Operating Equipment	$115,000	$0	$115,000
30 Planning, Engineering & Design	$24,261,000	$1,058,000	$25,319,000
31 Construction Management	$16,334,000	$713,000	$17,047,000
SUB-TOTAL	$248,130,000	$11,495,000	$259,625,000
30 Preconstruction Engineering and Design	$22,937,000	$1,063,000	$24,000,000
TOTAL	$271,067,000	$12,558,000	$283,625,000

399. If the value of the sponsor's contributions for the structural portion of the project discussed above is less than 25% of the project costs assigned to flood control, then the sponsor is required to pay during construction such additional amounts as are necessary for the sponsor's total contribution to equal 25%. If the value of the sponsor's contribution listed above is more than 25% of the project's structural costs, then the Federal contribution is reduced accordingly to less than 75%. Special cost-sharing provisions may apply if the sponsor's contribution exceeds 25% and the sponsor meets certain qualifications concerning its ability to pay.

400. For non-structural components of a flood control plan, the non-Federal sponsor is required to provide 25% of the cost and the Federal contribution is set at 75%. For cultural resources mitigation, the Federal government will contribute 100% of the cost for cultural mitigation up to a limit of 1% of the total Federal project cost; thereafter, the cost for cultural resources mitigation is shared 75% and 25% between the Federal government and non-Federal sponsors, respectively.

401. The sponsor is responsible for all operation, maintenance, and replacement costs after project completion. In providing the LERRD, the sponsor must comply with the provisions of the Uniform Relocations Assistance and Real Property Acquisition Policies Act of 1979 (Public Law 91-646), as amended. The sponsor must also participate in and comply with applicable Federal floodplain management and flood insurance programs.

402. In addition, the sponsor must agree to hold and save the United States free from damages due to the construction or operation and maintenance of the project, except for damages due to the fault or negligence of the United States or its contractors. A project may be initiated only after the sponsor has entered into a binding agreement with the Department of the Army.

403. The specific items of local cooperation for this project are:

a. Provide without cost to the United States all lands, easements, and rights-of-way, including suitable borrow areas, necessary for construction, operation and maintenance of the project, and all necessary relocations;

b. Hold and save the United States free from damage arising from construction, operation, and maintenance of the project, except for damages due to the fault or negligence of the United States or its contractors;

c. Operate, maintain, repair, replace, and rehabilitate the completed project in accordance with regulations or directions prescribed by the Federal government;

d. Pay during project construction at least 5% of the total project first cost assigned to structural flood control features;

e. Pay during project construction such additional amounts so that the total contribution of the non-Federal sponsor is not less than 25% of the total structural project first cost assigned to flood control;

f. Pay during project construction 25% of the total project first cost assigned to non-structural flood control features;

g. Comply with the provisions of the Uniform Relocations Assistance and Real Property Acquisition Policies Act of 1970 (Public Law 91-646), as amended;

h. Publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their guidance and leadership in preventing unwise future development in the floodplain and in adopting such regulation as may be necessary to prevent unwise future development and to ensure compatibility with protection levels provided by the project;

i. Participate in and comply with applicable Federal floodplain management and flood insurance programs;

j. At least annually notify affected interests regarding the limitations of the protection afforded by the project;

k. Comply with Section 601 of Title VI of the Civil Rights Act of 1964 (Public Law 88-352) and Department of Defense Directive 5500.II issued pursuant thereto and published as Part 300 of Title 32, Code of Federal Regulations, as well as Army Regulation 600-7, entitled, "Non-discrimination of the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army."

Cost Apportionment

404. The Water Resources Development Act of 1986, Section 103, which sets forth cost sharing for flood control projects, states that non-Federal interests must operate, maintain, and rehabilitate the project; must provide lands, easements, rights-of-way, relocations, and disposal areas (LERRD); and must contribute 5% of the cost assigned to flood damage reduction in cash. If the LERRD and the 5% cash do not exceed 25% of the total cost assigned to flood damage reduction, additional cash contribution must be provided to bring the total non-Federal share to 25%. If the 5% cash plus LERRD exceeds 30% of the total cost assigned to flood damage reduction, non-Federal interests may reimburse the excess over fifteen years. The non-Federal share is limited to 50%.

405. For non-structural components of the project, the Federal / non-Federal cost share is split 75% / 25% respectively. The non-Federal sponsor is responsible for LERRD associated with non-structural measures, and must also contribute cash to bring the total non-Federal share to 25%. If the LERRD associated with non-structural controls exceeds 25% of the cost, the non-Federal sponsor is credited for the excess over 25%. Cultural Resource preservation costs are 100% Federal responsibilities for up to 1% of the Federal cost of the project after which the cost is shared 75% and 25% between the Federal government and non-Federal sponsors, respectively.

406. The Federal share of the project's total first cost is $210,083,000. This represents 74.1% of the total. The Federal Government will design the project, prepare detailed plans/specifications, and construct the project, exclusive of those items specifically required of non-Federal interests.

407. The non-Federal share of the estimated total first cost of the proposed project is $73,542,000. The non-Federal cost consists of a number of components including lands, easements, rights-of-way, relocations, and disposals totaling $56,812,000; 25% of the costs associated with non-structural flood protection totaling $3,307,000; and a 5% cash contribution of $13,423,000. The non-Federal share represents 25.9% of the total project first costs. A breakdown of these Federal and non-Federal cost share is shown in Table 33. The fully funded project cost estimate of $331,042,000 includes project implementation first costs of $259,625,000 (April 1996 price level) inflated through the construction to a value of $307,042,000 plus the

previously expended PED cost of $24,000,000. The actual funding levels required from the Federal Government and the non-Federal sponsor will be based on the fully funded estimate, thus they will be higher than the apportioned first costs.

408. **Preconstruction Engineering & Design Cost Sharing**. The Preconstruction Engineering and Design (PED) phase of the project is also cost shared between the Federal Government and the non-Federal sponsor; however, these expenditures are initially paid for in full by the Federal Government. The non-Federal sponsor will reimburse the Federal Government for its share of these costs during the first year of construction.

409. For the Green Brook Flood Control Project the PED phase began in 1987 and will continue until the first set of plans and specifications are completed, and the expenditure of construction funds begins. The anticipated starting date for construction funding is October 1997. During this period the PED expenditures are estimated to be $24,000,000. Based on the overall project cost sharing of 74.1% Federal and 25.9% non-Federal, the local sponsor is obligated to reimburse the Federal Government $6,216,000 during the first year of construction to cover its share of expenditures during the PED phase.

410. The PED phase expenditures, commonly referred to as "sunk costs," are included in the project cost estimate but are not included in the NED costs. All future planning, engineering and design costs during the construction phase, however, are included in both the project cost estimate and the NED costs of project implementation. In summary, the total project cost for cost-sharing purposes, including PED phase costs, is $283,625,000, the Federal share of 74.1% being $210,083,000 and the non-Federal share of 25.9% being $73,542,000.

411. **Economic Costs vs Project Costs**. Since the economic analysis assesses the viability of future project investments, sunk costs of $24,000,000 are considered a project cost but not a NED cost for inclusion in the benefit-cost-ratio calculations.

TABLE 33
COST APPORTIONMENT
FEDERAL AND NON-FEDERAL RESPONSIBILITIES
RECOMMENDED PLAN

Item	Cost	Percent
Structural Components of Project		
Total Cost (Including PED costs)	$ 268,456,000	
Federal Share	198,221,000	73.0%
Non-Federal Share	70,235,000	27.0%
a. 5% Cash	13,423,000	
b. LERRD's	56,812,00	
Non-Structural Components of Project		
Total Cost (Including PED costs)	13,228,000	
Federal Share	9,921,000	75.0%
Non-Federal Share	3,307,000	25.0%
Cultural Mitigation		
Total Cost	1,941,000	
Federal Share	1,941,000	100%
Non-Federal Share	0	0%
Project Summary		
Total Cost	283,625,000	
Federal Share	210,083,000	74.1%
Non-Federal Share	73,542,000	25.9%

COST SUMMARY

Construction Phase		
Structural	$178,650,000	
F&W Mitigation	$10,113,000	
Mitigation LERRD's	$2,396,000	
LERRD's	$54,416,000	
Non-Structural	$12,109,000	
Cultural	$1,941,000	
Sub-Total Construction Phase		$259,625,000
Preconstruction Engineering and Design (PED) Phase		
Structural Components PED	$22,881,000	
Non-Structural Components PED	$1,119,000	
Sub-Total PED Phase		$24,000,000
TOTAL Project First Cost		$283,625,000

NOTES:

1. Total project first cost estimate, including both PED and Construction phase costs at April 1996 price levels.

Project Cooperation Agreement

412. The Project Cooperation Agreement (PCA) will define the responsibilities of the Corps and the non-Federal sponsor for project financing, operation and maintenance. The NJDEP will be required to provide a number of items of local cooperation, including the provision of all lands, easements and rights-of-way for construction , and the operation and maintenance of the project.

Construction Phasing

413. **General**. If found to be consistent with Federal budget criteria for new start construction, and if funds are available, construction funding could occur for the Corps' fiscal year 1999. Construction would begin in December of 1998, and would extend through May, 2009.

414. **Sequence of Construction**. There are several general design, construction and funding constraints which have been incorporated into the preliminary schedule.

a. Construction funding is obtained at the start of Fiscal Year 1999 (FY 99).

b. The construction sequence must minimize the risk of induced flooding.

c. The construction sequence should maximize the effectiveness of completed features.

415. These general guidelines are reflected in the sequencing of the major construction features. It is anticipated that each of these major elements will require one or more construction contracts for efficient implementation. Figures 59 and 60 present the layout of the project segments and the anticipated schedule for the construction elements. Schedule constraints for each of the seven major construction contract areas are described below.

416. Construction Area 1. Located at the confluence of Green Brook with the Raritan River, this most downstream portion of the project does not require construction of any other project contracts prior to implementation. Feature design in this area has been advanced in anticipation that the first construction contract will be within this area. Although hydrologic modeling indicates that it is not essential, it is desirable to complete the Green Brook portion of this contract prior to constructing any upstream levees. This sequence would avoid any unforeseen induced flooding.

417. Construction Area 2. This contract area consists of the detention facilities in the upper portion of the basin and is being deferred pending further local evaluation of the upper portion of the basin.

418. Construction Area 3. This portion of the project includes numerous levees and drainage facilities along Green Brook as well as the Bound Brook and Municipal Brook tributaries, with a tie-off at the downstream end of Stony Brook. In order to avoid any induced flooding associated with a loss of floodplain storage, construction will begin subsequent to completion of contracts in area 1. In order to avoid any potential induced flooding, the entire line of protection for this area should be completed prior to construction of the upstream channels on Green Brook and Stony Brook. Modification of the railroad bridge over Bound Brook and construction of the levees near the confluence of Bound Brook and Cedar Brook should not be completed prior to construction of levees along Bound Brook.

419. Construction Area 4. This includes the non-structural protection to floodplain buildings located upstream of the levees at the Green Brook-Bound Brook confluence and downstream of the levees at the Bound Brook-Cedar Brook confluence. Although construction in this area does not require prior completion of any other feature, the design level of protection will not be provided until the downstream railroad bridge modifications have been completed. As previously mentioned, however, the railroad bridge should not be modified without constructing the downstream levees . Further complicating the sequence of construction in this area is the potential for the downstream levees to create a slight increase in flood depths upstream of the railroad unless the bridge modification is complete. In consideration of these effects the construction sequence calls for area 4 to be constructed concurrent with the downstream levees on Bound Brook. Starting construction at the downstream end of area 4 will minimize the potential for induced flood damage. The upstream portions of this features should be completed prior to construction of any upstream levees.

420. Construction Area 5. This area consists of the Green Brook channel improvements upstream of Stony Brook and is being deferred pending further local evaluation of the upper portion of the basin..

421. Construction Area 6. The area 6 protection works, located at the Cedar Brook/Bound Brook confluence, should not be implemented until protection is in place on the lower portions of Bound Brook.

422. Construction Area 7. Consisting of channel improvements along Stony Brook, construction in this area is not required prior to implementing any other project feature. Although the hydrologic modeling does not specifically indicate any induced flooding attributable to this channel improvement, it is prudent to complete the downstream levees prior to construction.

Schedule of Expenditures

423. The annual funding schedule provided is based on the project construction schedule and cost estimate. Due to the difference in timing between the Federal government's and the non-Federal sponsor's fiscal years, the schedule is provided in terms of calender years. Subject to the availability of construction funding, a project construction schedule has been established, which assumes a construction start date of December 1998. The project completion date is estimated to occur in May 2009 yielding a construction period of 10½ years. The fully funded project cost for future expenditures including inflation is $307,042,000. This figure does not include the Preconstruction Engineering and Design cost of $24,000,000 which has already been expended by the Federal government. The funding schedule includes adjustments for price escalation to the mid-point in time for each construction area. The annual schedule of expenditures in Table 34 shows the project costs broken out into construction areas which coincide with the project construction schedule (See Figure 60). The bottom row of figures in Table 34 summarizes the annual schedule of expenditures.

TABLE 34
SCHEDULE OF EXPENDITURES IN $ THOUSANDS

Construction Segment	Cost, $000	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Construction Area 1													
1a Main St. Brdg/Seg. T	$11,755		$8,816	$2,939									
1b Segment T	$14,977		$4,992	$9,985									
1c Segments U & R	$28,841			$8,240	$20,601								
1d Segment A	$11,094				$7,396	$3,698							
1e Segment N	$2,200	$183	$2,017										
Construction Area 3													
3a Segment B	$33,009					$9,628	$16,504	$6,877					
3b Segment H	$12,499						$12,499						
3c Segment C	$48,856						$2,036	$24,428	$22,392				
3d Segment D	$20,426							$7,943	$12,483				
3e Segment I	$23,002									$23,002			
3f Segment J	$26,400										$16,133.0	$10,267.0	
3g Segment K	$18,320									$9,160	$9,160.0		
Construction Area 4													
4a Segment P	$7,258					$1,814	$3,111	$2,333					
4b Segment Q	$1,784					$1,041	$743						
Construction Area 6													
6a Segment E	$10,359									$9,496	$863.0		
6b Segment F	$7,253									$3,022	$4,231.0		
6c Segment G	$14,096										$11,747.0	$2,349.0	
Construction Area 7													
7a Segment L	$14,913											$6,628.0	$8,285.0
Total Cost	$307,042	$183	$15,825	$21,164	$27,997	$16,181	$34,893	$41,581	$34,875	$44,680	$42,134.0	$19,244.0	$8,285.0

1. Preconstruction Engineering and Design expenditures through FY-97 of $24,000,000 are not included in the above table.

2. Annual expenditures assuming unconstrained Federal and Non Federal Funding.

CONCLUSION

424. Federal interest is demonstrated by the project authorized by the Water Resources Development Act of 1986, as re-scaled and updated. The scaled down plan is the NED plan and is within the authorized project scope. The plan would provide significant flood protection to the lower, Stony Brook and upper portions of the Basin.

425. The recommended plan for implementation at this time consists of the elements of the NED plan in the lower and Stony Brook portions of the Basin. This recommendation is based on the New Jersey Department of Environmental Protection's (NJDEP) desire to implement these elements while deferring implementation of the plan in the upper portion of the basin until further evaluation of this portion is conducted. The evaluation desired by NJDEP would be based on the concerns raised by the public review of the draft General Reevaluation Report and ongoing investigations by local interests. Future Corps study of the upper portion as a separable element would be appropriate upon higher authority approval, availability of resources, and provided that the study be restricted to consideration of alternatives that are within the envelope of the recommended plan in the lower portion.

426. New York District has considered all aspects of these conclusions. These aspects include environmental, social and economic effects, engineering feasibility and compatibility of the project with desires and capabilities of the NJDEP and other interested parties.

RECOMMENDATION

427. The New York District recommends approval of this General Reevaluation Report and approval of the recommended plan for construction in the lower portion of the basin and the Stony Brook portion of the basin. The District also recommends further evaluation of the upper portion, as requested by the New Jersey Department of Environmental Protection, subject to the conditions specified in this General Reevaluation Report's conclusions. Upon approval, the General Reevaluation Report will be the basis for a Project Cooperation Agreement between the Federal Government and the New Jersey Department of Environmental Protection.

428. The recommendations contained herein reflect the information available at the time and current U.S. Army Corps of Engineers policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified at higher levels. The local sponsor will also be afforded an opportunity to comment further.

Gary Thomas
Colonel
Corps of Engineers
District Engineer

FIGURES

LIST OF FIGURES

LIST OF FIGURES

FIGURE DESCRIPTION

Figure No.	Description
Figure 1	Map of the overall Green Brook Basin and it's location within the State of New Jersey.
Figures 2 & 3	Plates taken from the 1980 Feasibility Report depicting the location of Plan A and Plan E improvements.
Figure 4	Flow diagram outlining plan formulation process during the Feasibility Study.
Figure 5	Project map index sheet prepared for this General Reevaluation Report. This map provides the layout key to the detailed plan sheets and a drawing cross reference table.
Figures 6 through 30	Detailed mappings of the project area showing the existing buildings, roadways, railways, delineation of the 150-year floodplain, and the proposed flood control features. The actual project area maps were prepared at a scale of 1"=200', these figures are reduced copies of those maps and are shown at an approximated scale of 1"=530'.
Figures 31 through 48	Profile drawings along the line of protection. In the areas of levee/ floodwall features, these drawings depict the existing and proposed grades along the levee/ floodwall alignment. Also shown are interior drainage facilities and the locations of roadways that cross the line of protection. In the areas of channel modifications, drawings depict the existing and proposed grades along the streambed and the bridges crossing over the brooks.
Figures 49 through 58	Engineering drawings of typical details showing the various project features including: levees, floodwalls, channels, detention control structures, gate closure structures, bridge replacements, pump stations, main outlets, and flood proofings.
Figures 59 and 60	Map providing the location of the project segments and the Estimated Project Construction Schedule broken down by construction area and segment.

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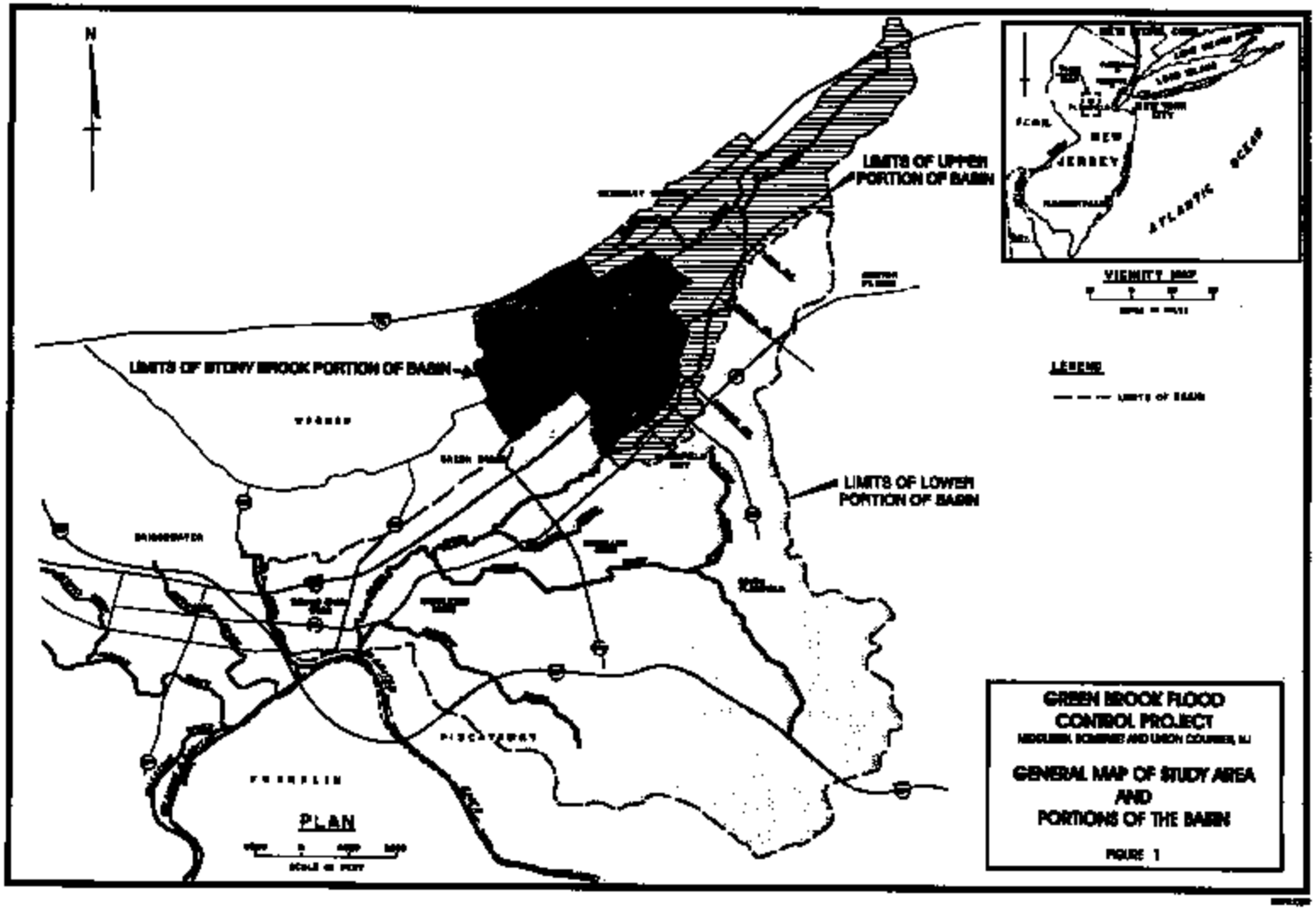
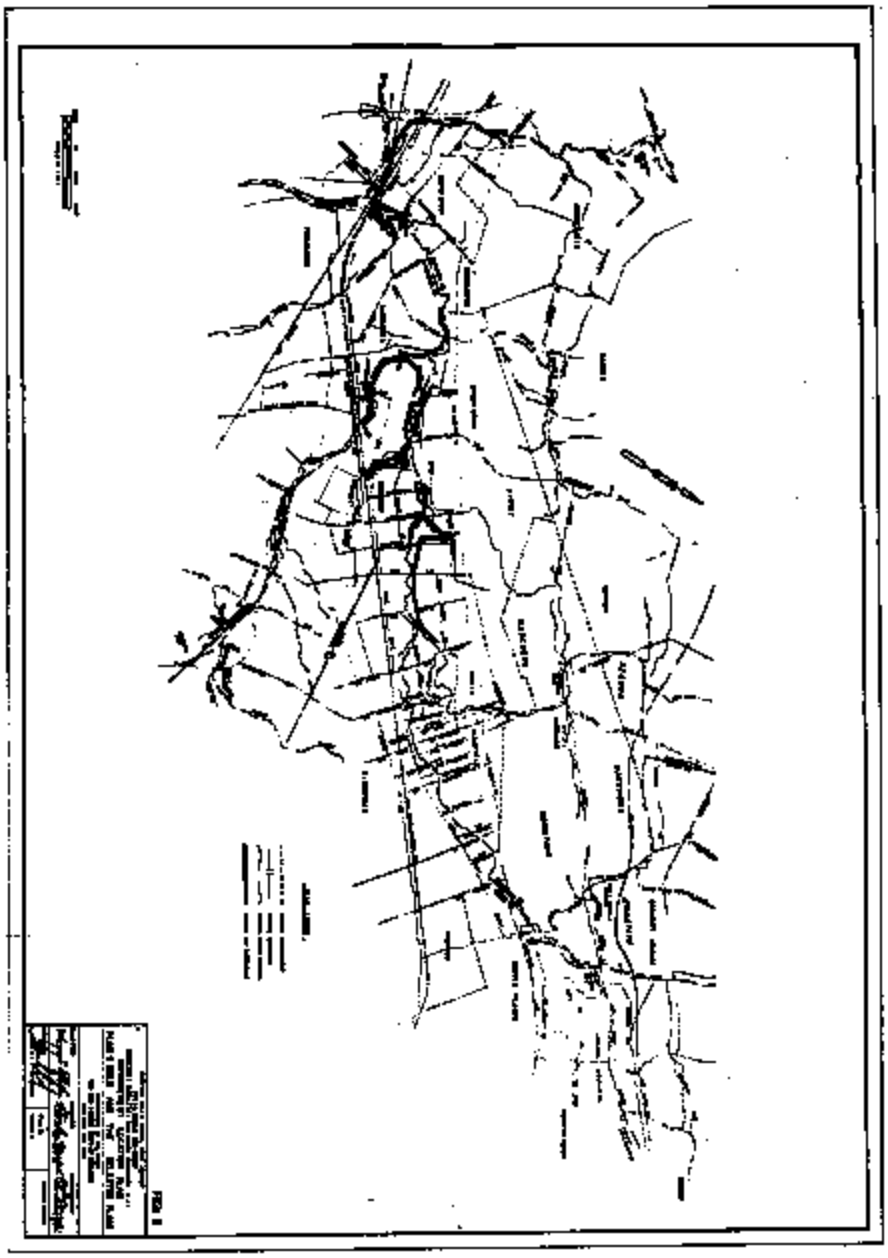
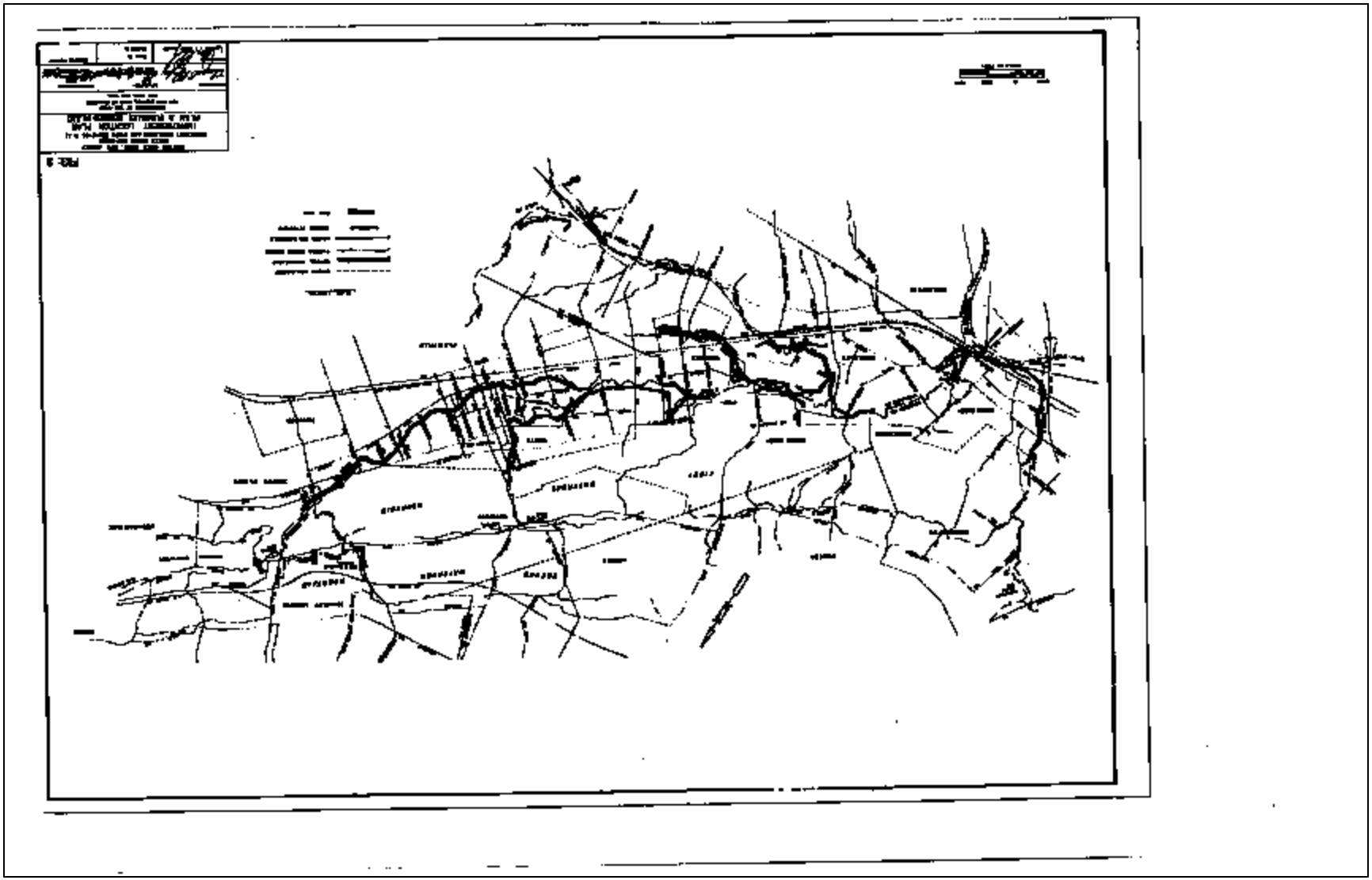
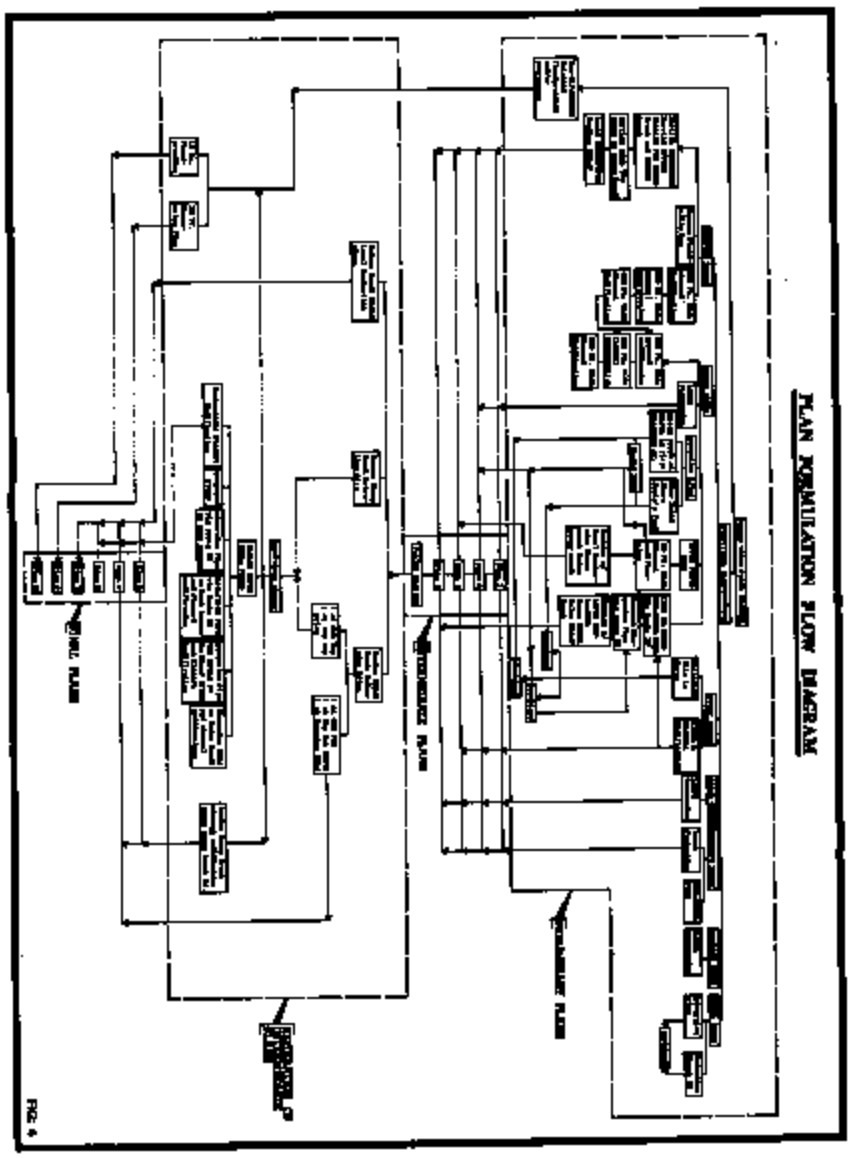
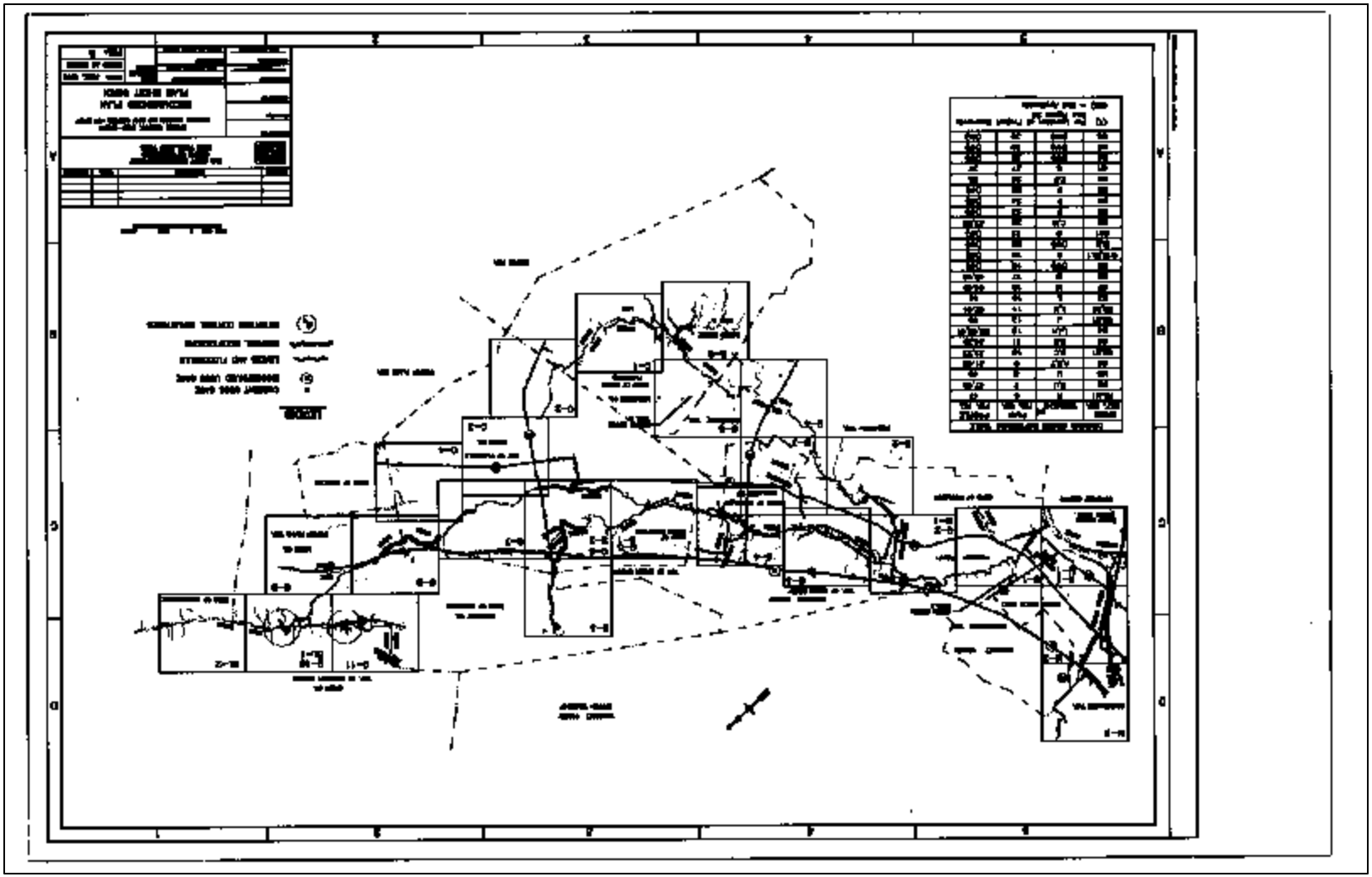
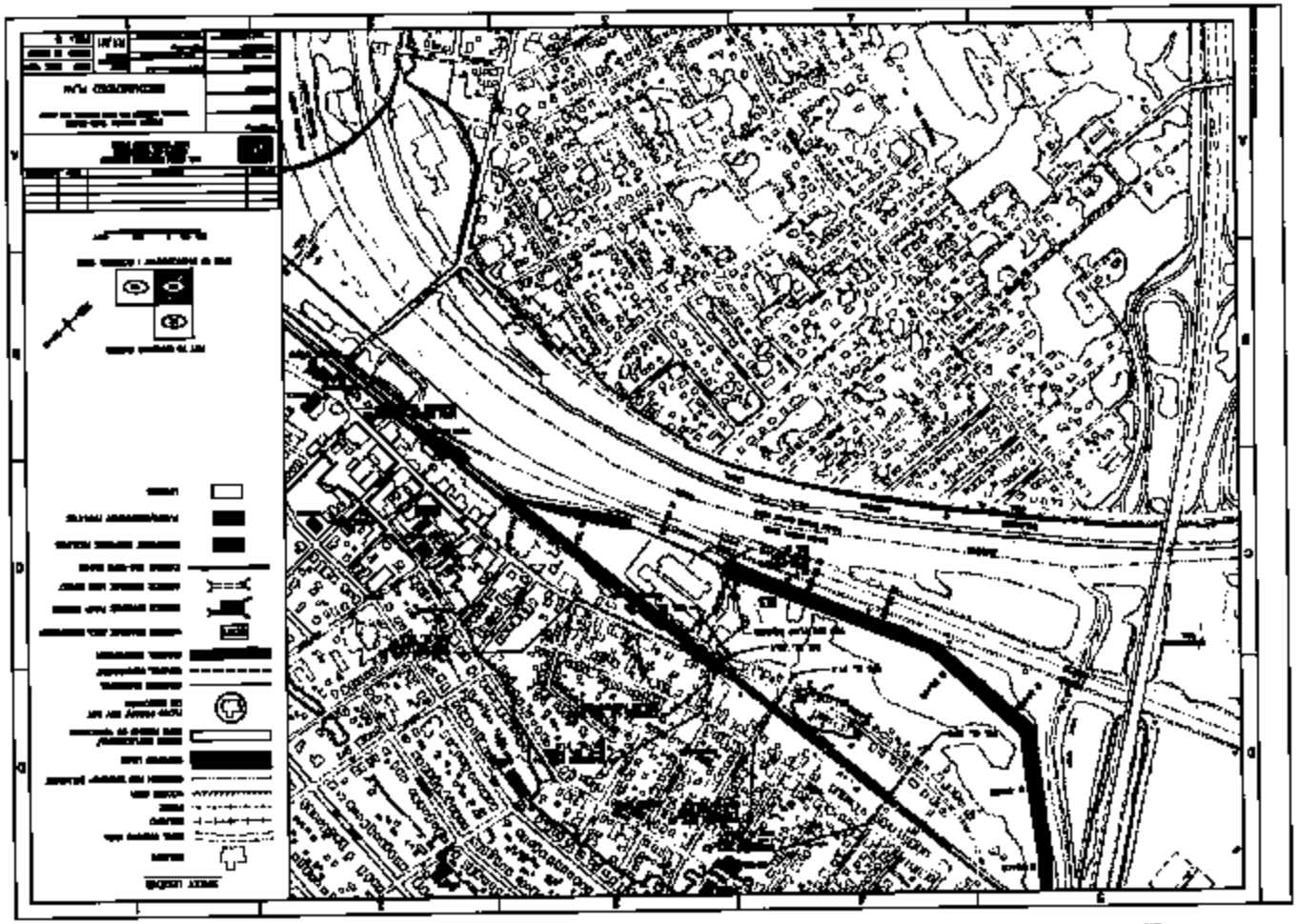

N
LIMITS OF UPPER PORTION OF BASIN
LIMITS OF STONY BROOK PORTION OF BASIN
LIMITS OF LOWER PORTION OF BASIN
WARREN
BRIDGEWATER
PISCATAWAY
FRANKLIN
PLAN
VICINITY MAP
NEW JERSEY
ATLANTIC OCEAN
LEGEND
GREEN BROOK FLOOD CONTROL PROJECT
GENERAL MAP OF STUDY AREA AND PORTIONS OF THE BASIN
FIGURE 1

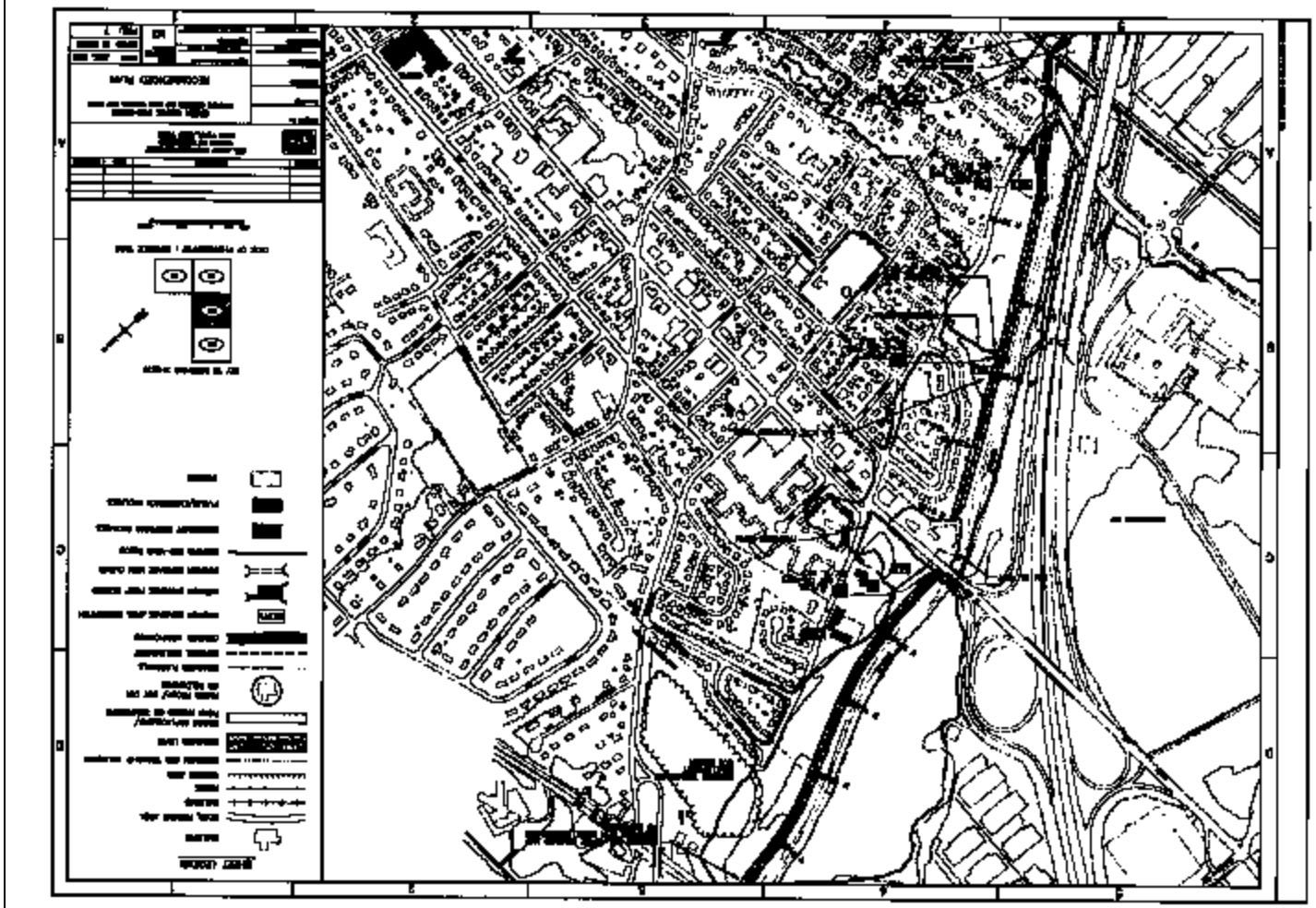


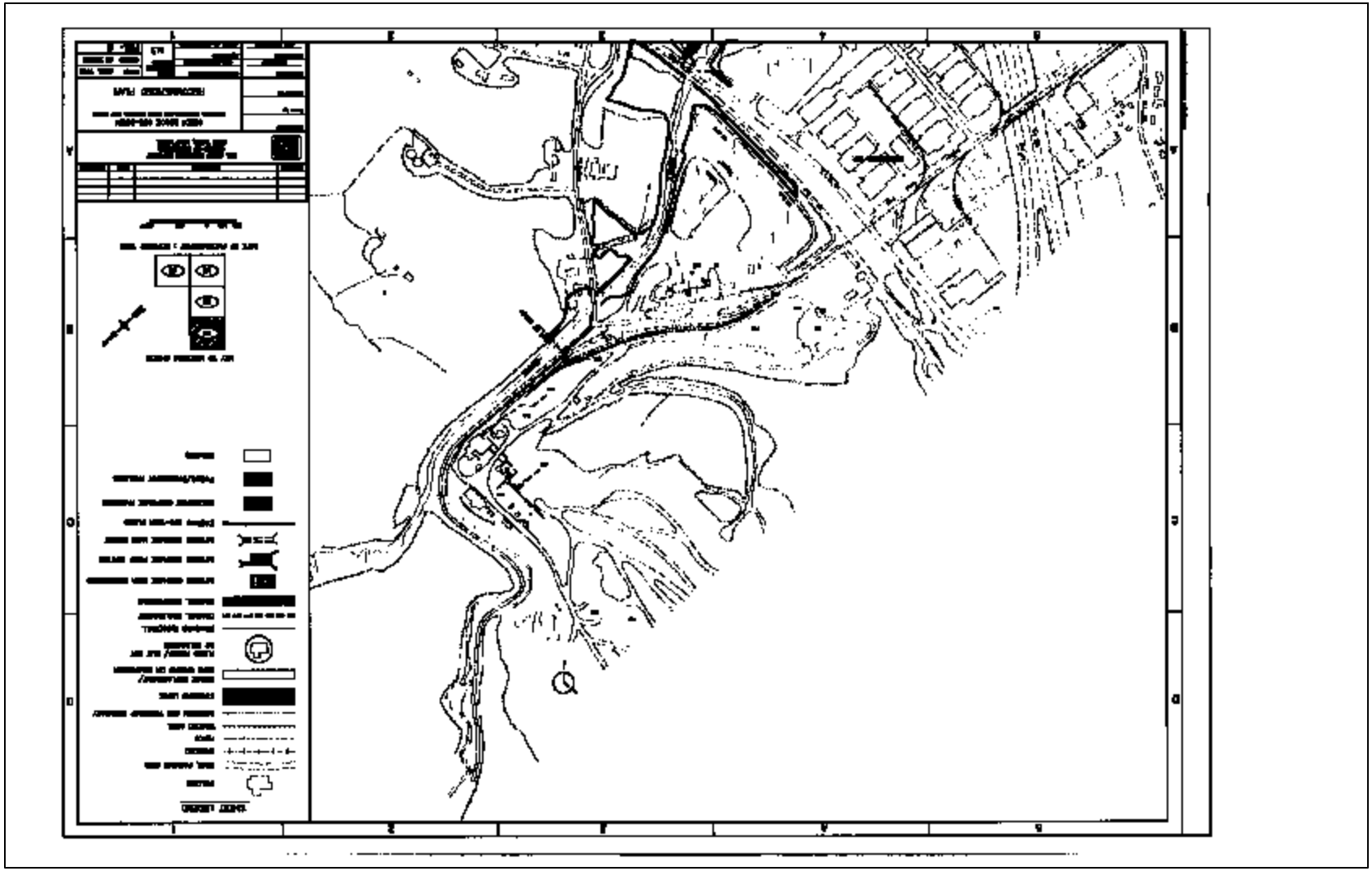


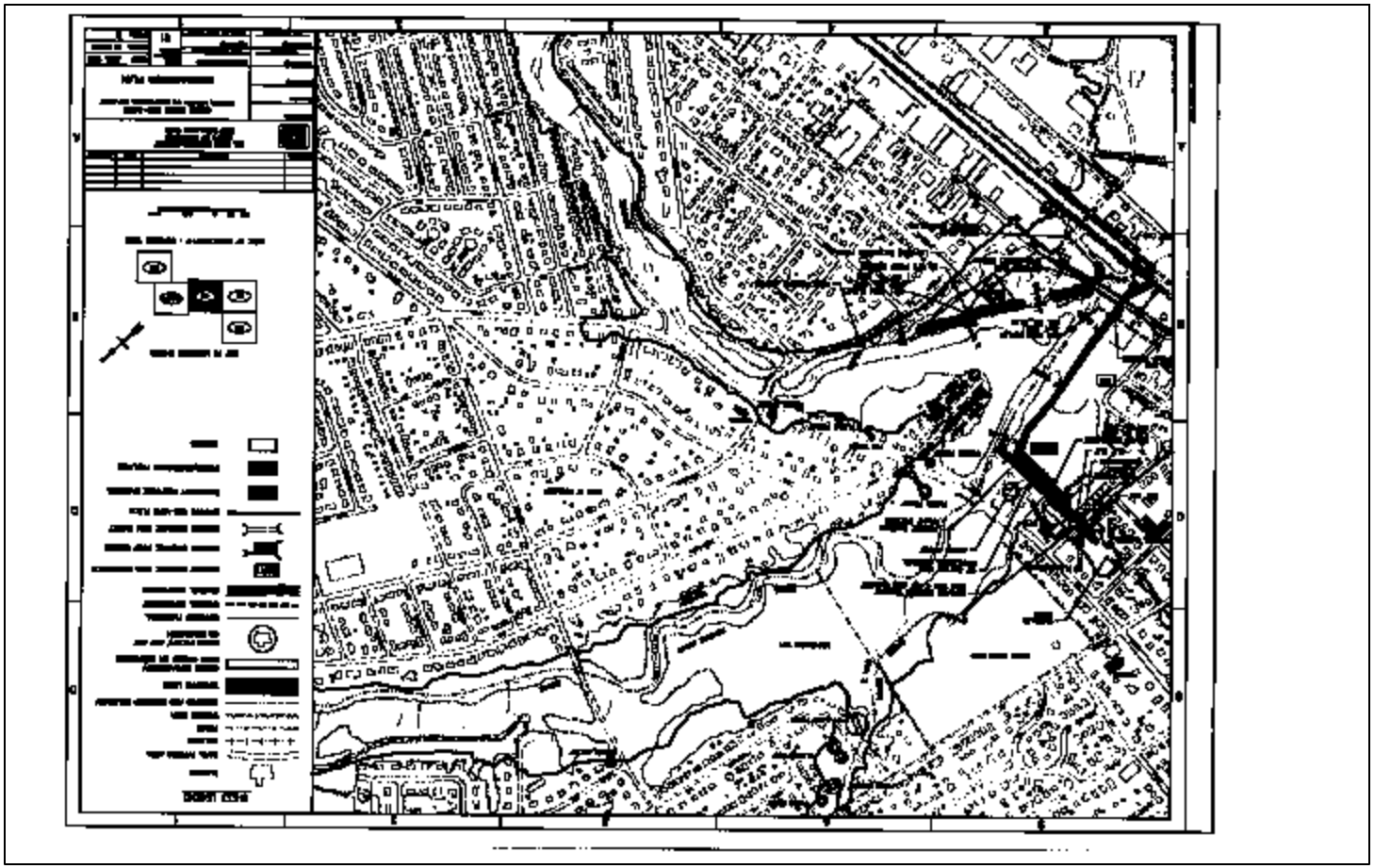

PLAN FORMULATION FLOW DIAGRAM

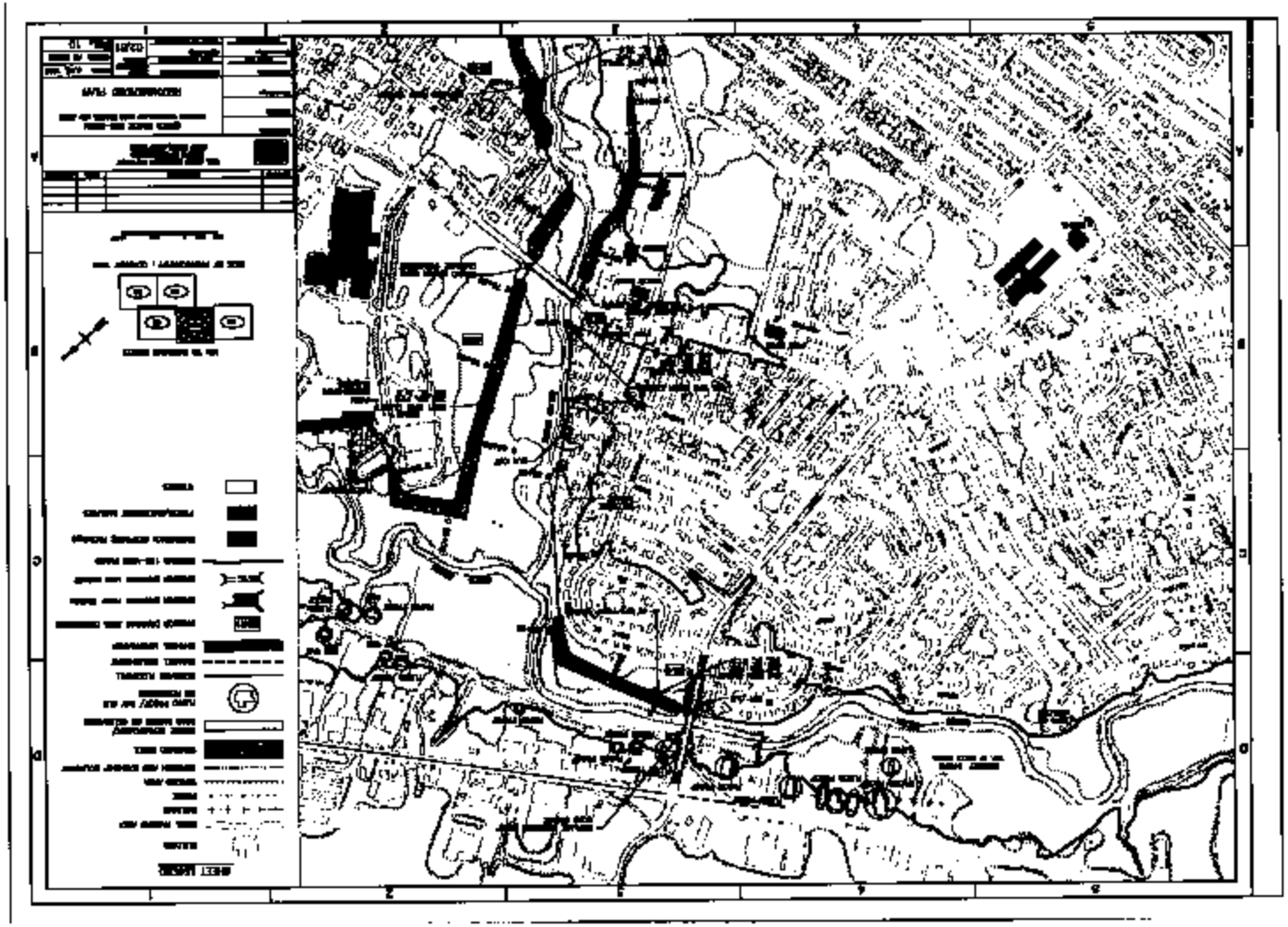


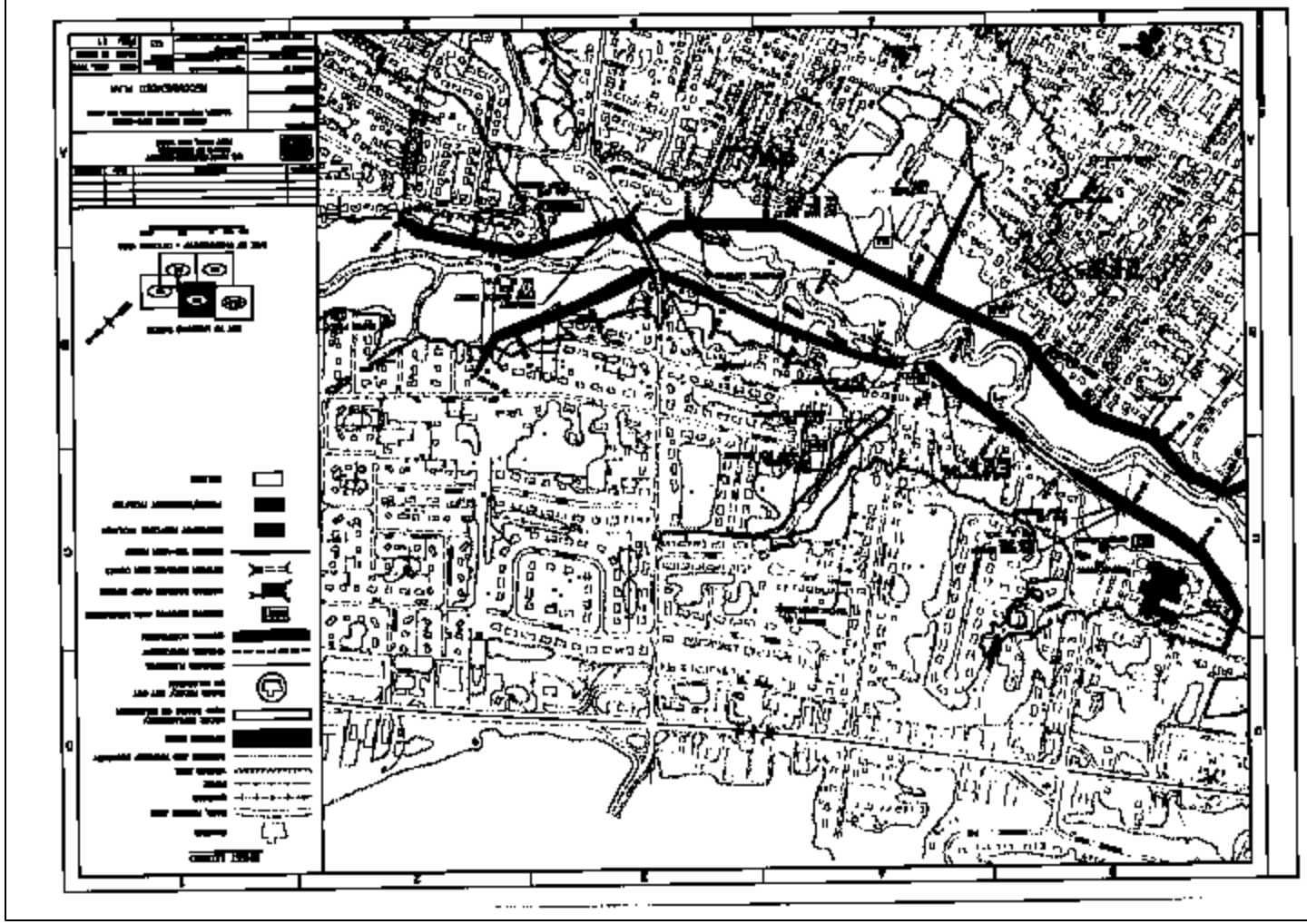


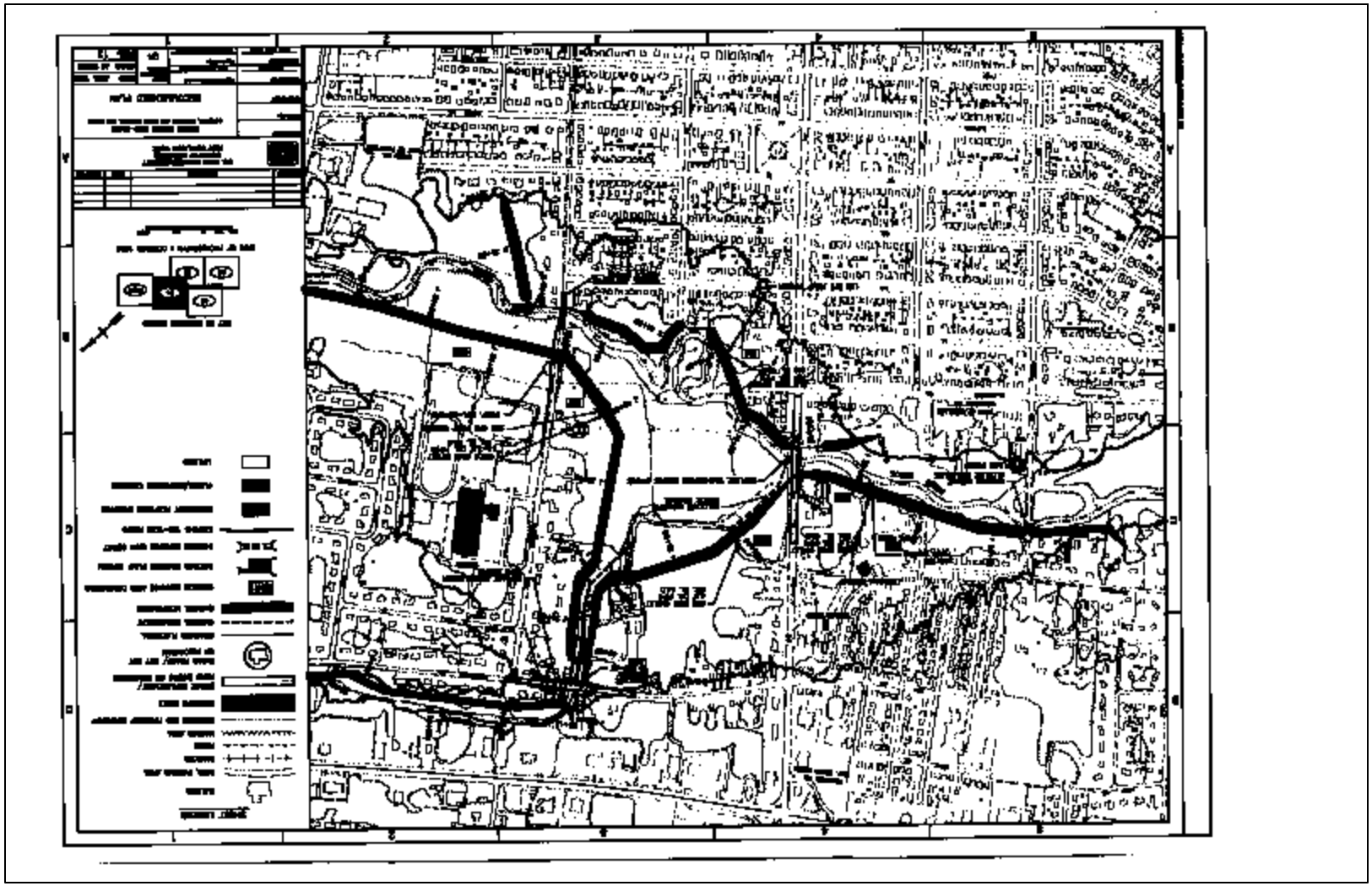


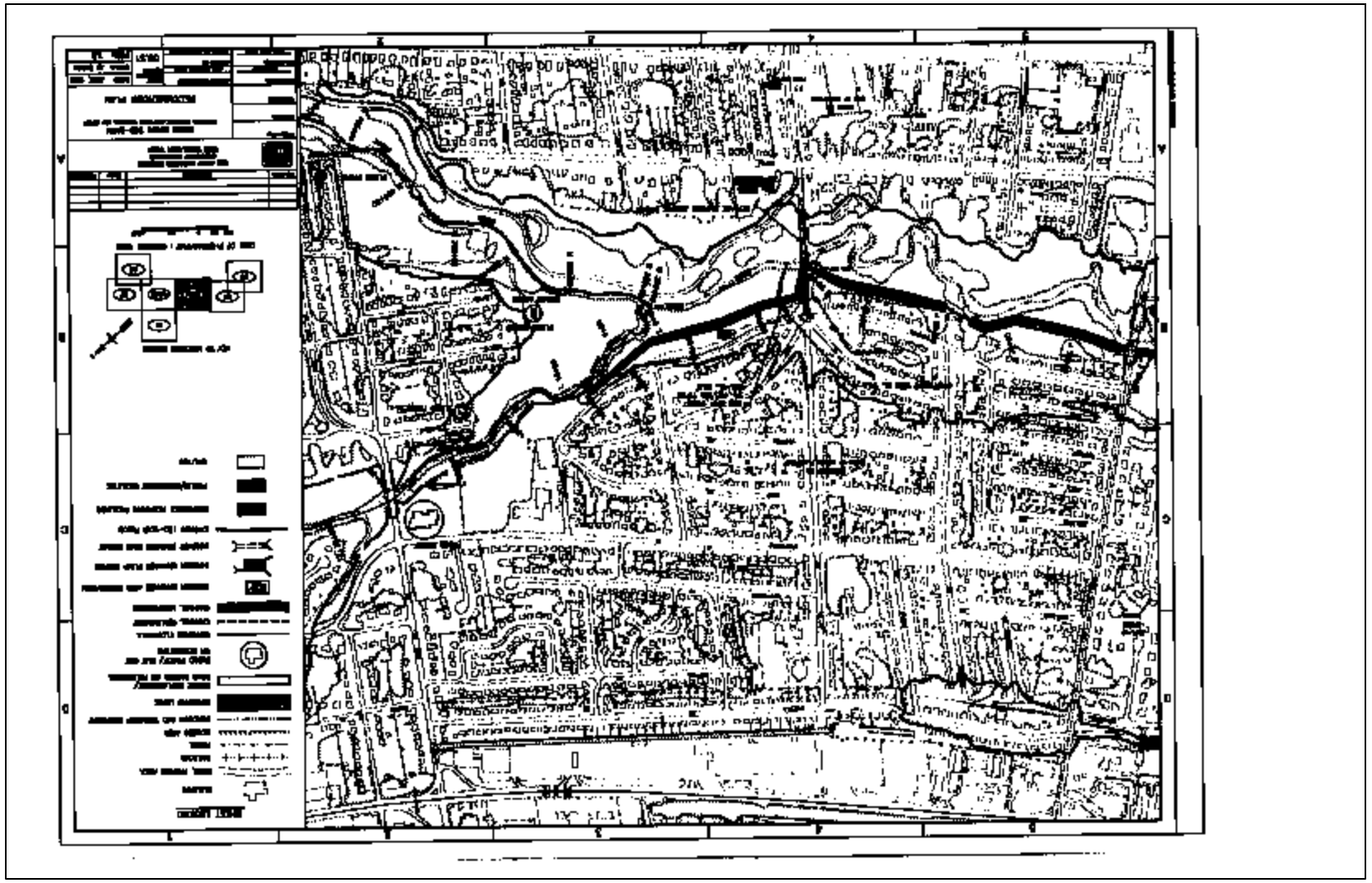


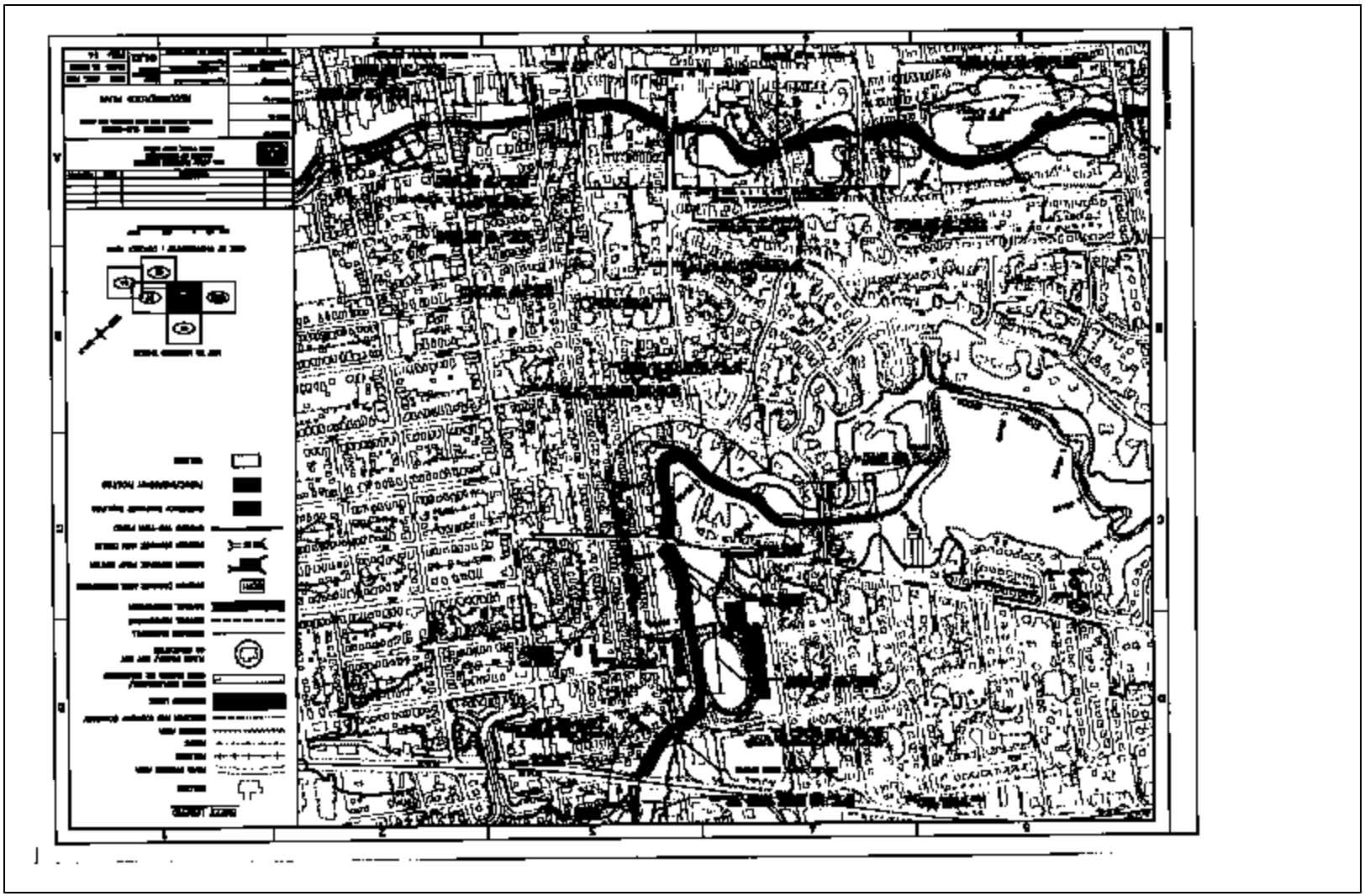


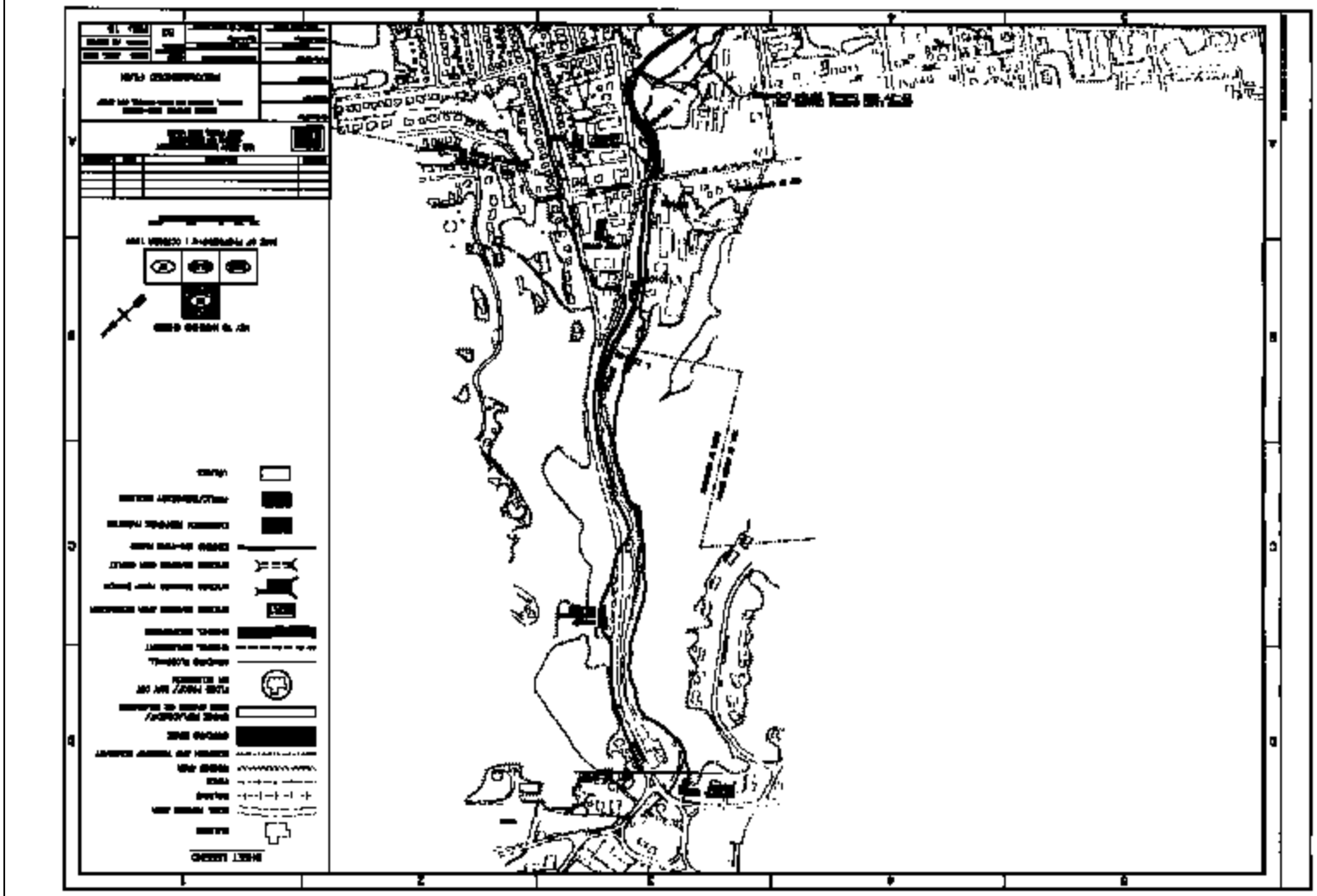


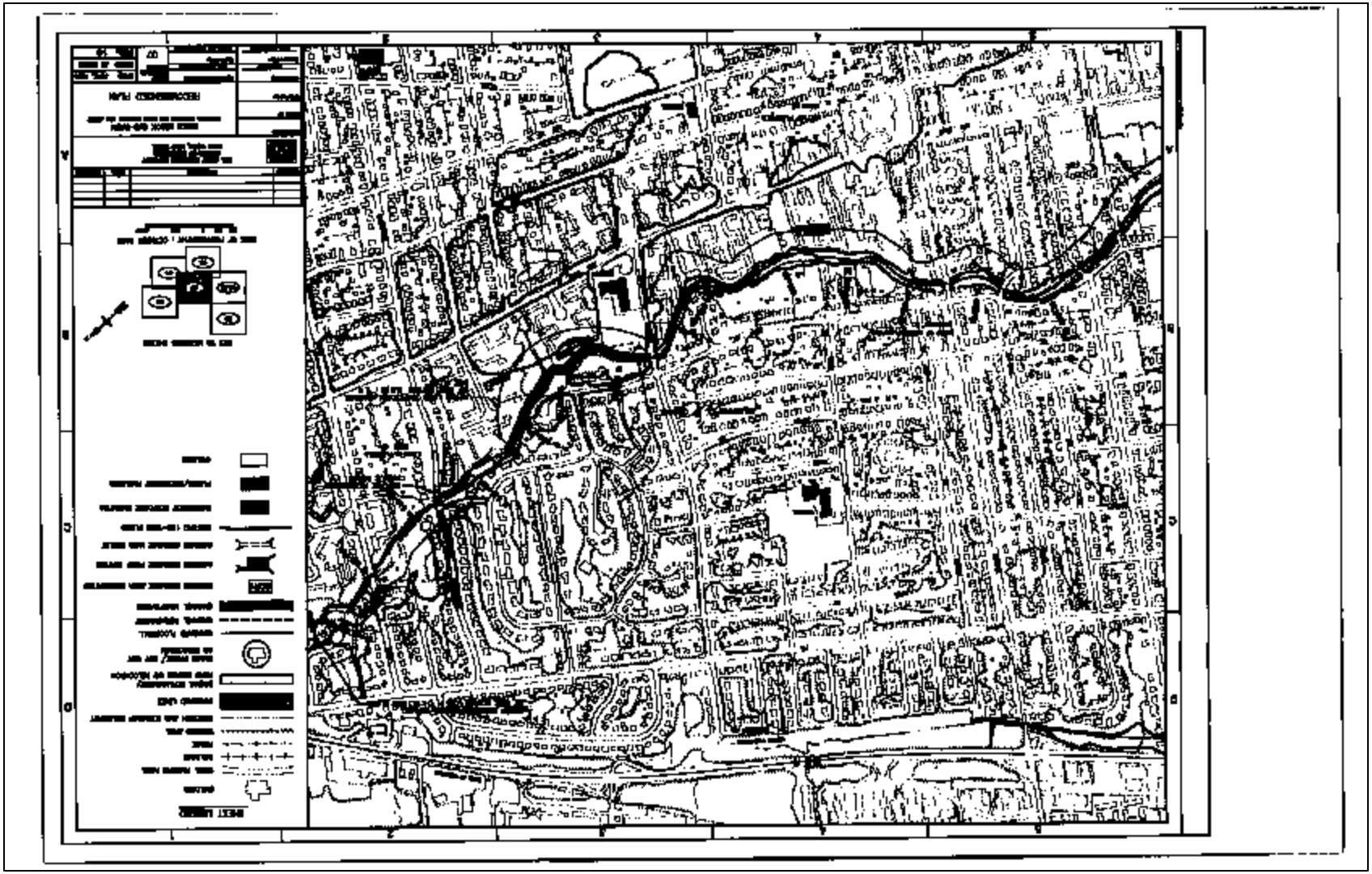


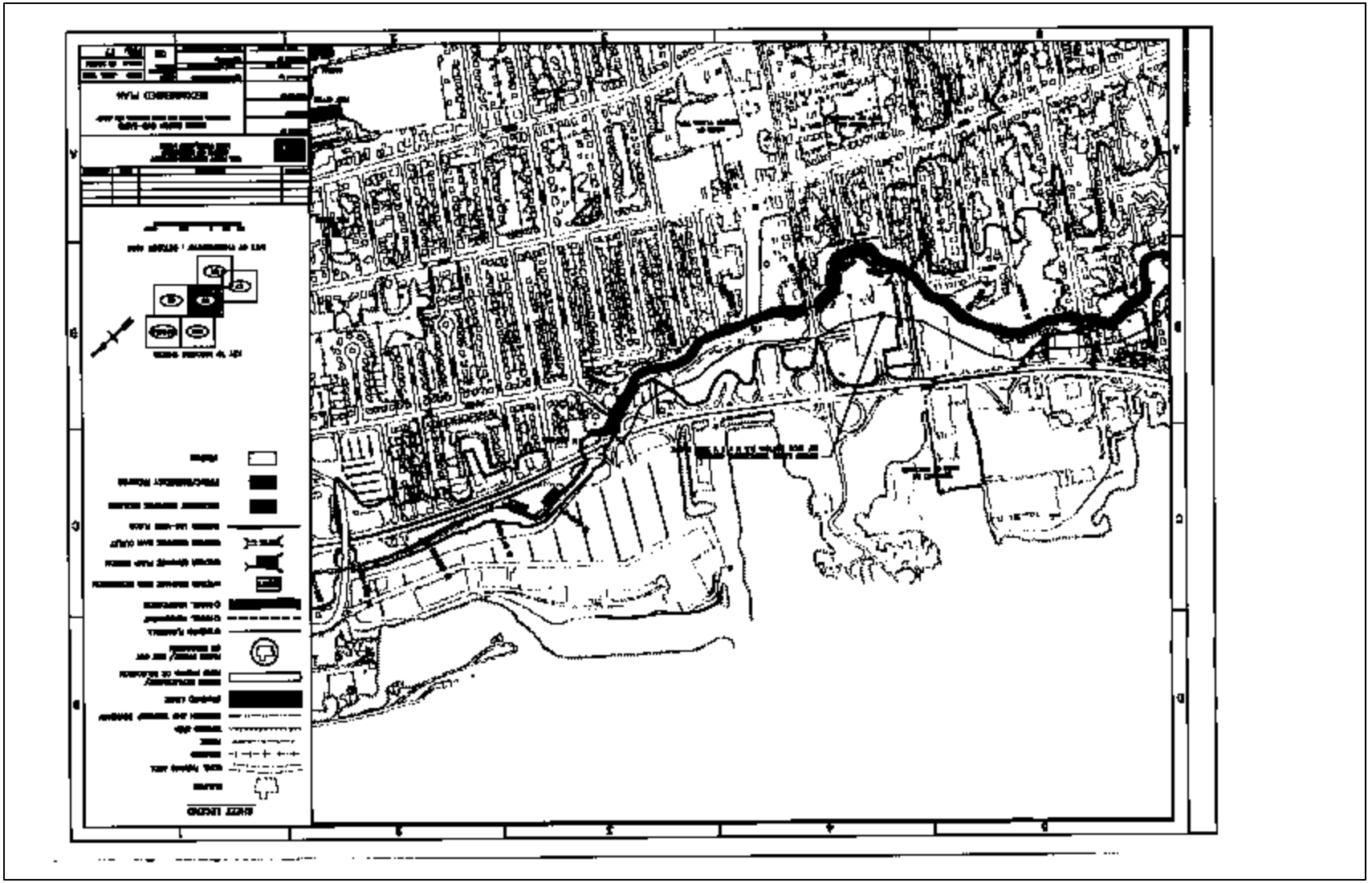


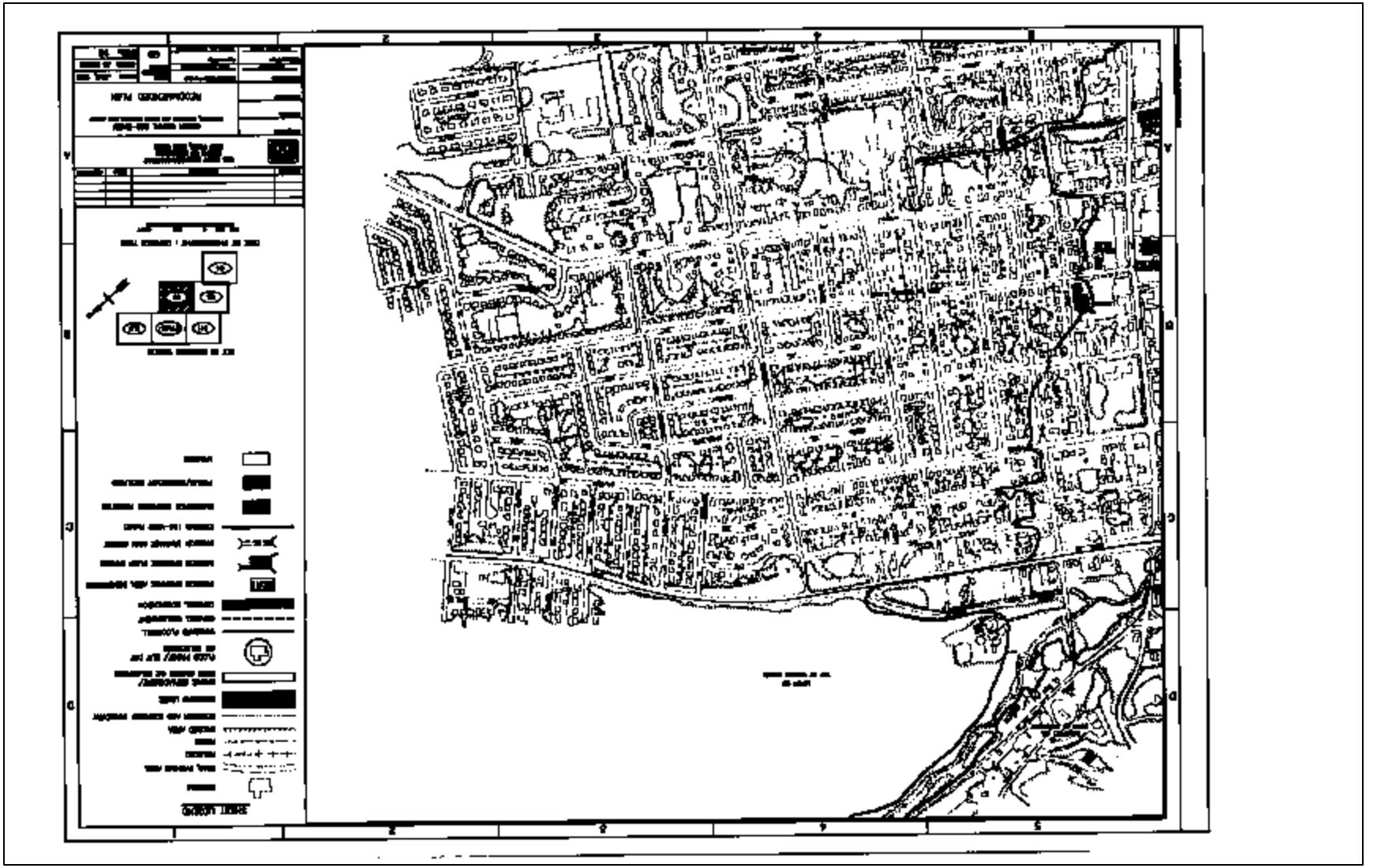


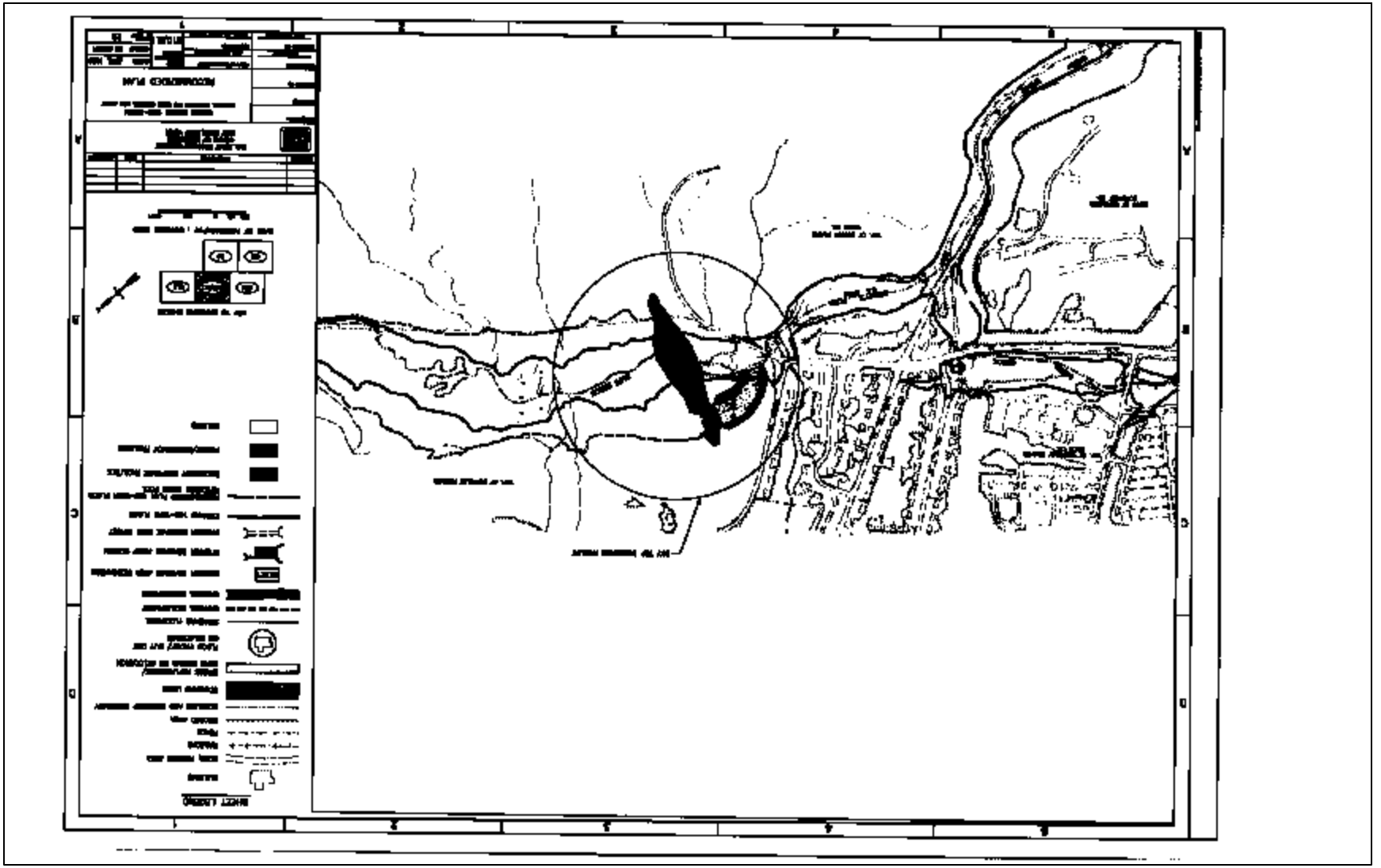


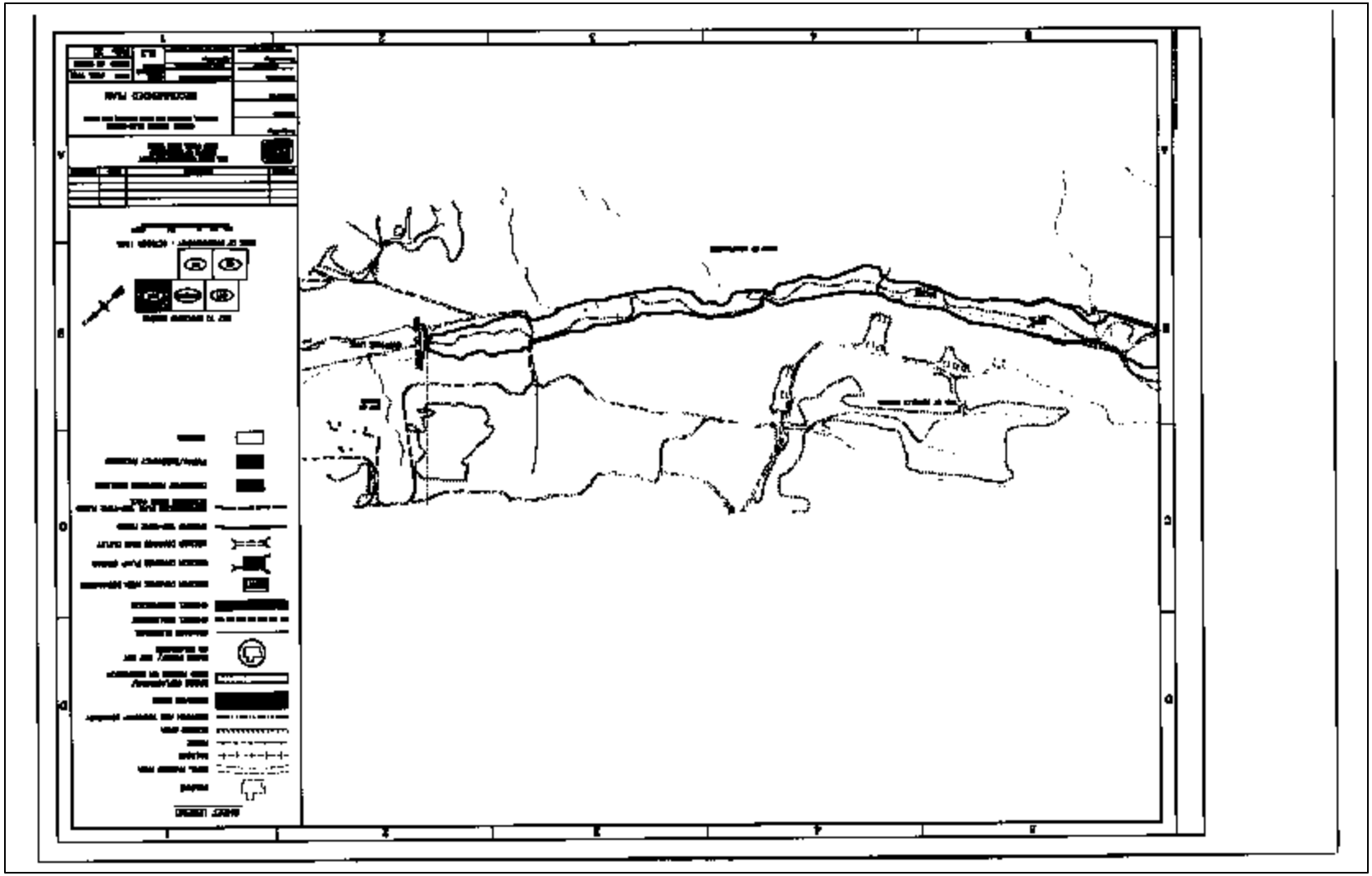


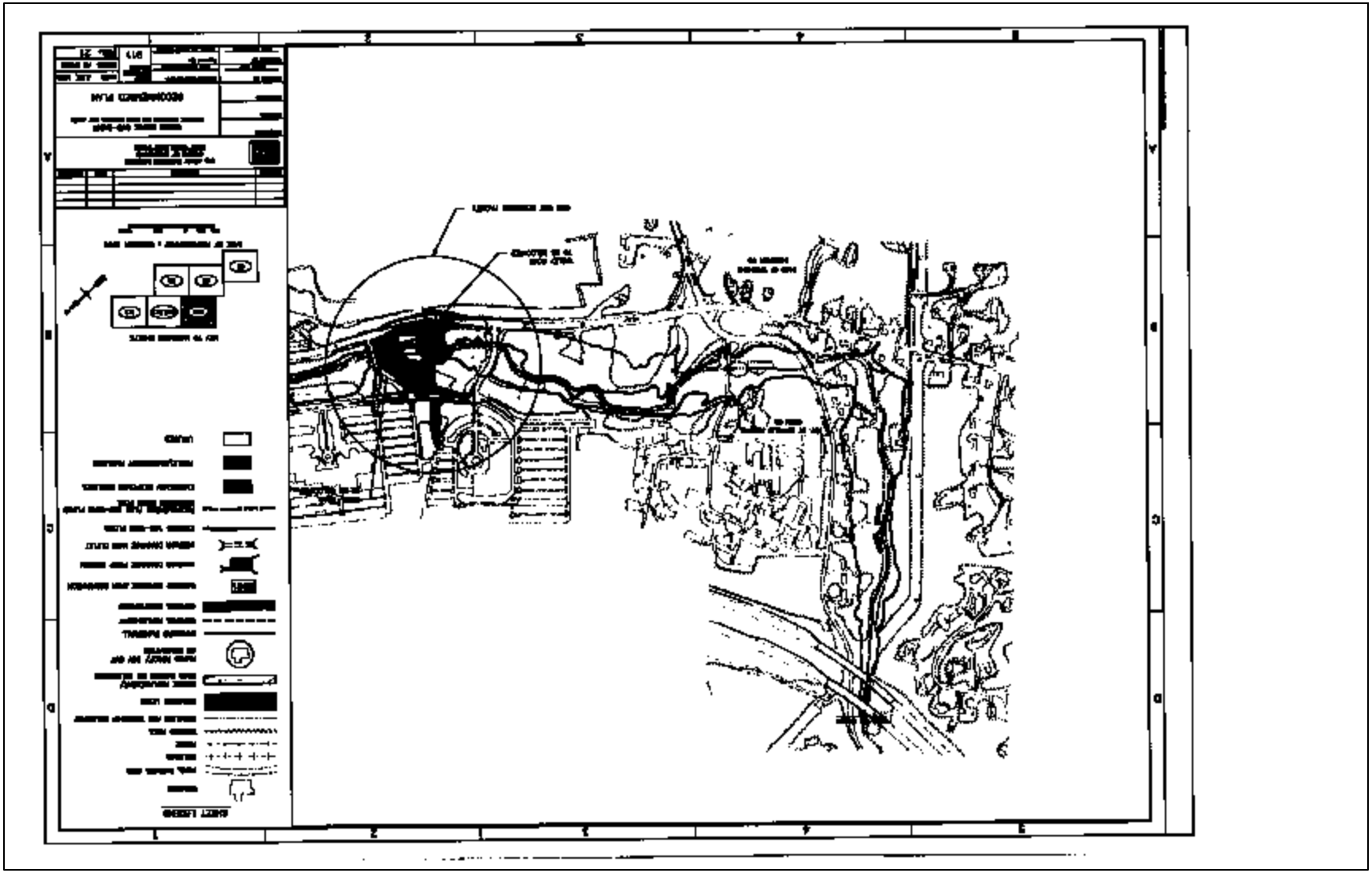


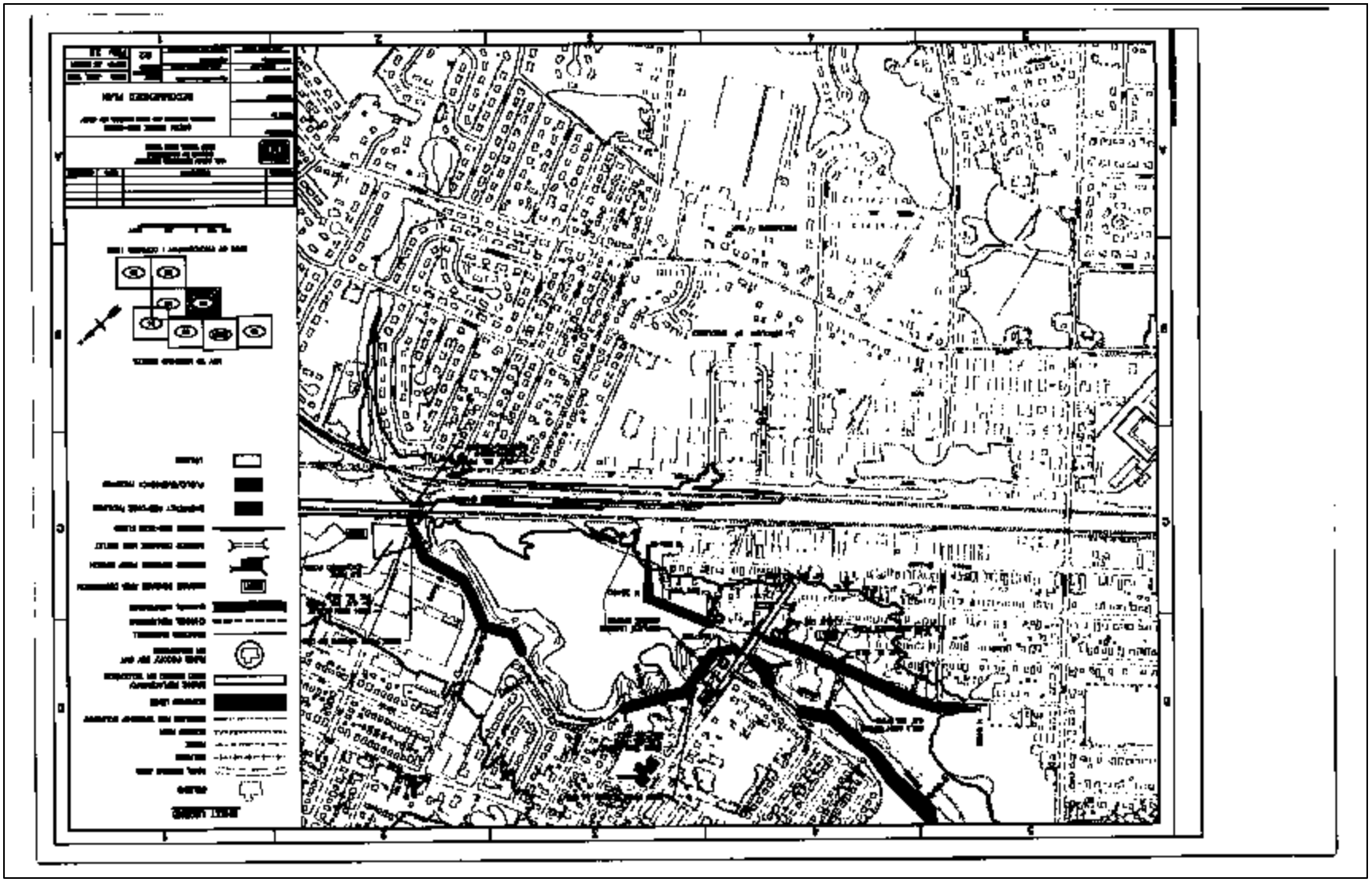


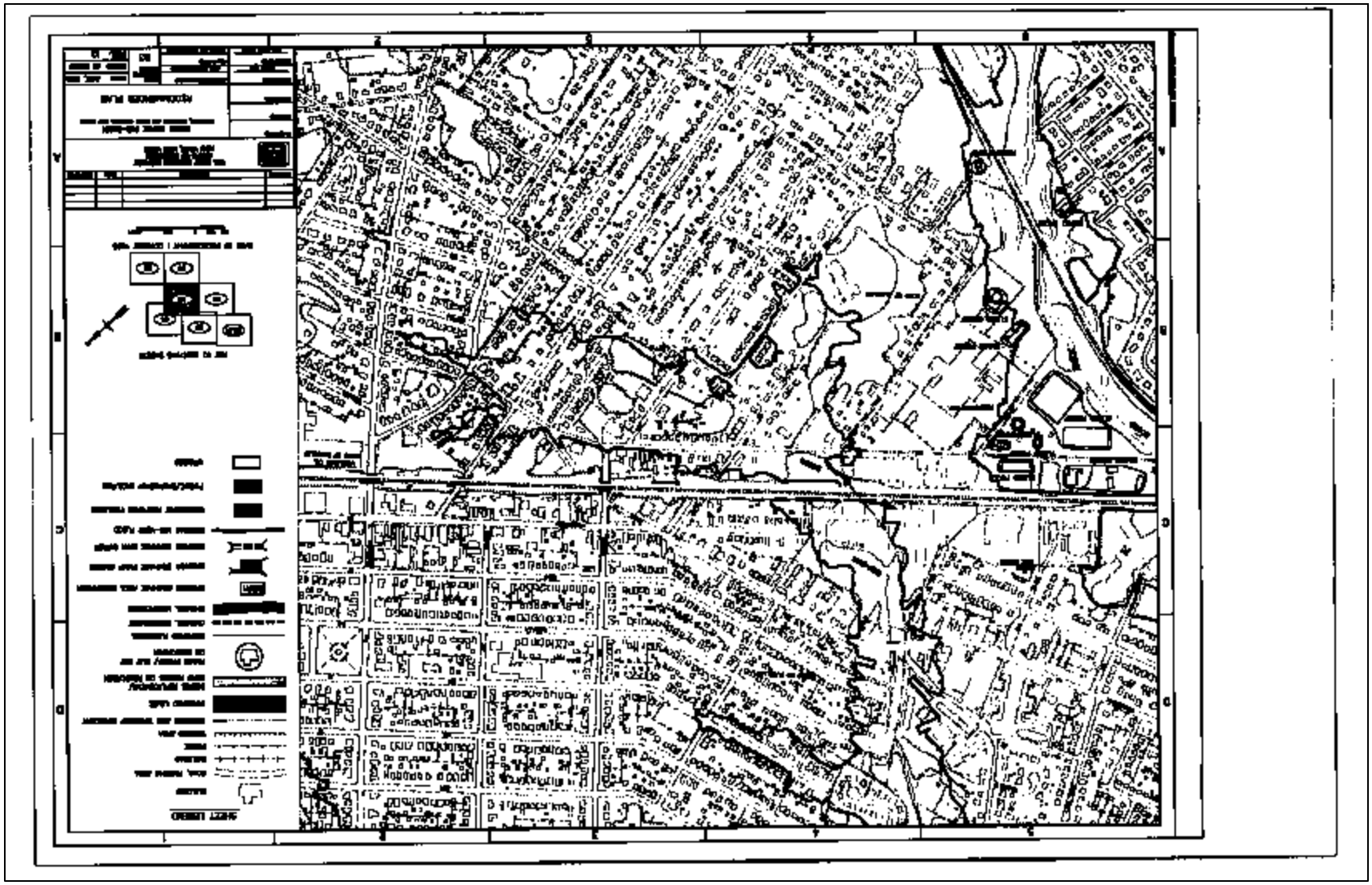


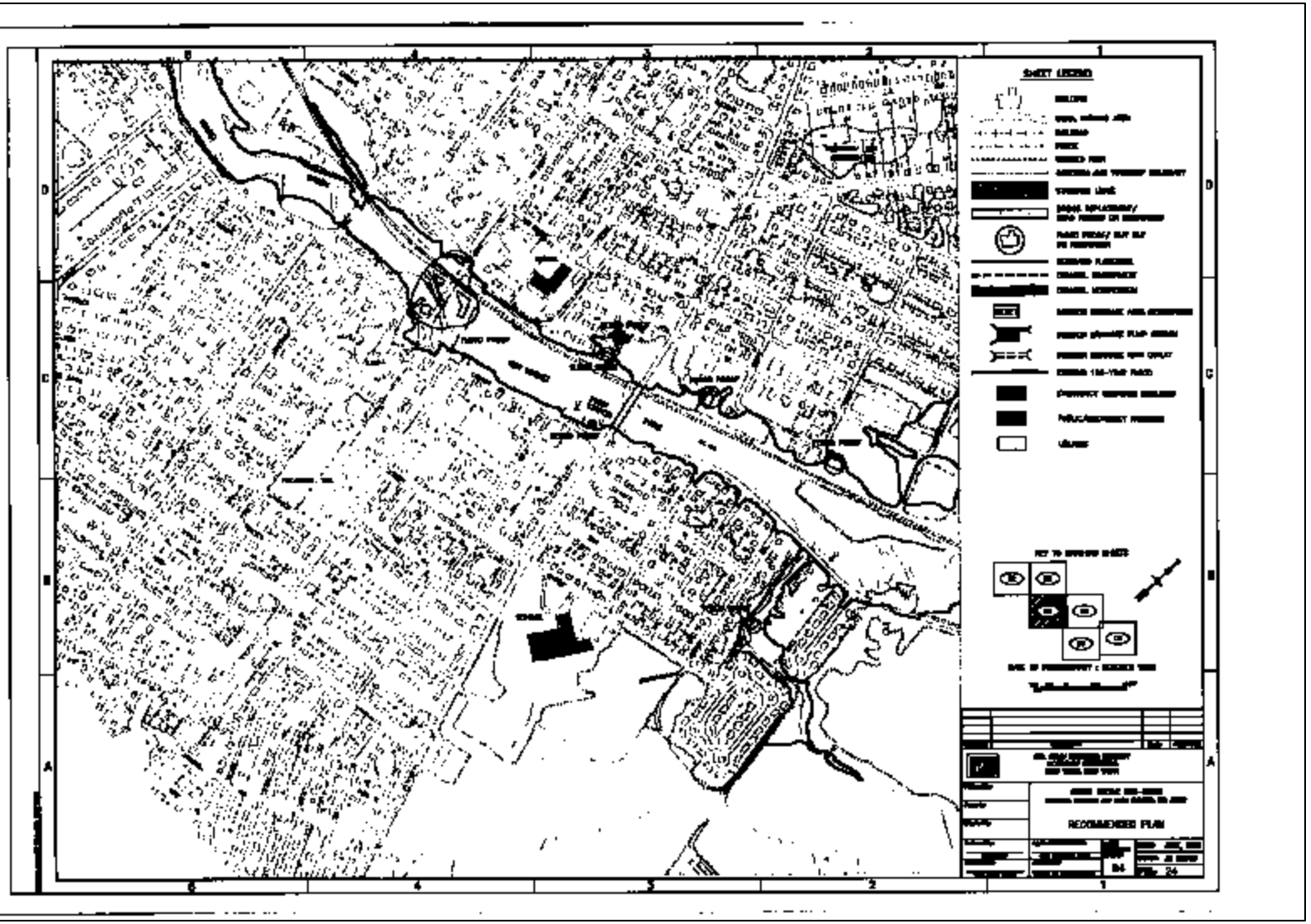


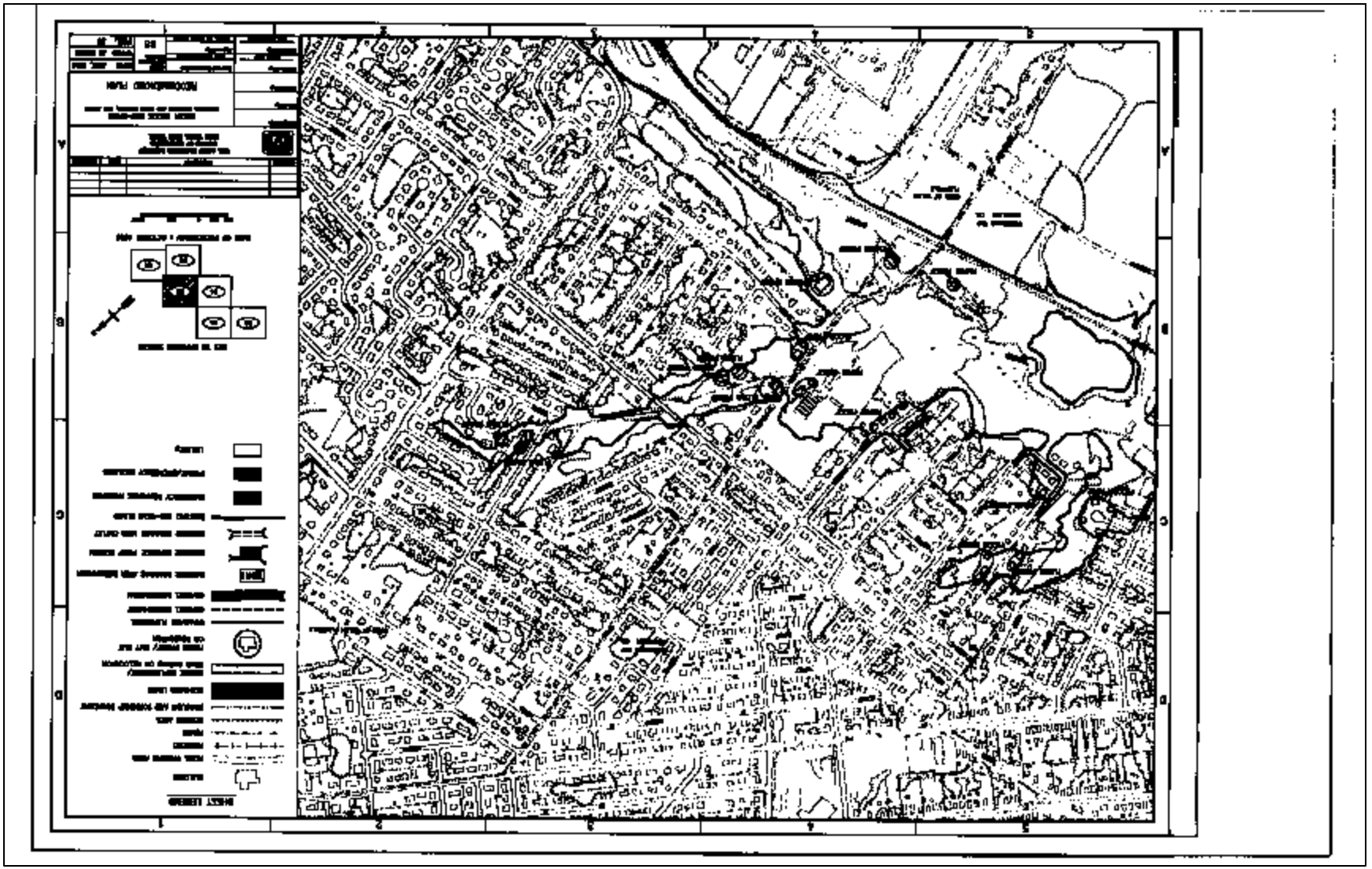


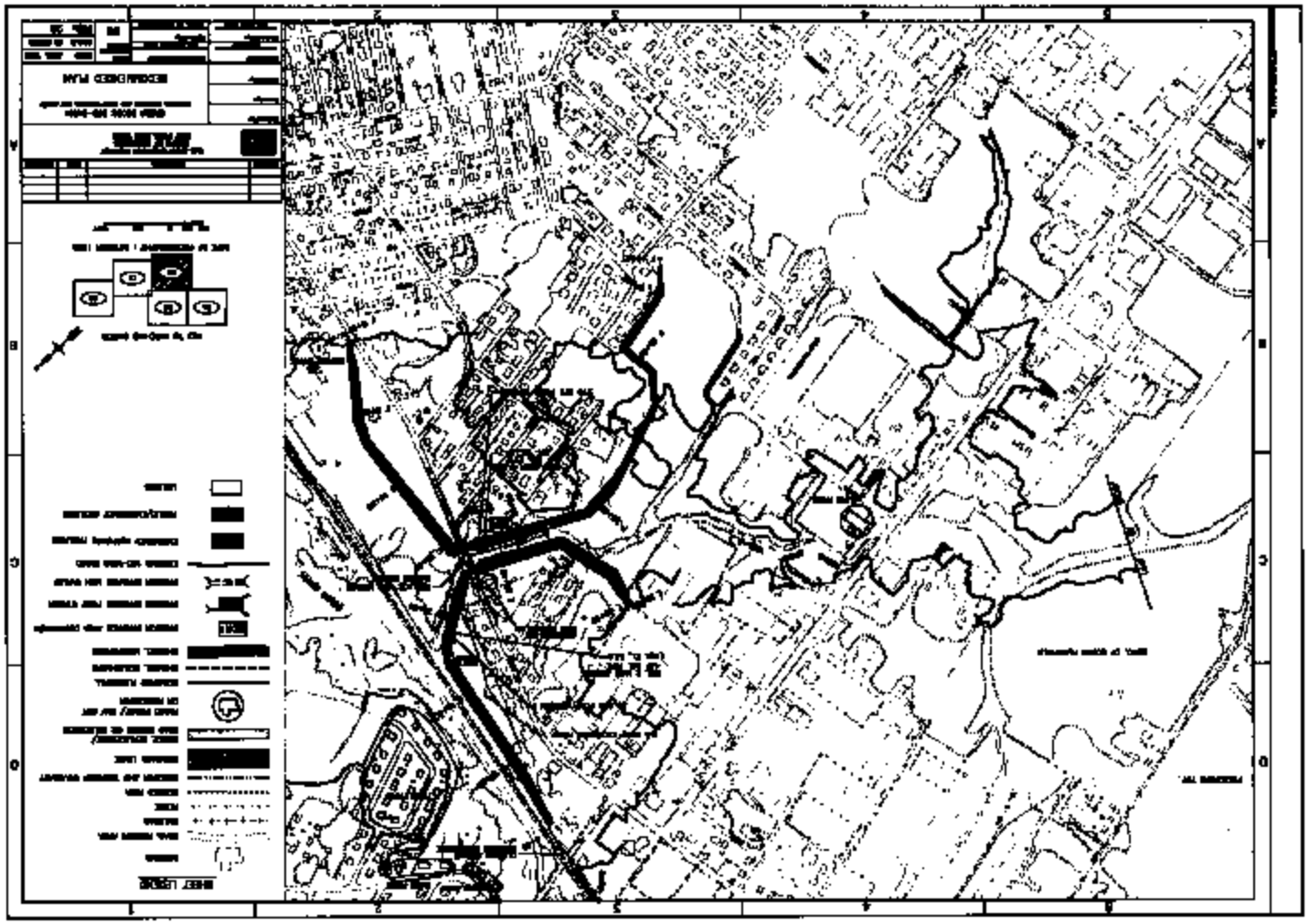


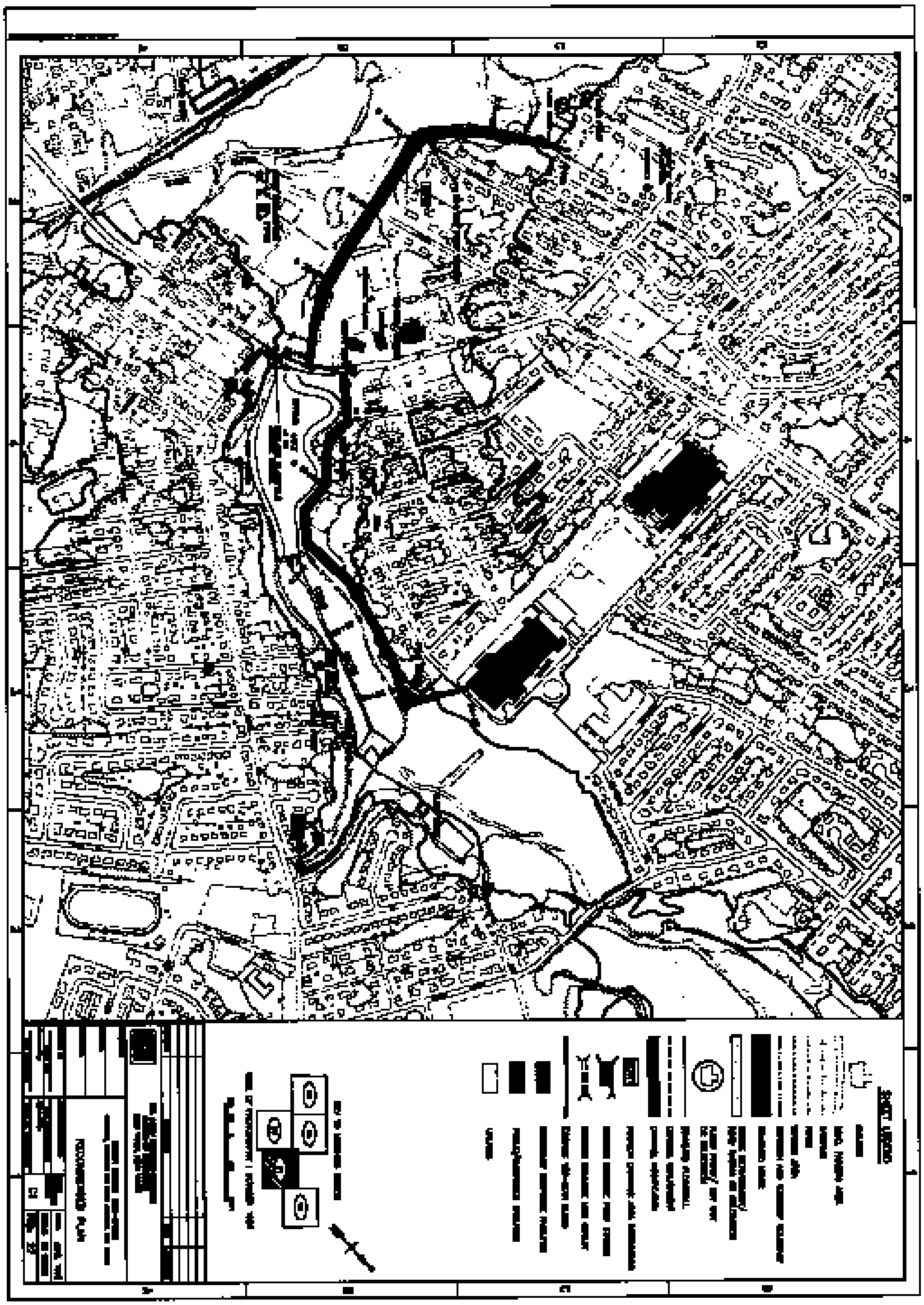


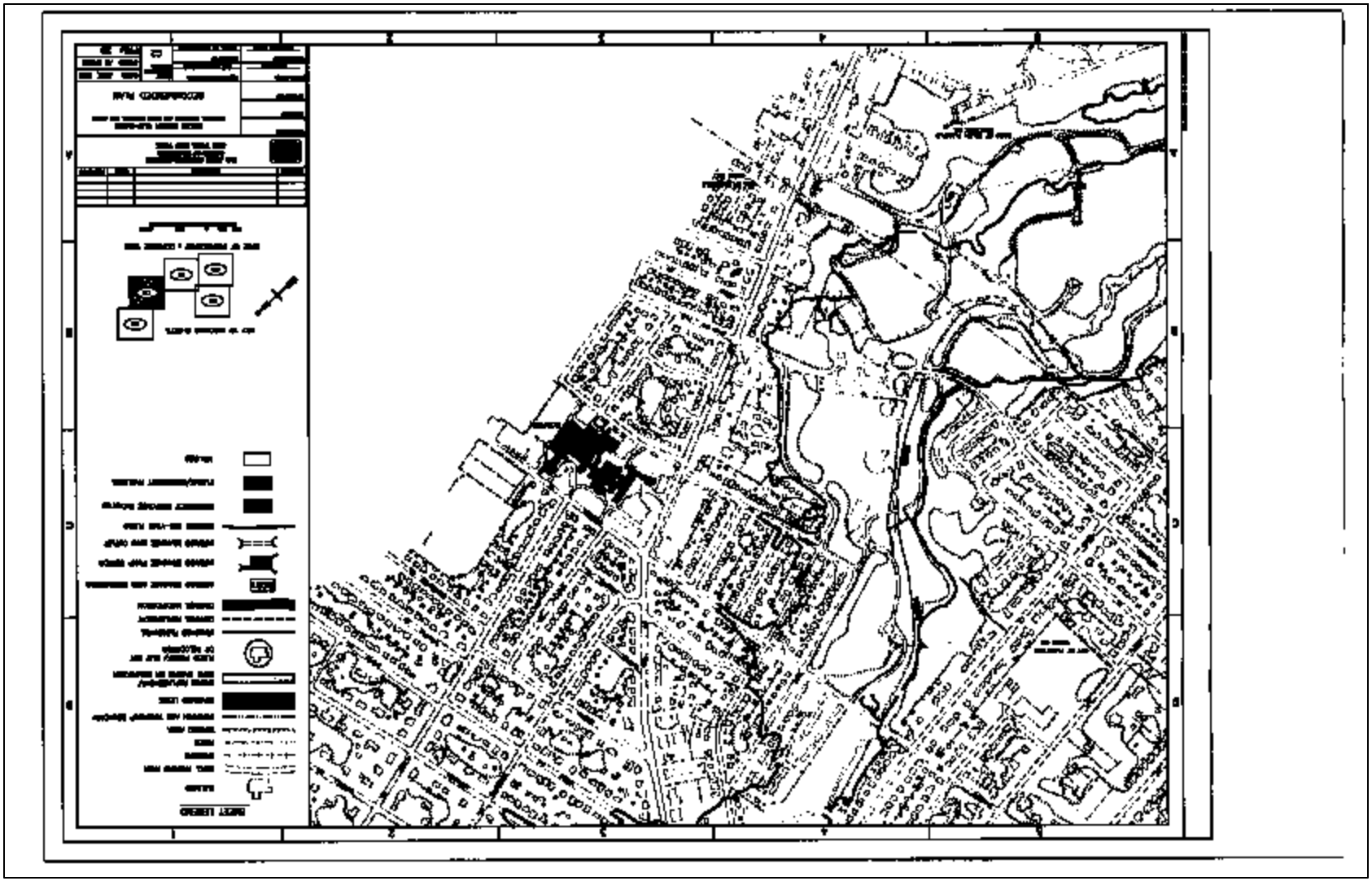


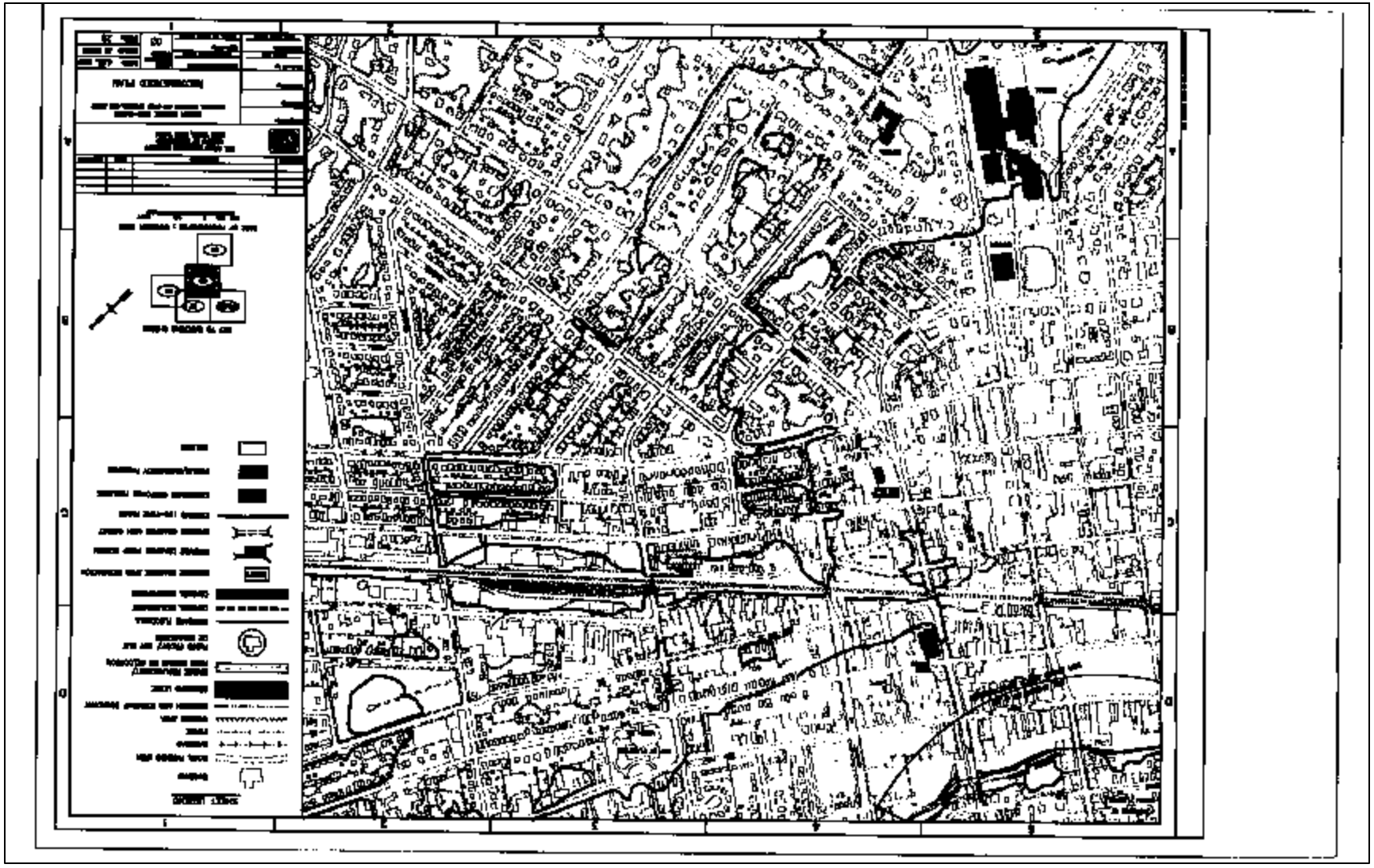

SHEET LEGEND
RECOMMENDED PLAN

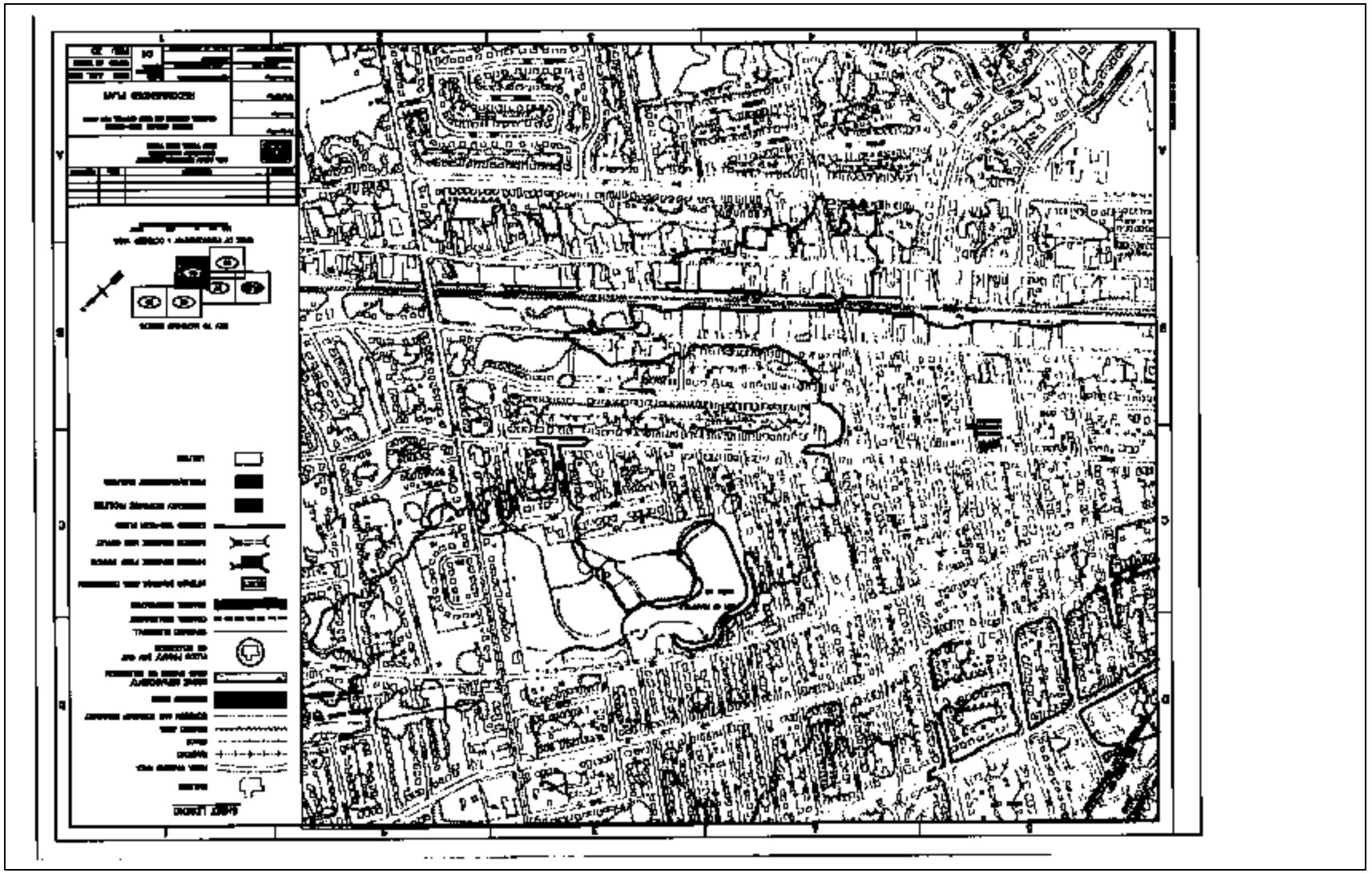


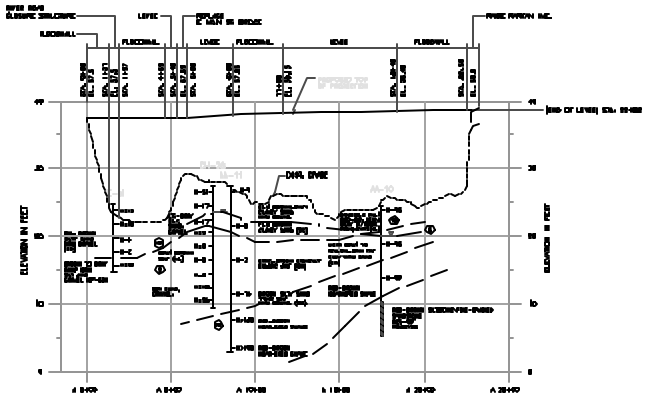








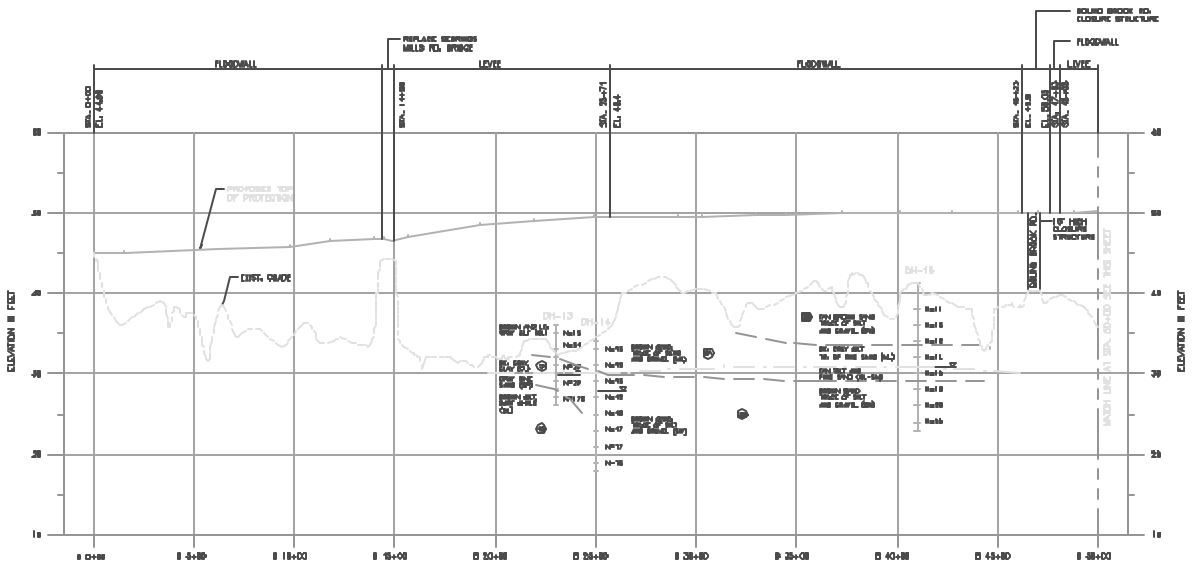




PROFILE SEGMENT A

GREEN BROOK FLOOD CONTROL PROJECT
LINE OF PROTECTION PROFILE
SEGMENT A

FIG: 31



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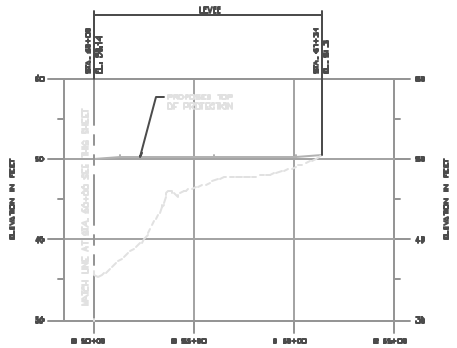
(SEE SHEET C8,B7)



℄ PROFILE SEGMENT B

(GREEN BROOK & SOUND BROOK LEFT BANK)
(SEE SHEET C8,B7)

SCALE IN FEET

SCALE IN FEET

No.	Description	Date	Approved

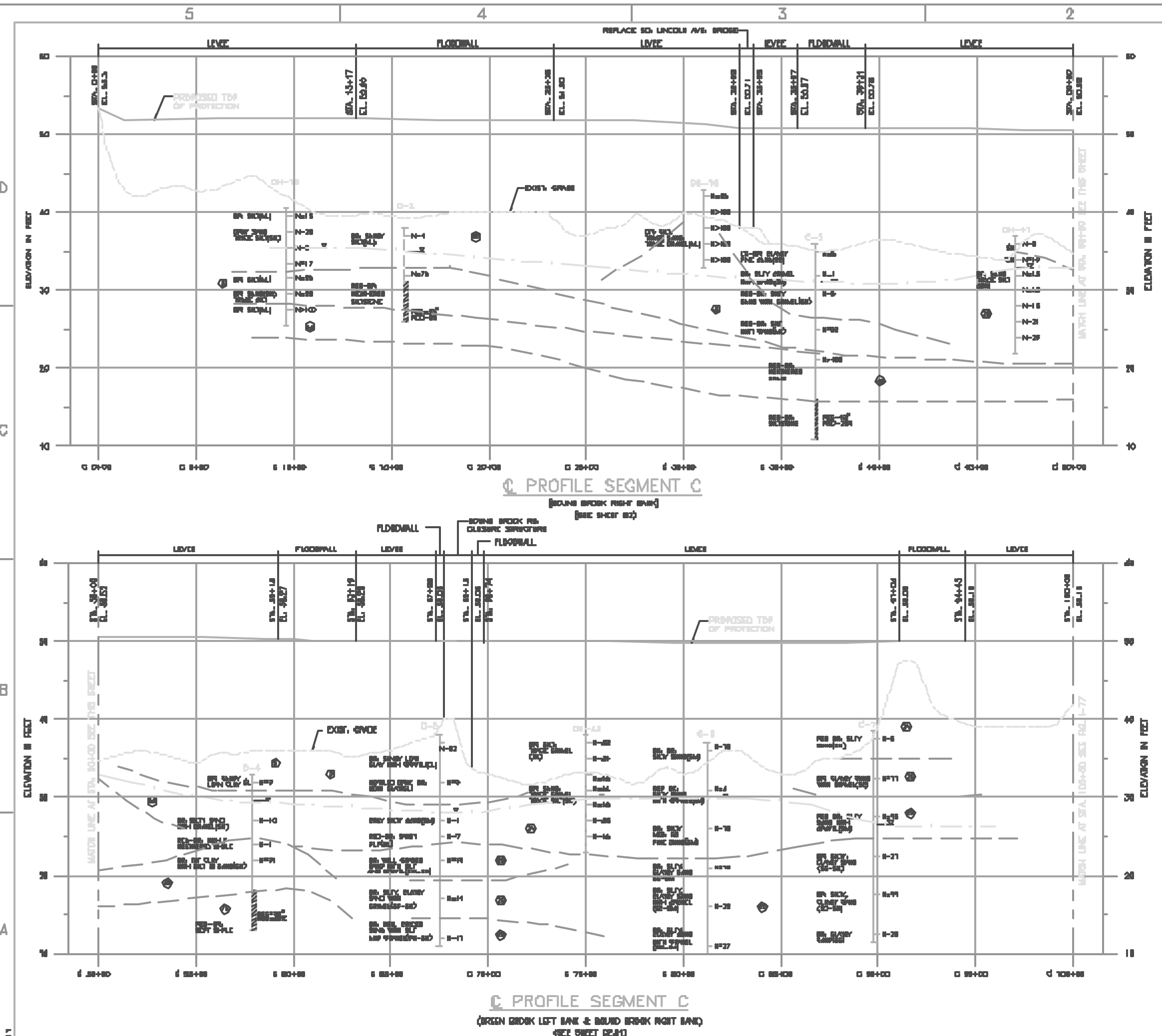
USACE

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NEW YORK, NEW YORK

GREEN BROOK FLOOD CONTROL PROJECT

LINE OF PROTECTION PROFILE
SEGMENT B

DATE: JUNE 1999
SCALE: AS SHOWN
FIG: 32



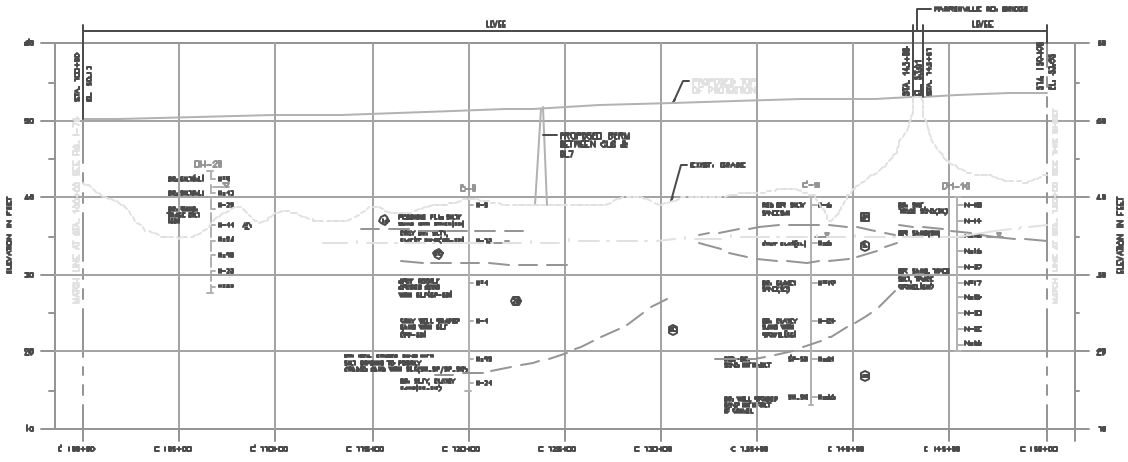
Revision	Description	Date	Approved

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NEW YORK, NEW YORK

SOMERSET, MIDDLESEX AND UNION COUNTIES, NEW JERSEY

GREEN BROOK FLOOD CONTROL PROJECT
LINE OF PROTECTION PROFILE
SEGMENT C
STA. 0+00 TO STA. 100+00

Designed by:
Drawn by:
Checked by:
Reviewed by:
Approval Recommended:
Sheet Reference Number:
DATE: JUNE 1996
SCALE: AS SHOWN
FIG: 33



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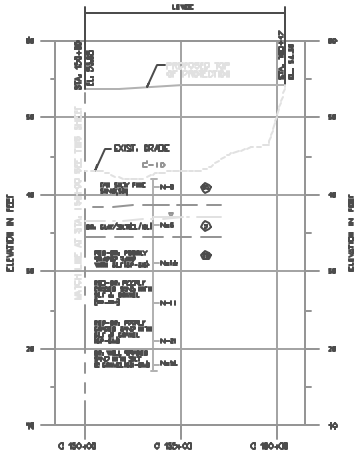

℄ PROFILE SEGMENT C

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(SEE SHEET 33)

SCALE IN FEET

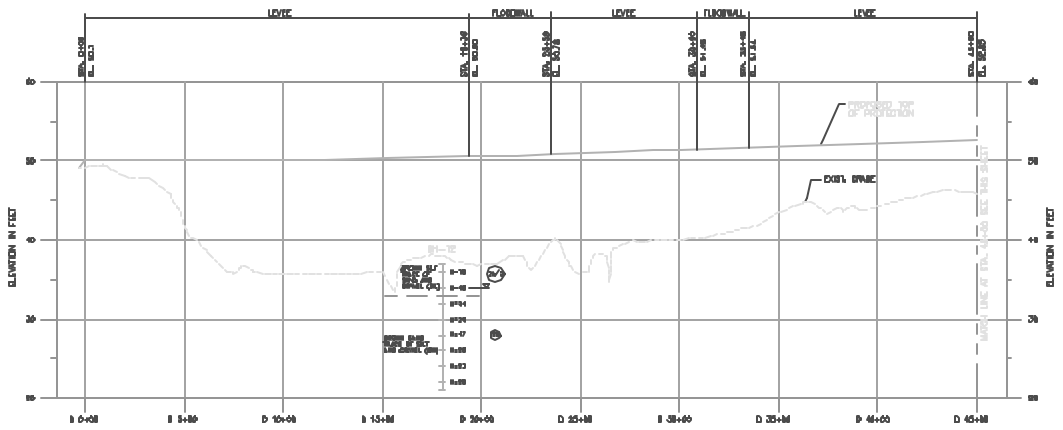
SCALE IN FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NEW YORK, NEW YORK

GREEN BROOK FLOOD CONTROL PROJECT

LINE OF PROTECTION PROFILE
SEGMENT C
STA.160+00 TO STA. 180+47

FIGR 34



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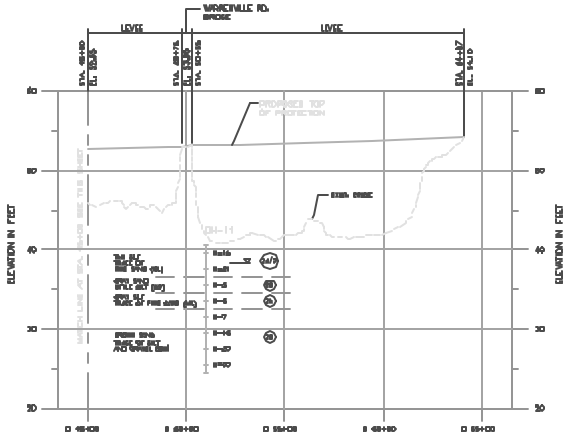

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(GREEN BROOK RIGHT BANK)

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NEW YORK, NEW YORK

GREEN BROOK FLOOD CONTROL PROJECT
LINE OF PROTECTION PROFILE
SEGMENT D

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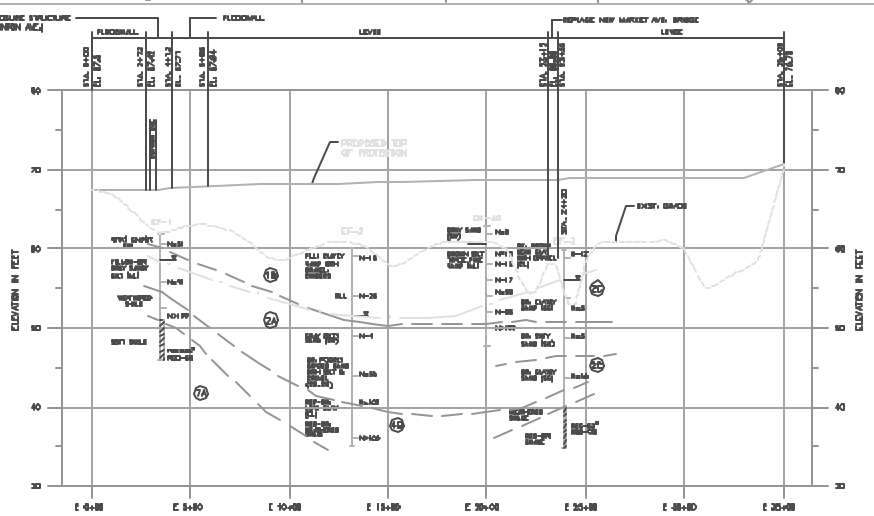

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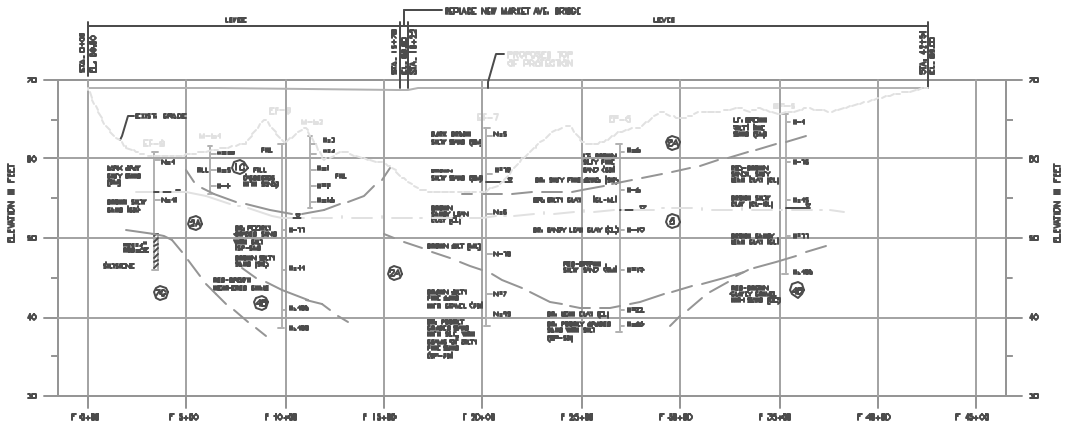


℄ PROFILE SEGMENT F

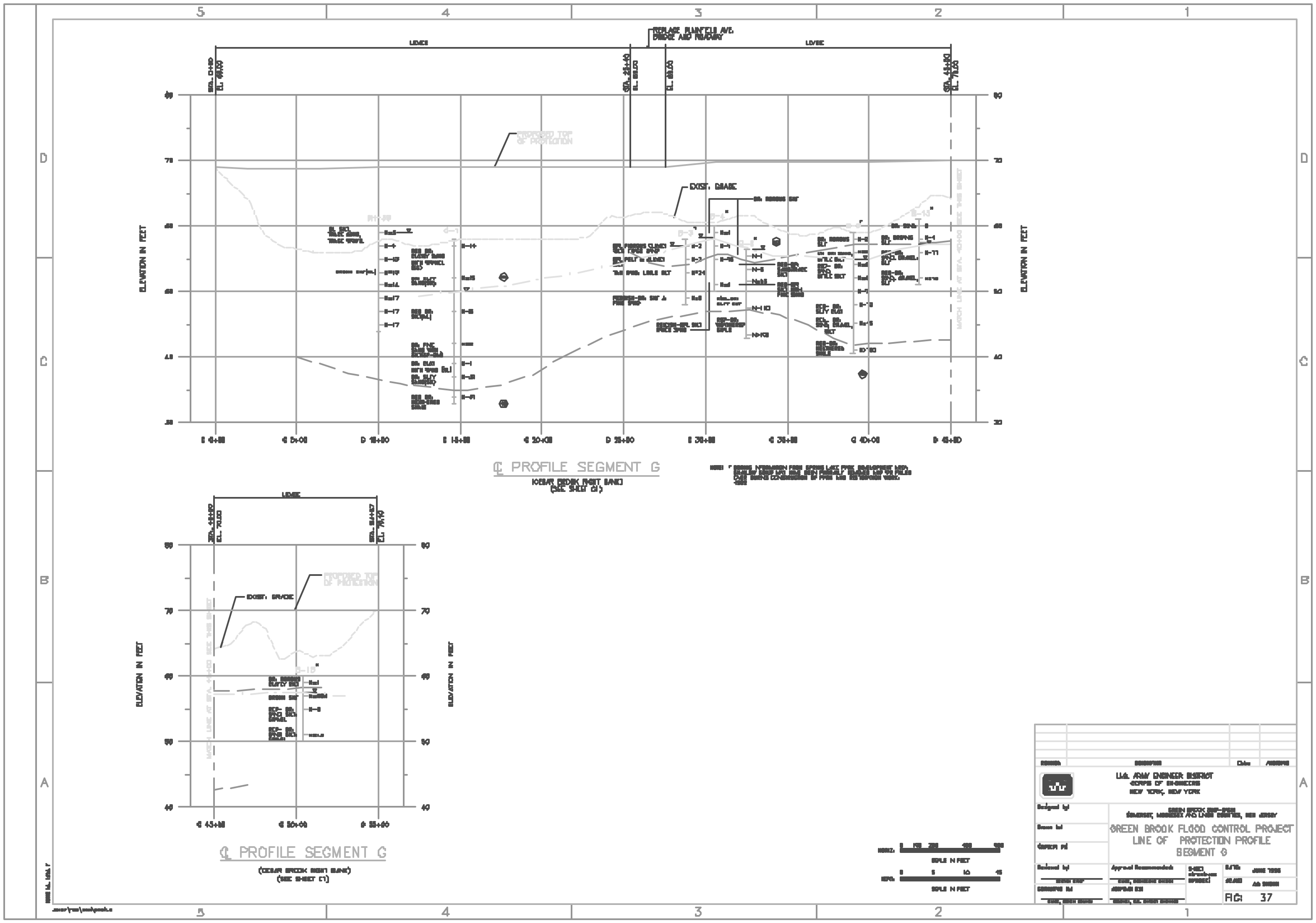
GRAND BROOK LEFT BANK & BOUND BROOK TRIBUTARY 3 RIGHT BANK)

No.	Description	Date	Approved

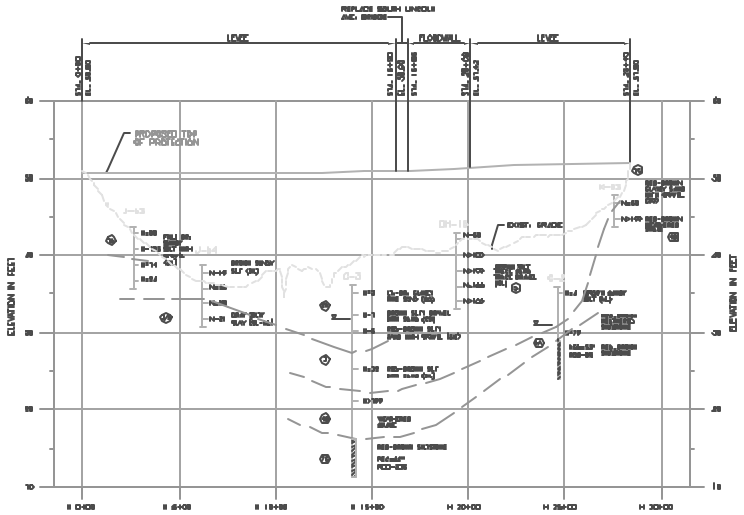
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NEW YORK, NEW YORK

GREEN BROOK FLOOD CONTROL PROJECT
LINE OF PROTECTION PROFILE
SEGMENTS E & F

FIG: 38



ELEVATION IN FEET
PROPOSED TOP OF PROTECTION
EXIST. GRADE
LEVEE
℄ PROFILE SEGMENT G
℄ PROFILE SEGMENT G
EXIST. GRADE
SCALE IN FEET
SCALE IN FEET
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NEW YORK, NEW YORK
Designed by:
Drawn by:
Checked by:
Reviewed by:
Approval Recommended:
GREEN BROOK FLOOD CONTROL PROJECT
LINE OF PROTECTION PROFILE
SEGMENT G
JUNE 1996
AS SHOWN
FIG: 37



℄ PROFILE SEGMENT H

(GREEN BROOK LEFT BANK)

(SEE SHEET 02)

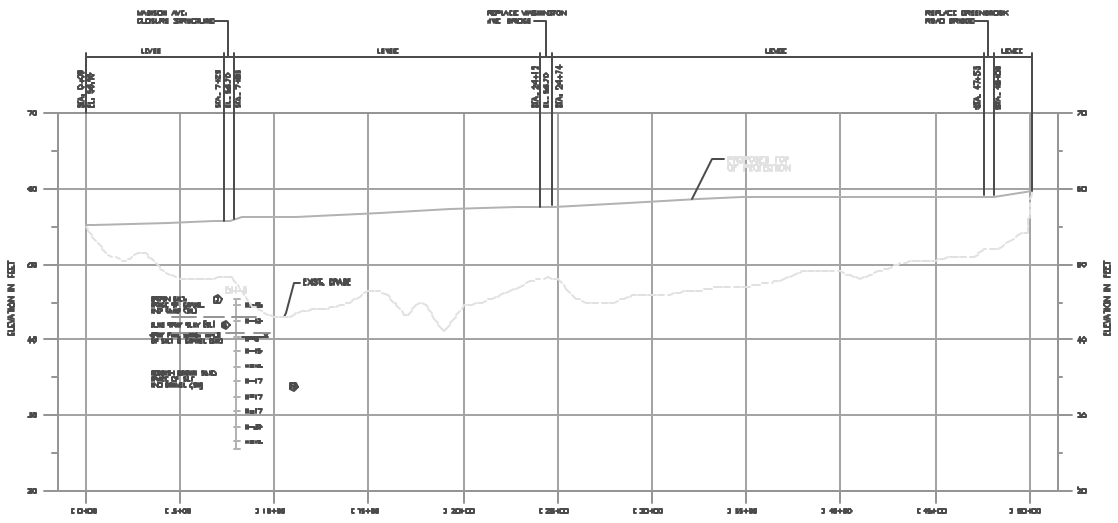
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NEW YORK, NEW YORK

GREEN BROOK FLOOD CONTROL PROJECT

LINE OF PROTECTION PROFILE

SEGMENT H

FIG: 38



℄ PROFILE SEGMENT I

(GREEN BROOK & RARITAN RIVER RIGHT BANK)

SEE SHEET 94

HORZ. SCALE IN FEET

VERT. SCALE IN FEET

Number	Description	Date	Approved

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NEW YORK, NEW YORK

Designed by

Drawn by

Checked by

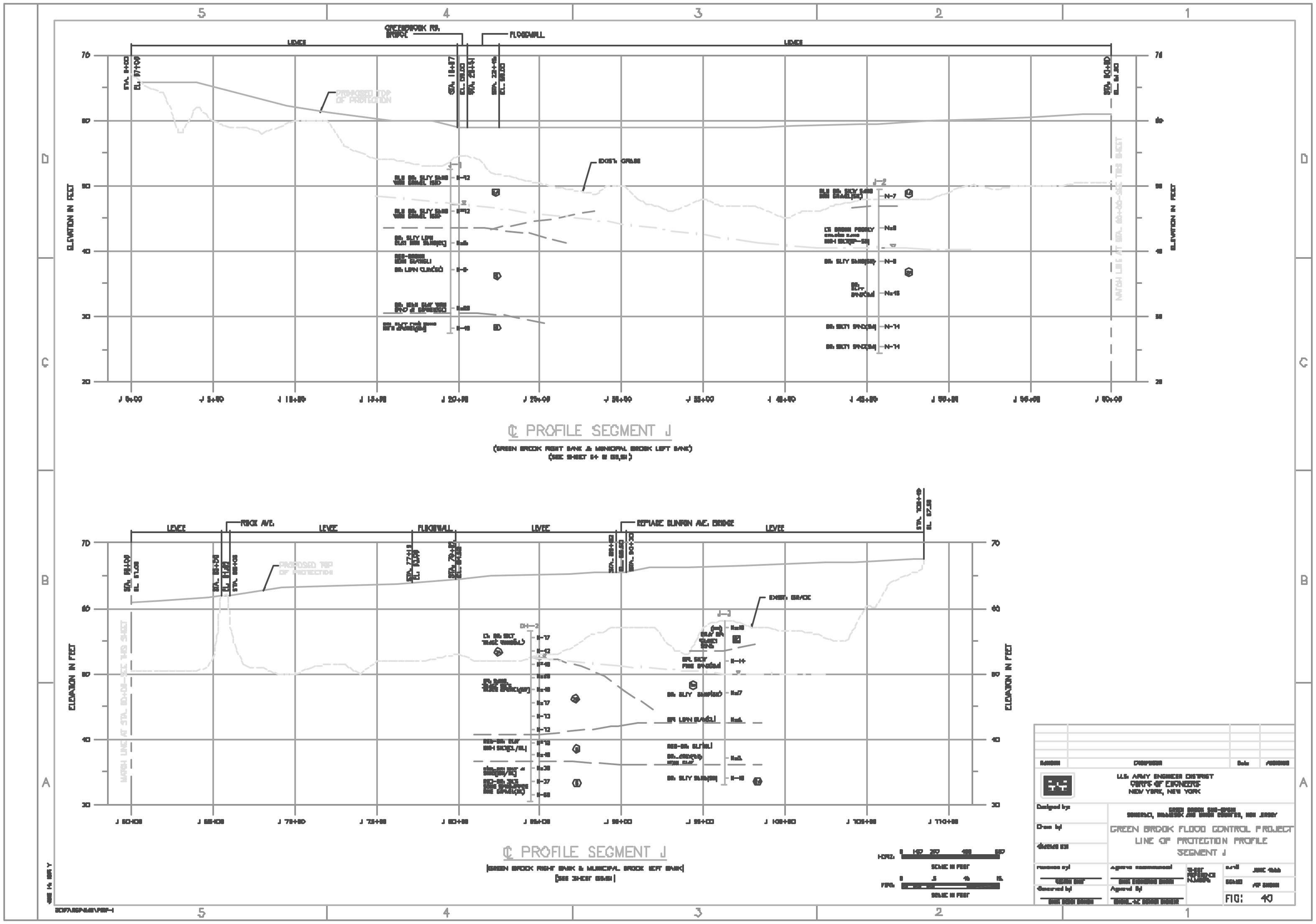
Reviewed by

Approved Recommended

Approved by

GREEN BROOK FLOOD CONTROL PROJECT
LINE OF PROTECTION PROFILE
SEGMENT I

FILE: 38


LEVEE
FLOODWALL
PROPOSED TOP OF PROTECTION
EXIST. GRADE
ELEVATION IN FEET
℄ PROFILE SEGMENT J
℄ PROFILE SEGMENT J
LEVEE
FLOODWALL
ROCK AVE.
PROPOSED TOP OF PROTECTION
EXIST. GRADE
ELEVATION IN FEET
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NEW YORK, NEW YORK
Designed by:
Drawn by:
GREEN BROOK FLOOD CONTROL PROJECT
LINE OF PROTECTION PROFILE
SEGMENT J
Approved by:
SHEET REFERENCE NUMBER:
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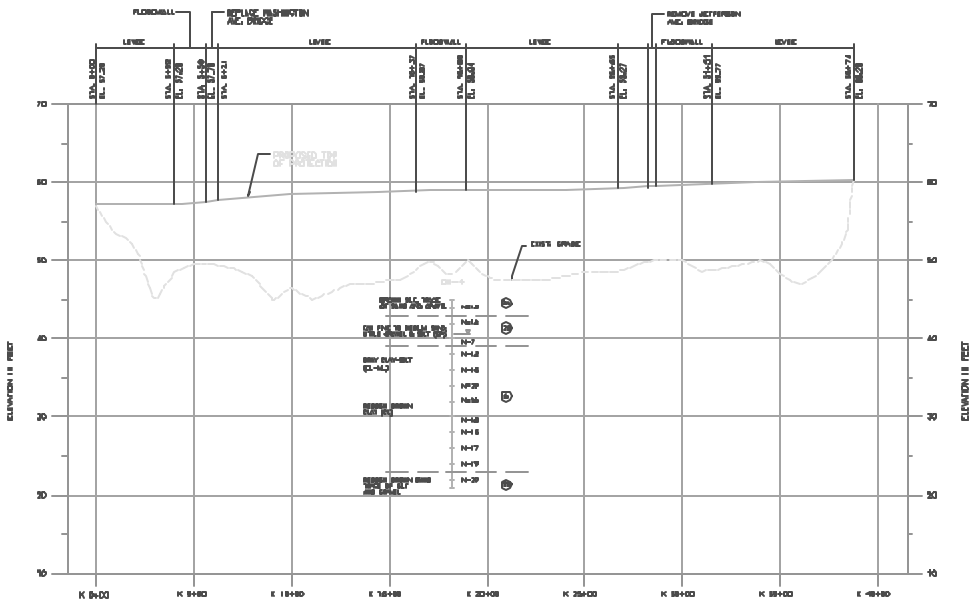

℄ PROFILE SEGMENT K

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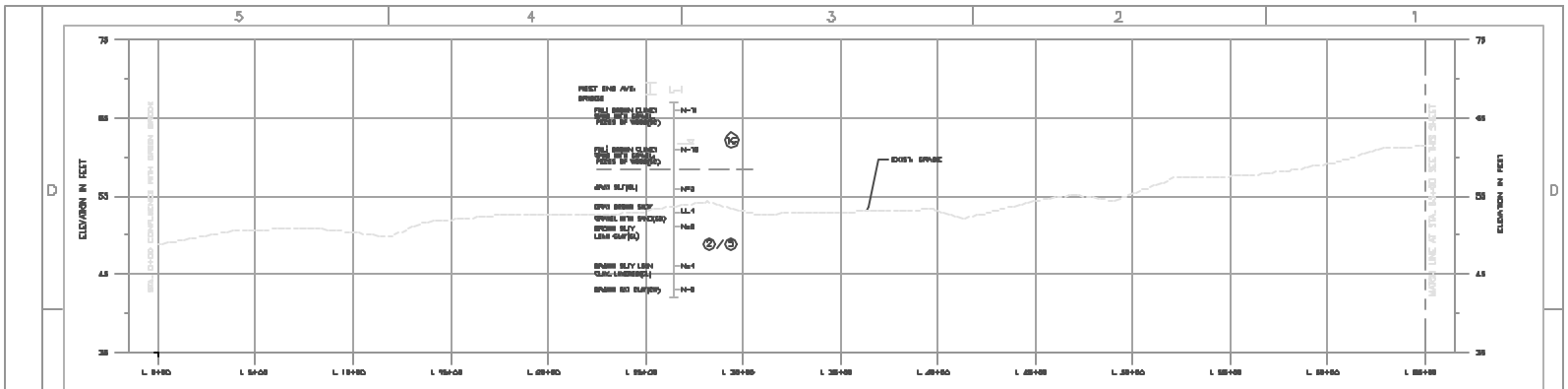
SEE SHEET C40

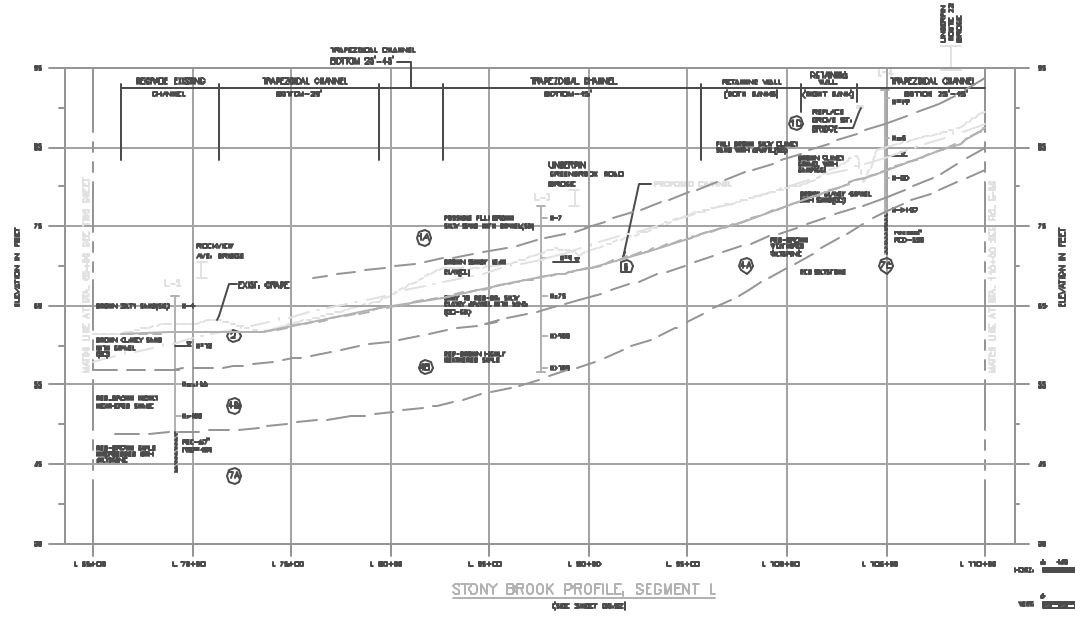
Number	Description	Date	Approved

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NEW YORK, NEW YORK

GREEN BROOK FLOOD CONTROL PROJECT
LINE OF PROTECTION PROFILE
SEGMENT K

FIG: 41





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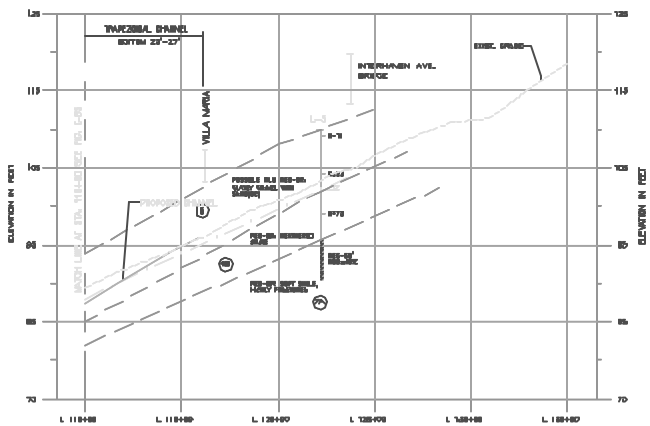
GREEN BROOK FLOOD CONTROL PROJECT
CHANNEL IMPROVEMENT PROFILE
STONY BROOK, SEGMENT L
STA. 0+00 TO STA. 110+00

FIG. 42



STONY BROOK PROFILE, SEGMENT L

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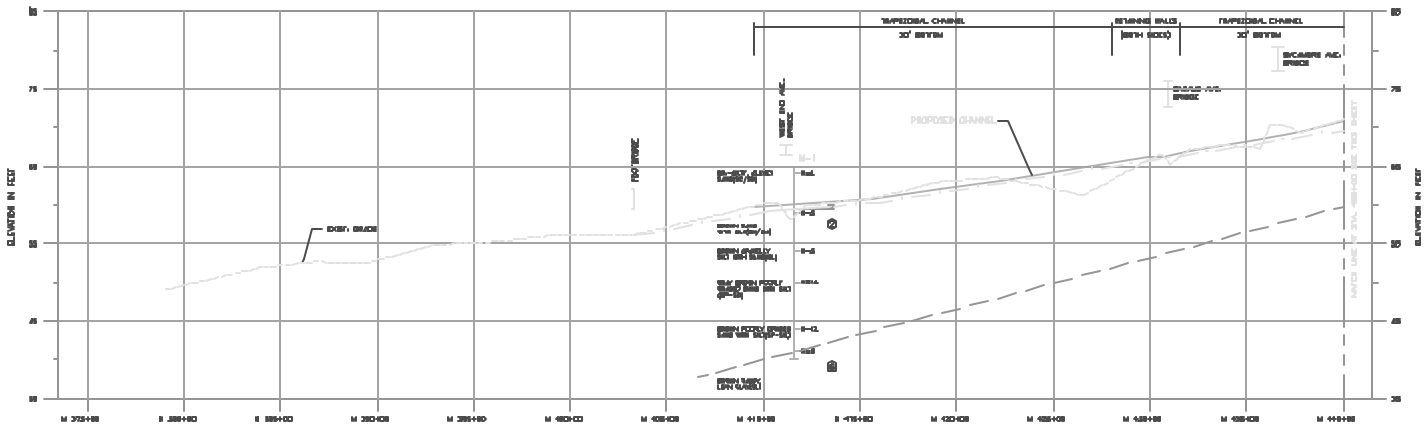
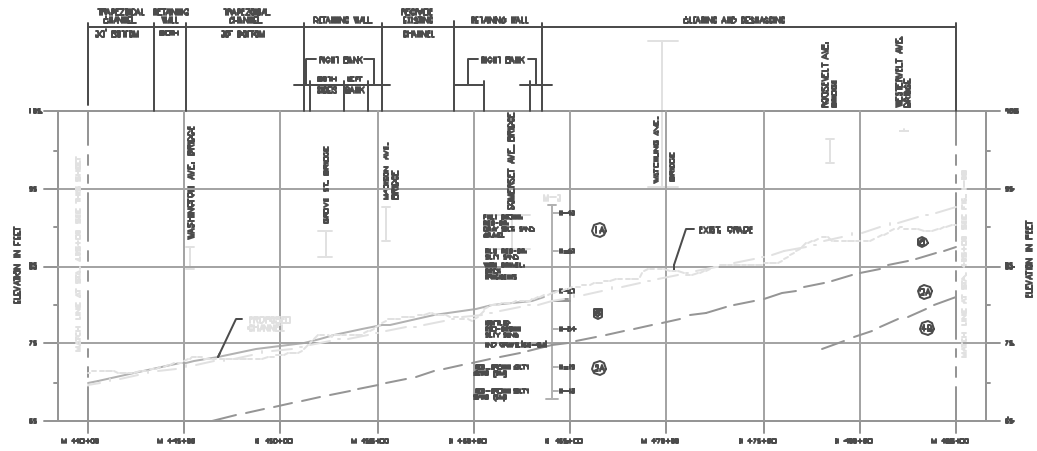
GREEN BROOK FLOOD CONTROL PROJECT
CHANNEL IMPROVEMENT PROFILE
STONY BROOK, SEGMENT L
STA. 110+00 TO STA. 135+00

FIG: 43



GREEN BROOK PROFILE, SEGMENT M

(GREEN BROOK ABOVE STONY BROOK CONFLUENCE)
(SEE SHEET 6A&B)



GREEN BROOK PROFILE, SEGMENT N

(GREEN BROOK ABOVE STONY BROOK CONFLUENCE)
(SEE SHEET 6A,6B & 6C)

SCALE IN FEET

SCALE IN FEET

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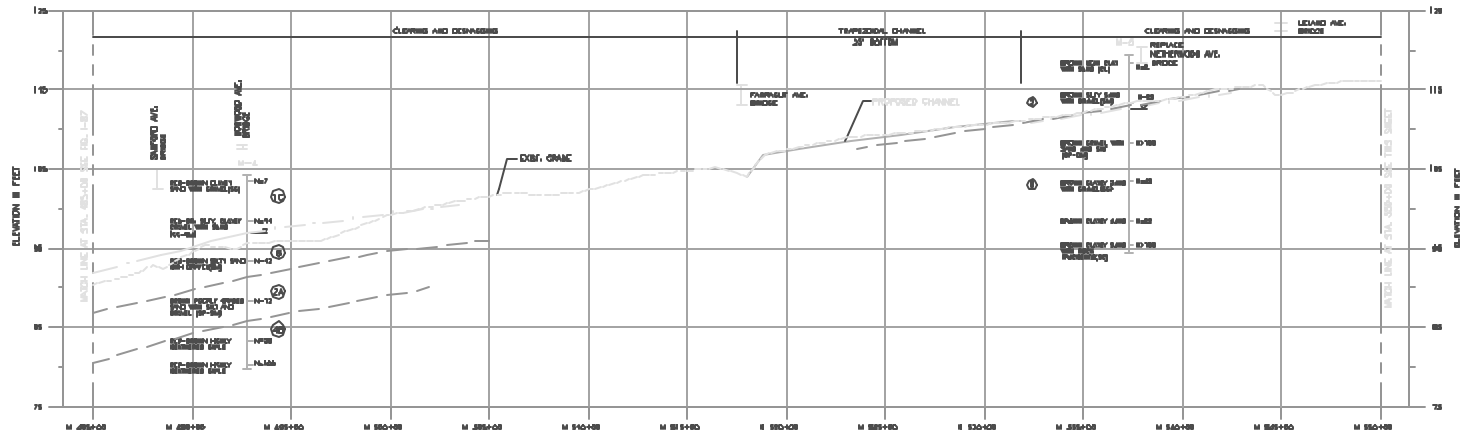
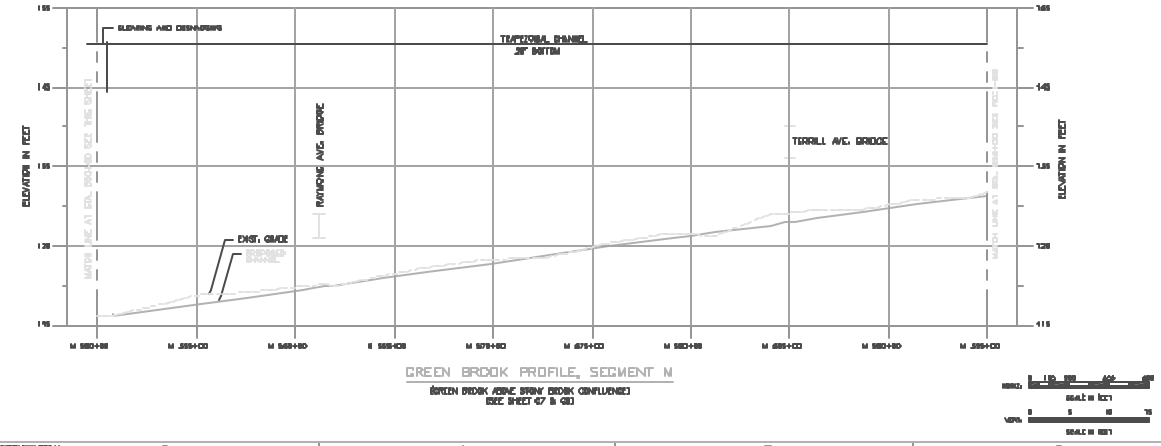
NEW YORK, NEW YORK

GREEN BROOK FLOOD CONTROL PROJECT
LINE OF PROTECTION PROFILE
GREEN BROOK, SEGMENT M
STA. 379+00 TO STA. 481+00

FIG. 44





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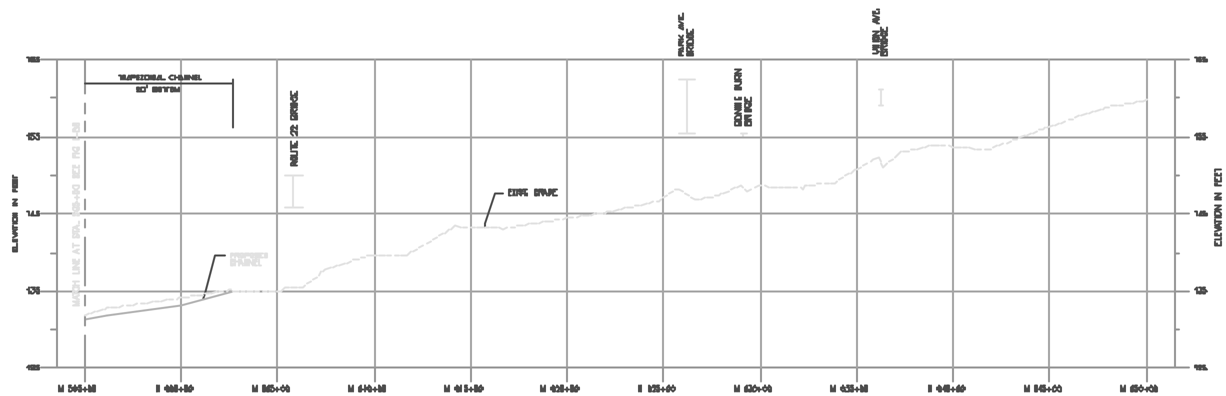
GREEN BROOK FLOOD CONTROL PROJECT
LINE OF PROTECTION PROFILE
GREEN BROOK SEGMENT M
STA. 485+00 TO STA. 525+00

FIG: 45



GREEN BROOK PROFILE, SEGMENT M

(GREEN BROOK ABOVE STONY BROOK CONFLUENCE)

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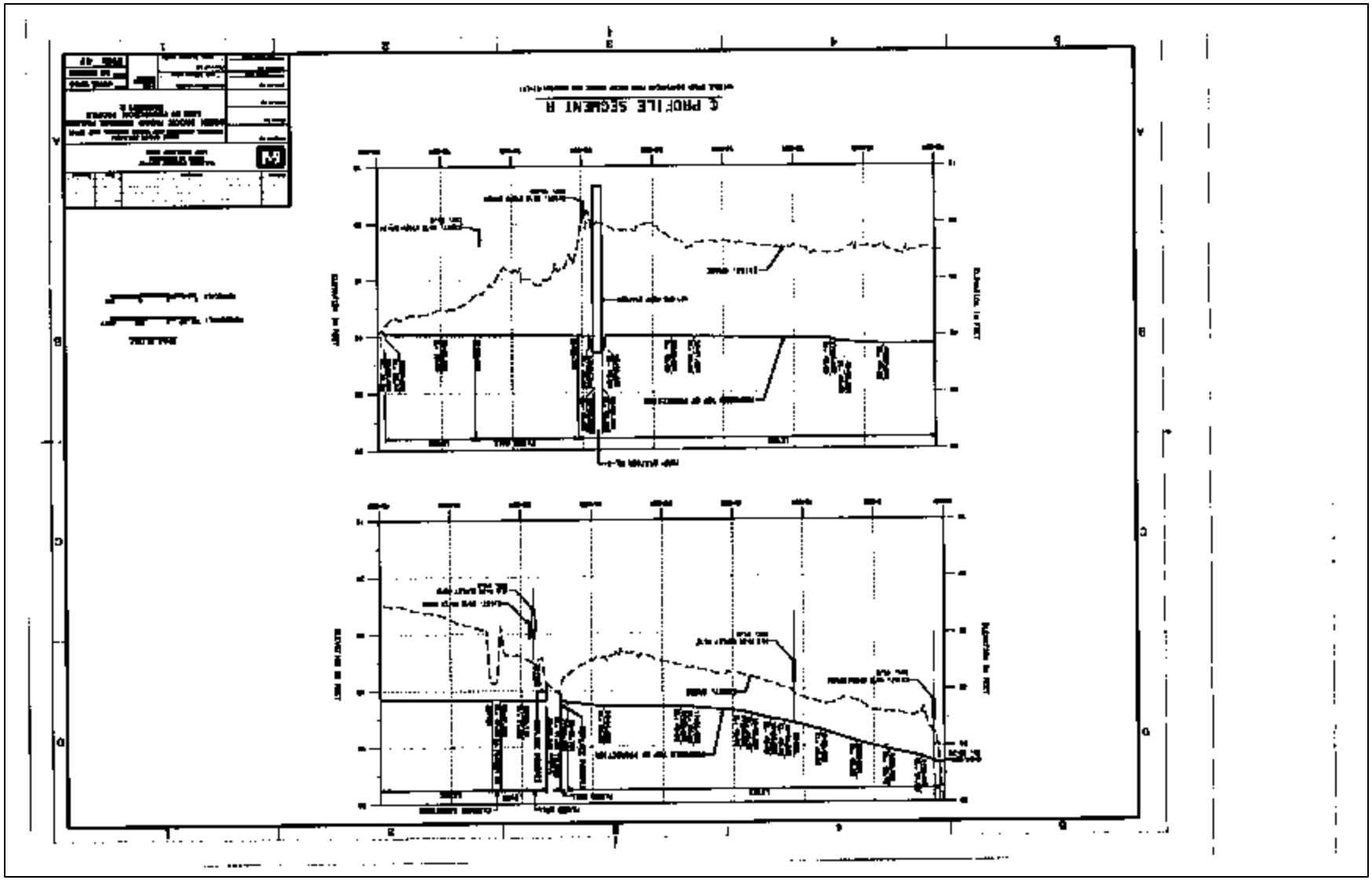
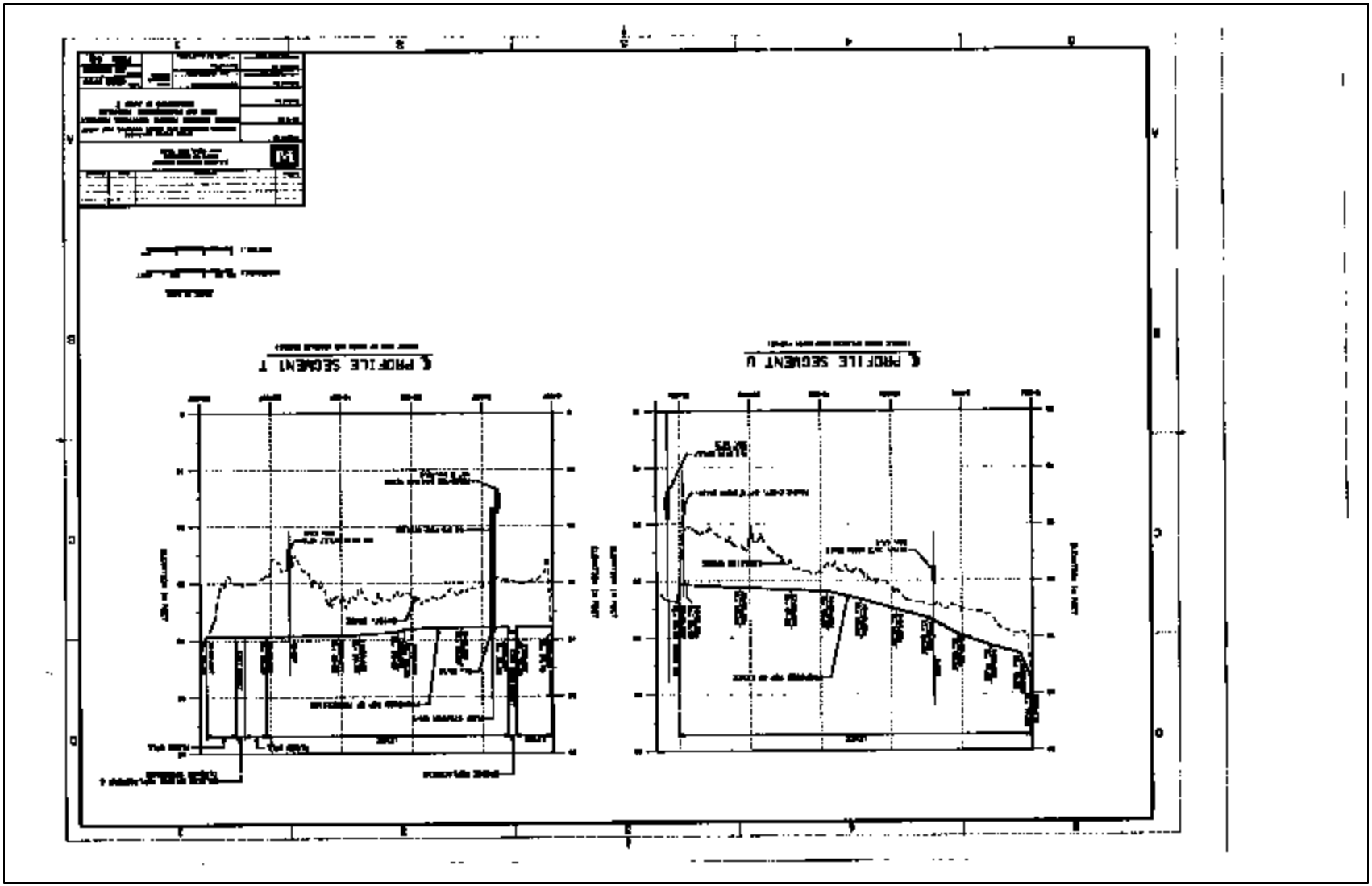
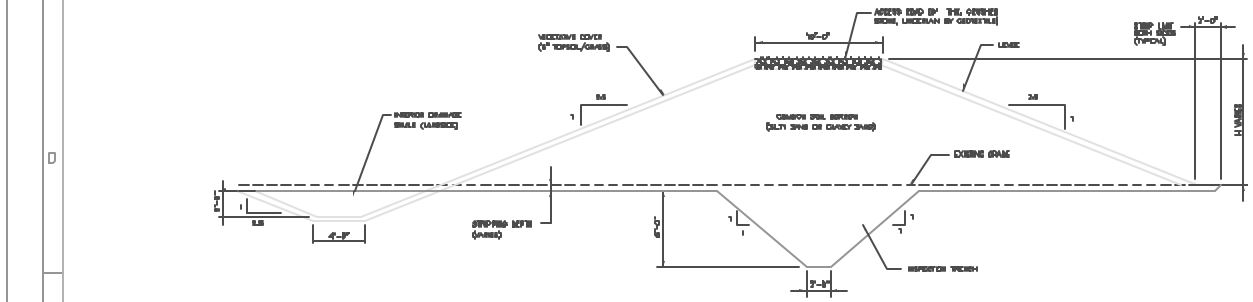
CORPS OF ENGINEERS
NEW YORK, NEW YORK

GREEN BROOK FLOOD CONTROL PROJECT
LINE OF PROTECTION PROFILE
GREEN BROOK, SEGMENT M
STA. 585+00 TO STA. 650+00

FIG. 48





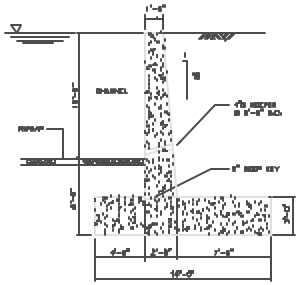


TYPICAL LEVEE SECTION

SCALE IN FEET

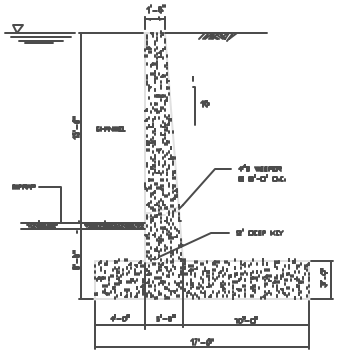
TYPICAL TRAPEZOIDAL CHANNEL

SCALE IN FEET



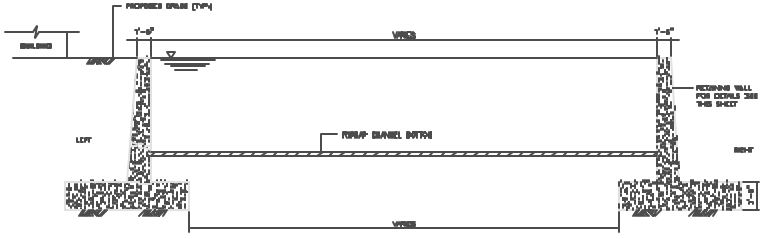
TYPICAL 10' HIGH RETAINING WALL

SCALE IN FEET



TYPICAL 15' HIGH RETAINING WALL

SCALE IN FEET



PROPOSED RECTANGULAR CHANNEL SECTION (TYP.)

SCALE IN FEET

Revision	Description	Date	Approved

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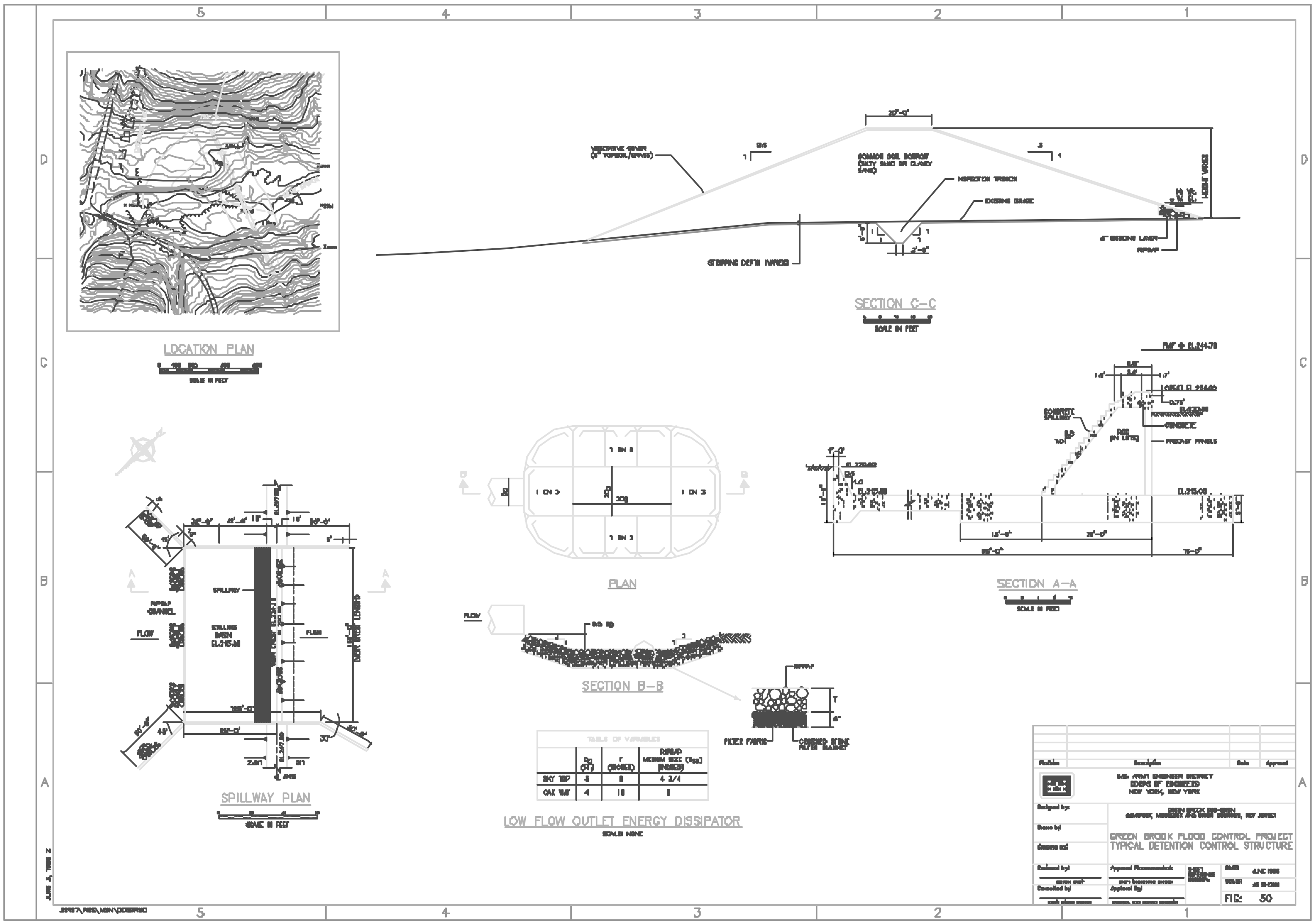
CORPS OF ENGINEERS
NEW YORK, NEW YORK

GREEN BROOK FLOOD CONTROL PROJECT
TYPICAL LEVEE AND
CHANNEL DETAILS

FIG: 49


LOCATION PLAN
SECTION C-C
SECTION A-A
PLAN
SECTION B-B
SPILLWAY PLAN
LOW FLOW OUTLET ENERGY DISSIPATOR
TABLE OF VARIABLES
SKY TOP
OAK WAY
4 3/4
FILTER FABRIC
U.S. ARMY ENGINEER DISTRICT
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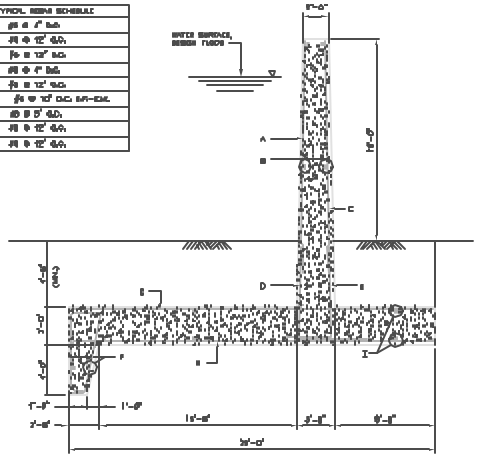
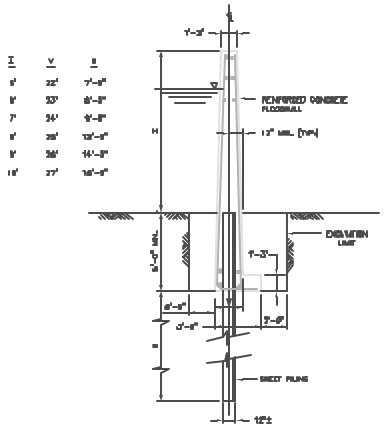
NEW YORK, NEW YORK
GREEN BROOK FLOOD CONTROL PROJECT
TYPICAL DETENTION CONTROL STRUCTURE
FIG: 50

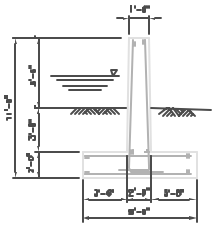
TYPICAL REBAR SCHEDULE	
A	#6 @ 6" O.C.
B	#6 @ 12" O.C.
C	#6 @ 12" O.C.
D	#6 @ 6" O.C.
E	#6 @ 12" O.C.
F	#6 @ 12" O.C. ALT-EQUAL
G	#6 @ 6" O.C.
H	#6 @ 12" O.C.
I	#6 @ 12" O.C.



TYPICAL TYPE A WALL



TYPICAL TYPE B WALL



TYPICAL TYPE C WALL

0 4 8

SCALE IN FEET

Number	Description	Date	Approved

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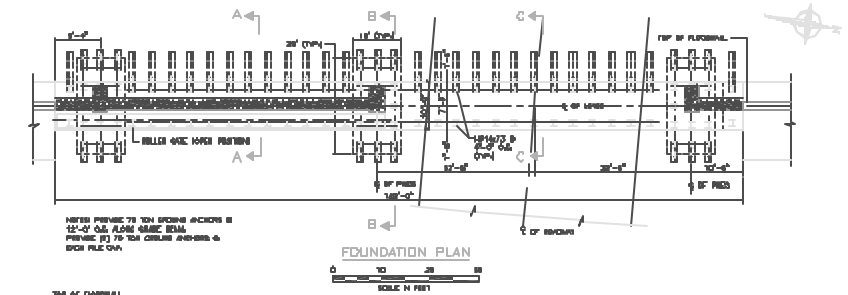
NEW YORK, NEW YORK

GREEN BROOK FLOOD CONTROL PROJECT
TYPICAL FLOODWALL SECTIONS

FIG: 31

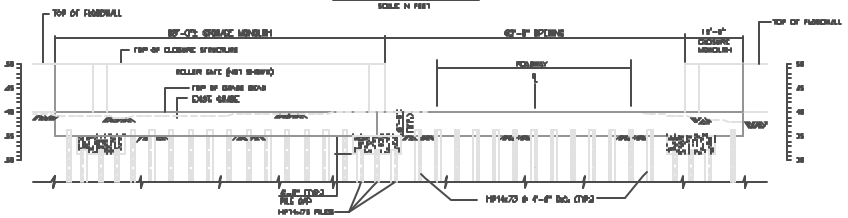
PLAN VIEW

SCALE IN FEET



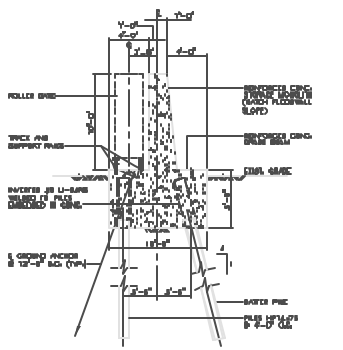
FOUNDATION PLAN

SCALE IN FEET



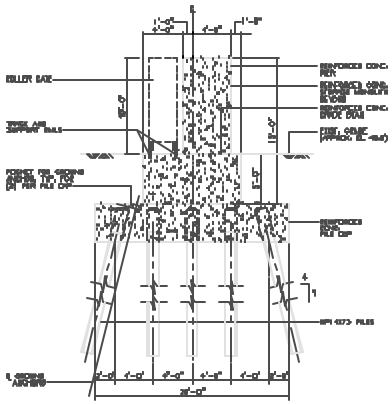
ELEVATION

SCALE IN FEET



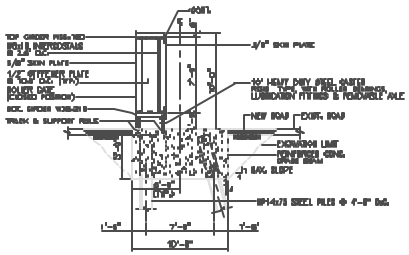
SECTION A–A

SCALE IN FEET



SECTION B–B

SCALE IN FEET



SECTION C–C

SCALE IN FEET

Revision	Description	Date	Approved

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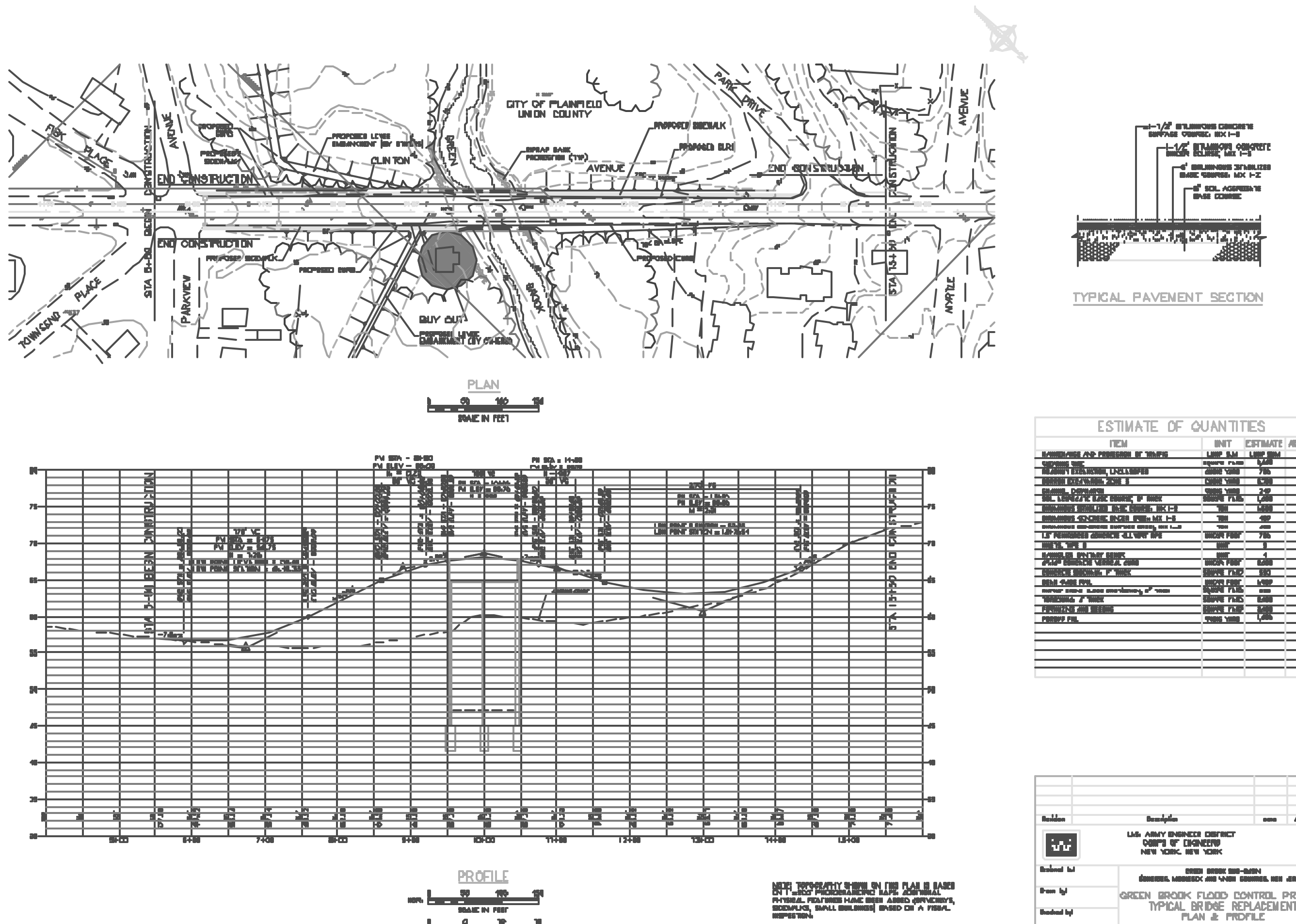
CORPS OF ENGINEERS
NEW YORK, NEW YORK

GREEN BROOK FLOOD CONTROL PROJECT
TYPICAL ROLLER GATE
CLOSURE STRUCTURE

FIG: 52

PLAN VIEW
PLAN - GATE LEAF
ELEVATION - GATE LEAF
SECTION A-A
PLAN OF MITER DETAIL
SECTION THRU BOTTOM HINGE
PLAN OF TOP HINGE
SECTION B-B
SECTION C-C
PLAN - SUBSTRUCTURE



ESTIMATE OF QUANTITIES

ITEM	UNIT	ESTIMATE	AS-BUILT
MAINTENANCE AND PROTECTION OF TRAFFIC	LUMP SUM	LUMP SUM	
CLEARING SITE	SQUARE YARD	[illegible]	
ROADWAY EXCAVATION, UNCLASSIFIED	CUBIC YARD	785	
[illegible]	CUBIC YARD	[illegible]	
CHANNEL EXCAVATION	CUBIC YARD	249	
SOIL AGGREGATE BASE COURSE, 6" THICK	SQUARE YARD	[illegible]	
BITUMINOUS STABILIZED BASE COURSE, MIX I-2	TON	[illegible]	
BITUMINOUS CONCRETE BINDER COURSE, MIX I-5	TON	[illegible]	
BITUMINOUS CONCRETE SURFACE COURSE, MIX I-5	TON	[illegible]	
15" REINFORCED CONCRETE CULVERT PIPE	LINEAR FOOT	[illegible]	
INLETS, TYPE B	UNIT	[illegible]	
MANHOLES, SANITARY SEWER	UNIT	4	
[illegible] CONCRETE VERTICAL CURB	LINEAR FOOT	[illegible]	
CONCRETE SIDEWALK, 4" THICK	SQUARE YARD	[illegible]	
BEAM GUIDE RAIL	LINEAR FOOT	[illegible]	
[illegible]	SQUARE YARD	[illegible]	
TOPSOILING, 4" THICK	SQUARE YARD	[illegible]	
FERTILIZING AND SEEDING	SQUARE YARD	[illegible]	
POROUS FILL	CUBIC YARD	[illegible]	

Revision	Description	Date	Approval

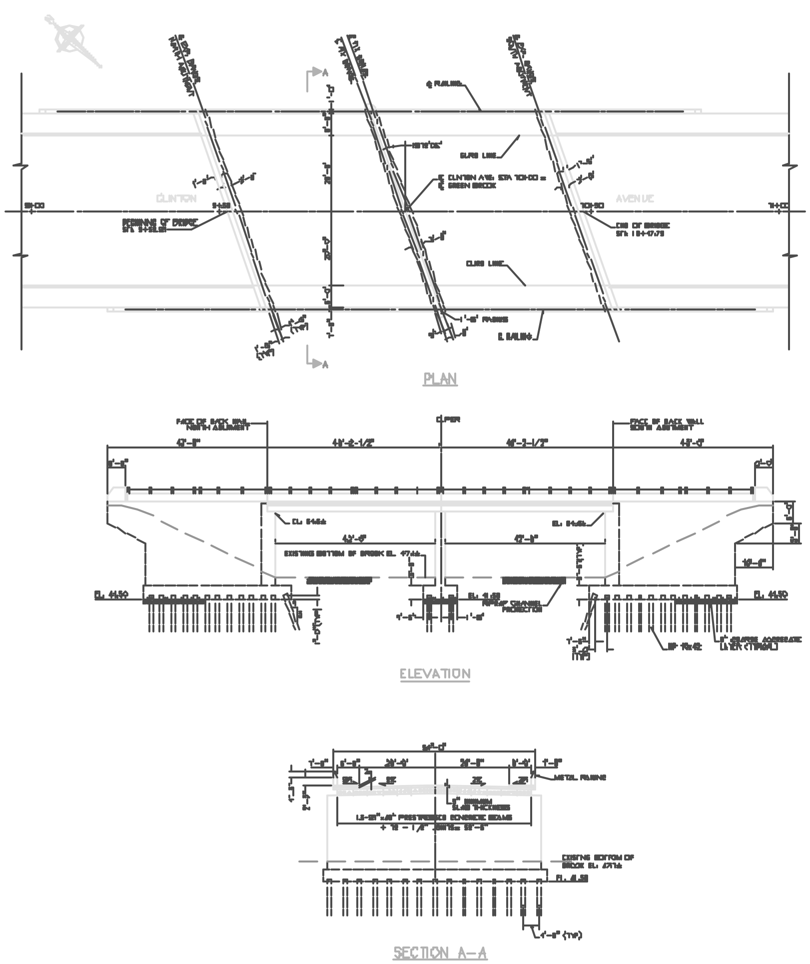
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NEW YORK, NEW YORK

Designed by:
Drawn by:
Checked by:

GREEN BROOK SUB-BASIN
SOMERSET, MIDDLESEX AND UNION COUNTIES, NEW JERSEY

GREEN BROOK FLOOD CONTROL PROJECT
TYPICAL BRIDGE REPLACEMENT
PLAN & PROFILE

DATE: JUNE 1996
SCALE: AS SHOWN
FIG: 54



ESTIMATE OF QUANTITIES

ITEM	UNIT	ESTIMATE	AS-BUILT
CLEARING SITE, REMOVAL OF EXISTING BRIDGE	LUMP SUM	LUMP SUM	
FOUNDATION EXCAVATION	CUBIC YARD	4,200	
COFFERDAM (PSA27)	SQUARE FOOT	12,000	
3" COARSE AGGREGATE LAYER	CUBIC YARD	185	
CONCRETE IN SUBSTRUCTURES, FOOTINGS (CLASS B)	CUBIC YARD	620	
CONCRETE IN SUBSTRUCTURES, RETAINING WALLS (CLASS B)	CUBIC YARD	297	
CONCRETE IN SUBSTRUCTURES, ABUTMENT WALLS (CLASS A)	CUBIC YARD	316	
CONCRETE IN SUBSTRUCTURES, PIER SHAFTS (CLASS A)	CUBIC YARD	135	
CONCRETE IN SUPERSTRUCTURES, DECK SLABS (CLASS A)	CUBIC YARD	87	
CONCRETE IN SUPERSTRUCTURES, SIDEWALKS (CLASS A)	CUBIC YARD	58	
CONCRETE IN SUPERSTRUCTURES, PARAPETS (CLASS A)	CUBIC YARD	31	
REINFORCEMENT STEEL IN STRUCTURES	POUND	48,000	
REINFORCEMENT STEEL IN STRUCTURES, EPOXY COATED	POUND	14,000	
5-1/2"x8-3/4" PREFORMED ELASTOMERIC JOINT SEALER	LINEAR FOOT	170	
PRESTRESSED CONCRETE BEAM 21"x48"	LINEAR FOOT	1,400	
STEEL H-PILES, HP 12x53	LINEAR FOOT	12,000	
METAL RAILING [illegible] ALUMINUM	LINEAR FOOT	317	
BENCHMARKS	EACH	77	

GENERAL NOTES

DESIGN SPECIFICATIONS
1. 1992 FIFTEENTH EDITION AASHTO STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES (WITH INTERIMS) AS MODIFIED BY SECTION 3 OF NJDOT DESIGN MANUAL FOR BRIDGES AND STRUCTURES.

CONSTRUCTION SPECIFICATIONS
1. 1989 NJDOT STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION AS MODIFIED BY THE SUPPLEMENTARY SPECIFICATIONS

LIVE LOAD
1. AASHTO HS 20-44 + 25% (HS25) OR TANDEM 24 KIP AXLES AT 4 FEET CENTERS, WHICHEVER GOVERNS.

CONCRETE DESIGN STRESSES
1. SPECIFIED DESIGN COMPRESSIVE STRENGTH (f'c)
CLASS A ....4,000 PSI
CLASS B ....3,000 PSI
2. CLASS DESIGN STRENGTHS
CLASS A ....4,000 PSI
CLASS B ....3,700 PSI
3. ALLOWABLE STRENGTHS, EXTREME FIBER IN COMPRESSION
CLASS A ....1,600 PSI
DECK SLABS OF
VEHICULAR BRIDGES........1,400 PSI
CLASS B ....1,200 PSI

REINFORCEMENT STEEL
1. ASTM A615 (GRADE 60) (FS)=24,000 PSI

SUPERSTRUCTURE
1. DEAD LOAD INCLUDES 25 LBS/SQ. FT. PROVISION FOR FUTURE 2" THICK OVERLAY ON BRIDGE DECK.

0 10 20 30
SCALE IN FEET

Revision	Description	Date	Approved

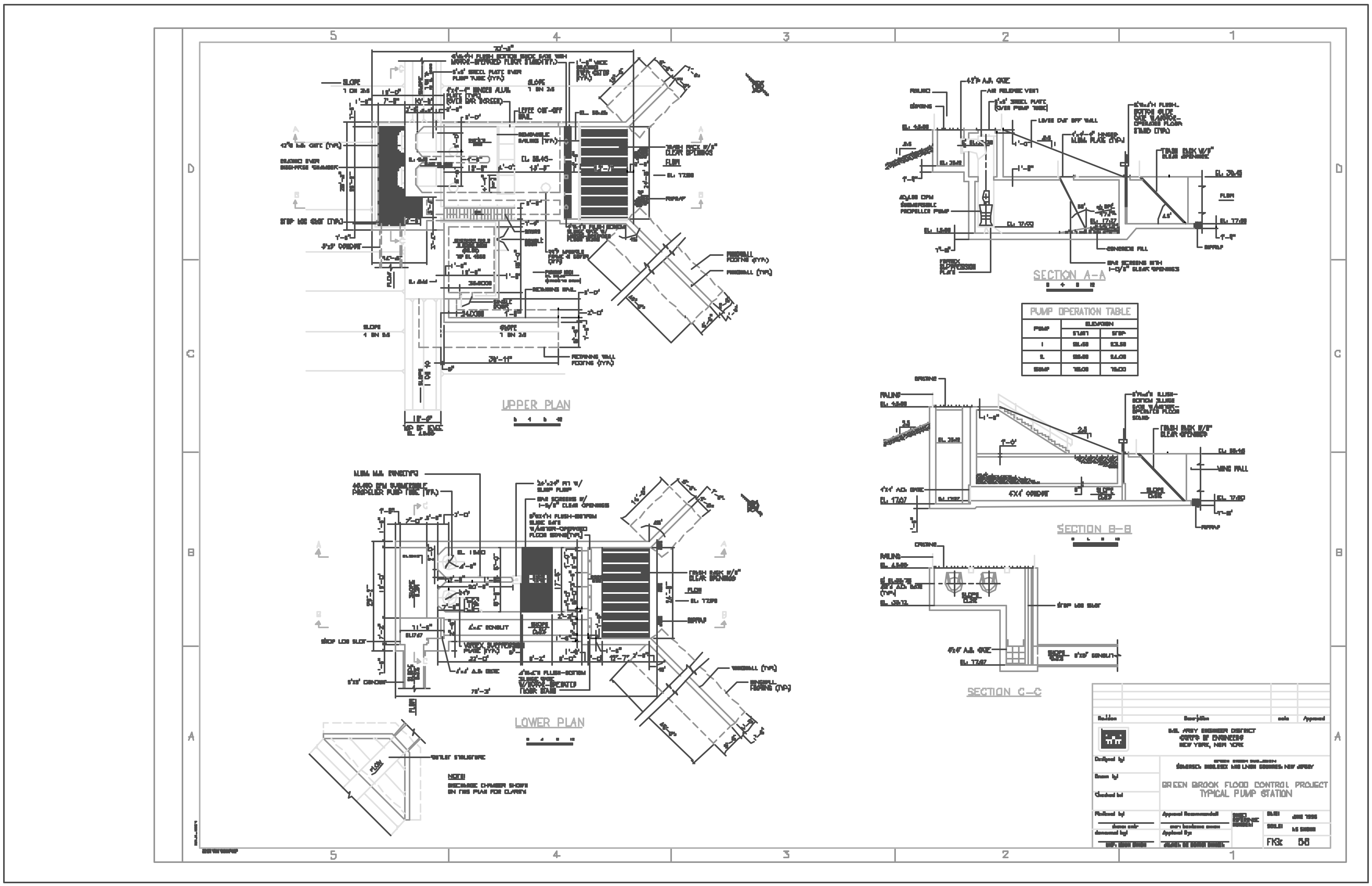
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NEW YORK, NEW YORK

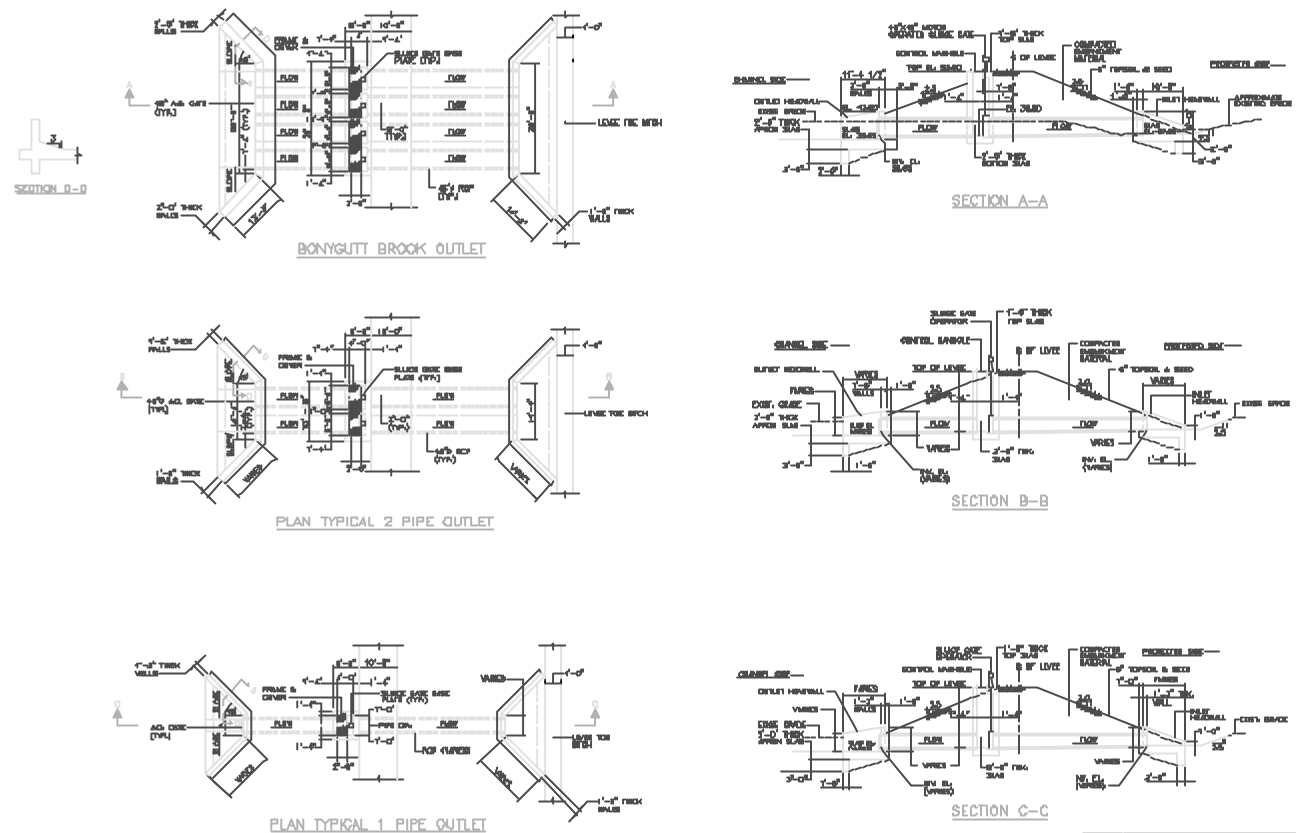
Designed by:
Drawn by:
Checked by:

GREEN BROOK SUB-BASIN
SOMERSET, MIDDLESEX AND UNION COUNTIES, NEW JERSEY

GREEN BROOK FLOOD CONTROL PROJECT
TYPICAL BRIDGE REPLACEMENT DETAILS

Reviewed by: [illegible]
Approval Recommended: [illegible]
Sheet Reference Number
Submitted by: [illegible]
Approved by: [illegible]
DATE: JUNE 1997
SCALE: AS SHOWN
FIG. 66


UPPER PLAN
LOWER PLAN
SECTION A–A
PUMP OPERATION TABLE
PUMP
ELEVATION
START
STOP
SECTION B–B
SECTION C–C
CONCRETE FILL
VING WALL
RIPRAP
4'X4' CONDUIT
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NEW YORK, NEW YORK
GREEN BROOK FLOOD CONTROL PROJECT
TYPICAL PUMP STATION
FIG: 5-6



Revision	Description	Date	Approved

U.S. ARMY ENGINEER DISTRICT
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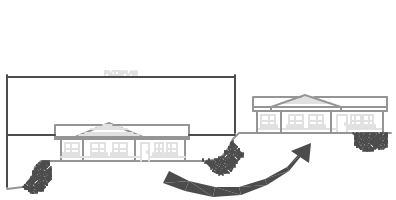
NEW YORK, NEW YORK

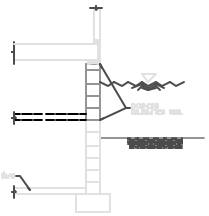
GREEN BROOK SUB-BASIN
SOMERSET, MIDDLESEX AND UNION COUNTIES, NEW JERSEY

GREEN BROOK FLOOD CONTROL PROJECT
TYPICAL MAIN OUTLET DETAILS
INTERIOR DRAINAGE

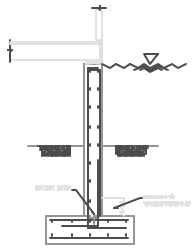
Designed by:
Drawn by:
Checked by:
Reviewed by:
Approval Recommended:
Submitted by:
Approved by:
SHEET REFERENCE NUMBER
DATE: JUNE 1996
SCALE: AS SHOWN
FIG: 57



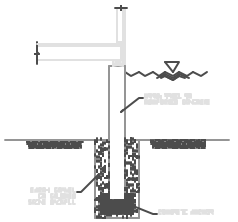
TYPICAL RELOCATION VIEW



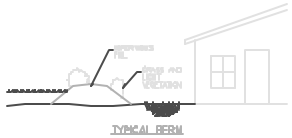
TYPICAL ELEVATION ON EXTENDED WALLS



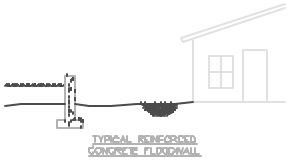
TYPICAL ELEVATION ON PIERS



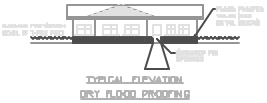
TYPICAL ELEVATION ON POSTS OR COLUMNS



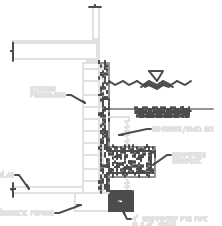
TYPICAL BERM



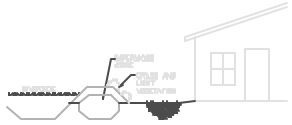
TYPICAL REINFORCED CONCRETE FLOODWALL



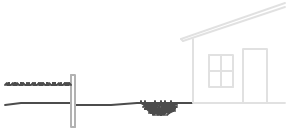
TYPICAL ELEVATION DRY FLOOD PROOFING



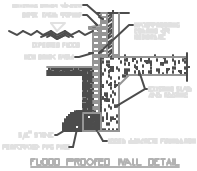
TYPICAL HYDROSHIELD DRY FLOOD PROOFING



TYPICAL LEVEE



TYPICAL STEEL SHEET PILING FLOODWALL

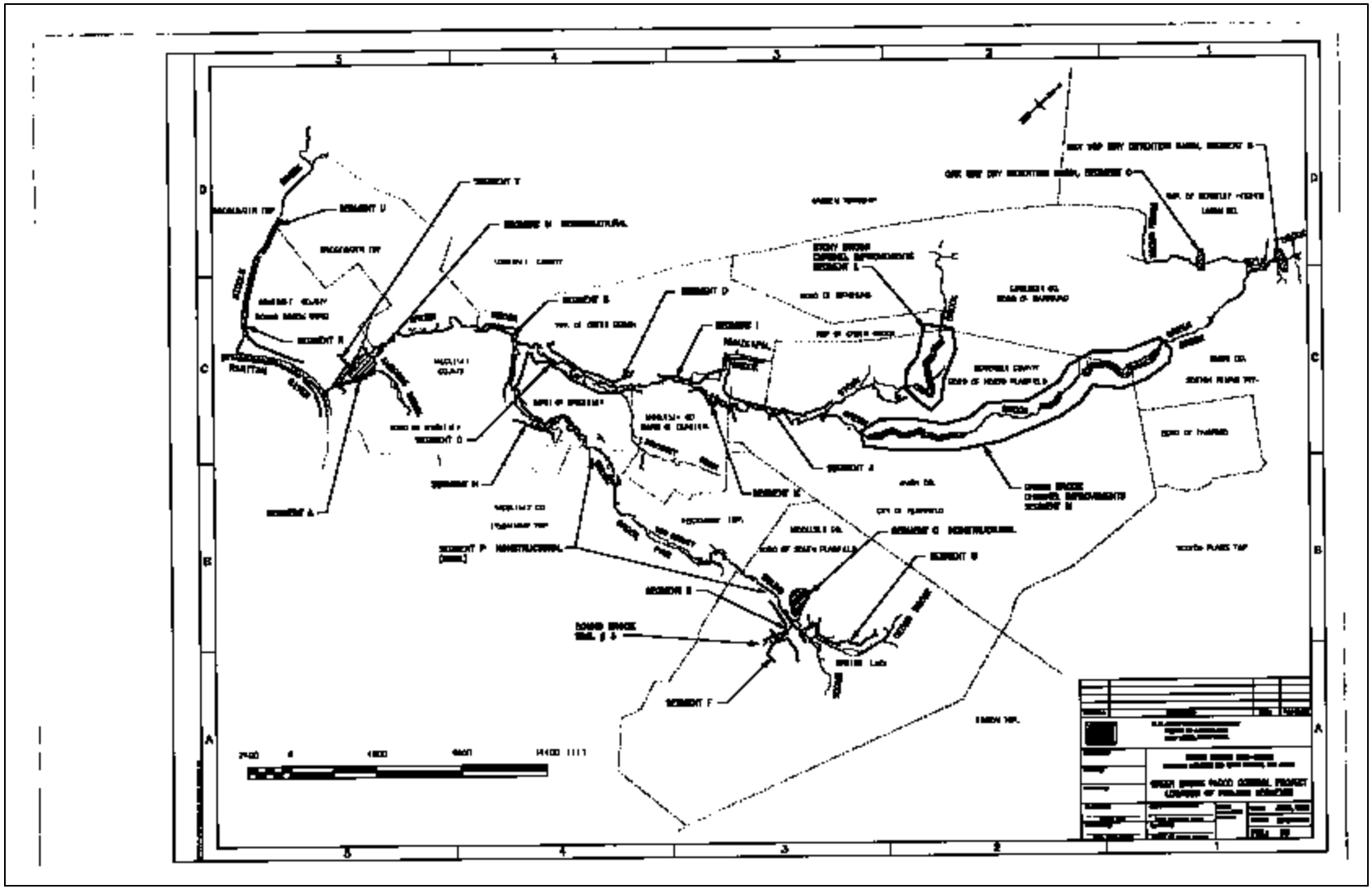


FLOOD PROOFED WALL DETAIL

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NEW YORK, NEW YORK

GREEN BROOK FLOOD CONTROL PROJECT
TYPICAL FLOOD PROOFING MEASURES

FIG: 68



RECOMMENDED PLAN

ESTIMATED PROJECT CONSTRUCTION SCHEDULE

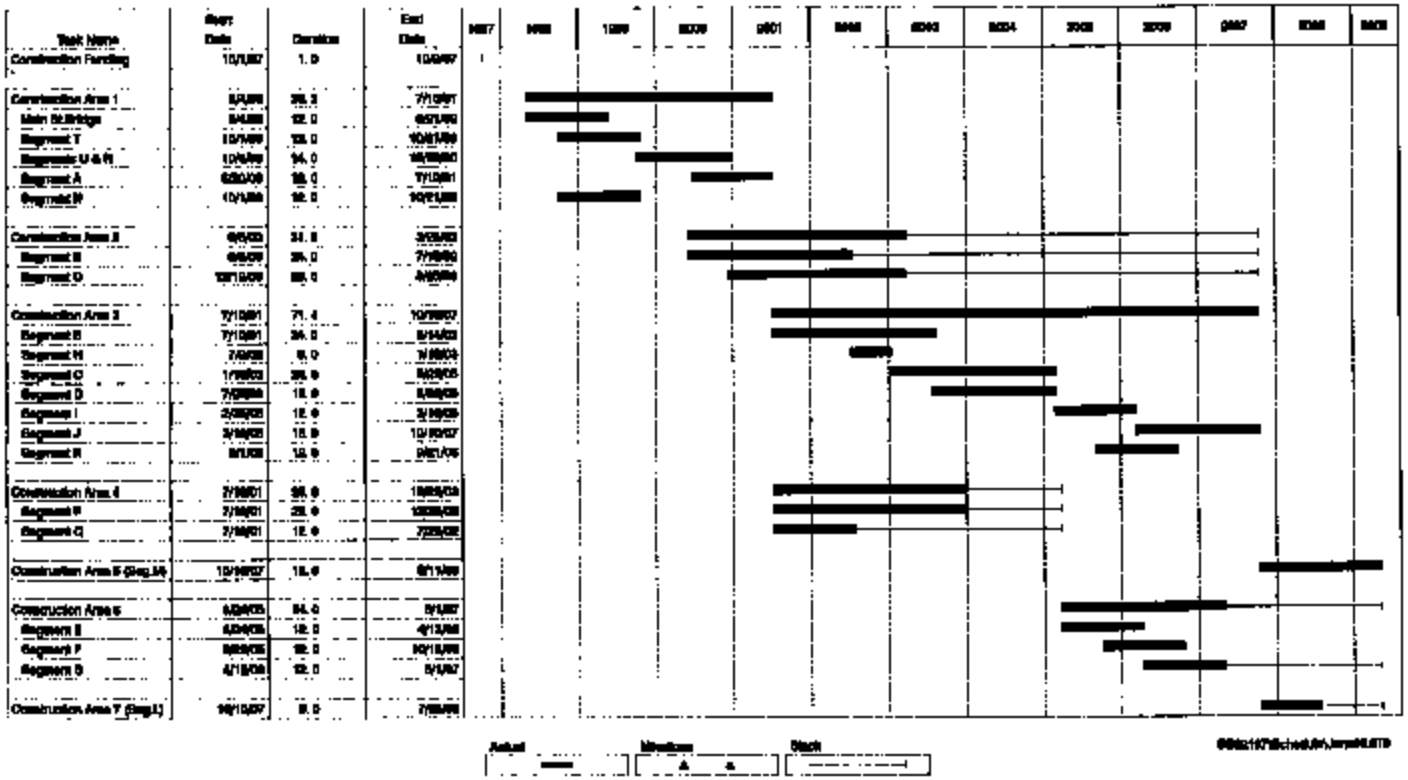


FIGURE 80