US Army Corps
of Engineers
New York District

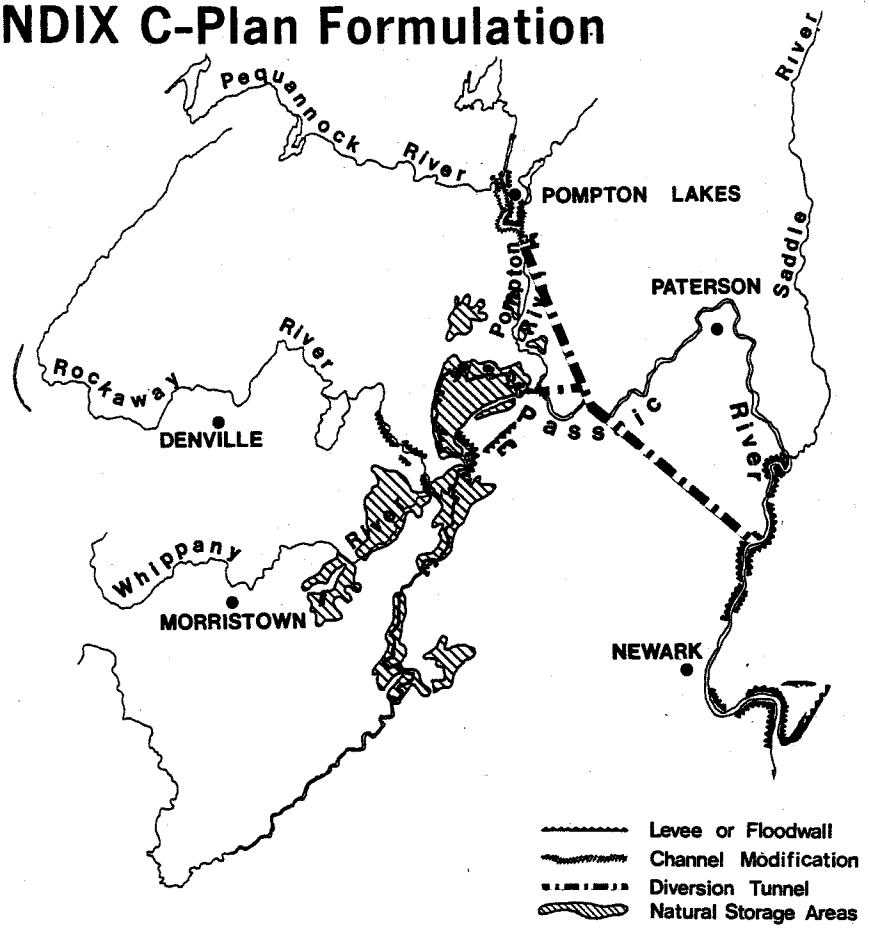
PASSAIC RIVER BASIN STUDY

Passaic River Basin, New Jersey and New York
Phase I - General Design Memorandum

Flood Protection Feasibility Main Stem Passaic River

Main Report

APPENDIX C-Plan Formulation



December 1987

Vol. IV

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

Subject	Page
SECTION 1 - INTRODUCTION	
GENERAL	C-1
ORGANIZATION	C-1
AUTHORIZATION	C-2
STUDY CLASSIFICATION	C-2
PURPOSE	C-2
CONGRESSIONAL GUIDANCE	C-5
SCOPE	C-5
PAST CORPS OF ENGINEERS PLANNING	C-8
CURRENT STUDY REPORTS	C-9
RECENT SMALL PROJECT REPORTS	C-12
REPORTS BY OTHERS	C-14
WATER RESOURCES DEVELOPMENT ACT OF 1986	C-14
BASIN DESCRIPTION	C-14
POLITICAL DIVISIONS	C-16
TOPOGRAPHY	C-16
Lower Valley	C-16
Central Basin	C-21
Highland Area	C-22
SECTION 2 - WITHOUT PROJECT CONDITIONS	
INTRODUCTION	C-23
HUMAN RESOURCES	C-23
Demographic and Community Characteristics	C-23
Personal and Family Economic Characteristics	C-24
Future Socioeconomic Profiles	C-25
LAND USE	C-28
Existing Development	C-29
Future Land Use Changes	C-31
Urbanization	C-34
Central Basin Wetlands and Natural Storage	C-39
Historic Trends	C-42
a. Lands Contained Within Floodway Delineations	C-43
b. Parkland or Open Space Zoning Designation	C-43
c. Section 404 of the Clean Water Act (PL 92-500)	C-47
d. Non-Federal Regulatory Action	C-47
e. Recent Non-Federal Actions	C-48
f. Future Natural Storage Losses	C-49

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

Subject	Page
CENTRAL BASIN FUTURE NATURAL FLOOD STORAGE SUMMARY	C-52
Acquisition Plans	C-55
City of Passaic Redevelopment Plans	C-56
BIOLOGICAL RESOURCES	C-57
Terrestrial Resources	C-57
Lower Valley Flora and Fauna	C-58
Central Basin Flora and Fauna	C-58
Upper Passaic River Terrestrial Resources	C-59
Future Conditions of Terrestrial Resources	C-60
Aquatic Resources and Water Quality	C-61
Lower Passaic River	C-62
Central Passaic River	C-63
Pompton River	C-63
Pequannock River	C-63
Ramapo River	C-64
Wanaque River	C-64
Rockaway River	C-64
Whippany River	C-64
Future Conditions of Aquatic Resources and Water Quality	C-65
Endangered and Threatened Species	C-66
CULTURAL RESOURCES	C-67
Prehistoric Sites and Density Distributions	C-67
Historic Sites and Density Distributions	C-68
TRANSPORTATION	C-68
Existing and Future Facilities	C-68
Bridges	C-71
RECREATION	C-72
HAZARDOUS SUBSTANCES SITES	C-74
WATER SUPPLY	C-77
Existing Water Supply Systems	C-77
Range of Deficits	C-80
Future Water Supply Needs	C-81
WASTEWATER	C-81
Point Source Discharges	C-81
Non-Point and Intermittent Point Sources (NPS/IPS)	C-82
WATER QUALITY	C-82
Surface Water Quality	C-83
Groundwater Quality	C-84
Sediment Transport and Riverbed Composition	C-84

3

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

Subject	Page
HYDROPOWER	C-85
AIR QUALITY	C-85
NOISE	C-86
AESTHETICS	C-86
FLOOD DAMAGES	C-87
Lower Passaic Damage Reaches	C-90
Central Passaic Damage Reaches	C-90
Upper Passaic Damage Reaches	C-95
Pompton, Lower Ramapo, Wanaque and Pequannock Rivers Damage Reaches	C-95
Future Conditions	C-95
NON-FEDERAL FLOOD CONTROL PROGRAMS	C-96
State of New Jersey Flood Control Program	C-96
Flood Hazard Area Regulations	C-97
Storm Water Management Regulations	C-98
Early Floodwarning System	C-99
Snagging and Clearing	C-99
Local Levee Projects	C-100
SECTION 3 - PROBLEM IDENTIFICATION	
GENERAL	C-101
PROBLEMS AND NEEDS	C-101
FLOODING PROBLEM	C-103
Passaic River and Major Tributaries	C-103
Minor Tributaries	C-104
WATER SUPPLY PROBLEM	C-106
ENVIRONMENTAL CONCERNS	C-111
Water Quality	C-111
Anadromous Fish	C-112
State Stocking Program	C-112
Wetlands	C-112
Endangered and Threatened Species	C-113
Cultural Resources	C-113
Toxic and Hazardous Wastes	C-114
Aesthetics	C-114
EROSION PROBLEM	C-114
OTHER NEEDS	C-114
PLANNING CONSTRAINTS	C-115
MODIFICATION OF PROBLEM AND OPPORTUNITY STATEMENTS	C-117
UTILIZING PROBLEM AND OPPORTUNITY STATEMENTS IN PLAN FORMULATION	C-118

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

Subject	Page
SECTION 4 - PLAN FORMULATION APPROACH	
MANAGEMENT MEASURES	C-120
PLAN CATEGORIES	C-123
Basin-Wide Emergency and Local Land Management Category	C-123
"Building Block" Category	C-125
Basin-Wide Plan Category	C-125
"BUILDING BLOCK" APPROACH	C-125
TECHNICAL BASIS FOR PLAN FORMULATION	C-126
Lower Passaic River	C-126
Central Passaic River	C-131
Upper Passaic River	C-136
SECTION 5 - PLAN FORMULATION RESULTS	
I - EMERGENCY AND LOCALLY IMPLEMENTABLE LAND MANAGEMENT PLANS	
INTRODUCTION	C-137
FLOODWARNING/PREPAREDNESS	C-137
Existing Floodwarning/Preparedness System	C-139
Recommended Improvements to Preparedness System	C-142
FLOODPLAIN MAPPING	C-145
PUBLIC EDUCATION	C-146
PRESERVATION OF NATURAL STORAGE	C-146
STORM WATER MANAGEMENT	C-148
FLOODPLAIN ZONING	C-150
Flood Insurance	C-151
Floodplain Evacuation	C-151
TECHNICAL ASSISTANCE	C-152
II - "BUILDING BLOCKS"	
INTRODUCTION	C-154
BUILDING BLOCK #1 - PERMANENT EVACUATION	C-155
BUILDING BLOCK #2 - FLOODPROOF/RAISE	C-159
BUILDING BLOCK #3 - PERMANENT EVACUATION, FLOODPROOF/RAISE	C-159
Design Criteria	C-159
a. Floodproofing	C-163
b. Raising	C-163

5

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

Subject	Page
c. Nonstructural Wall	C-163
d. Permanent Evacuation	C-164
Methodology	C-164
Results	C-165
BUILDING BLOCK #4 - DAM AND BRIDGE MODIFICATION	C-165
Bridges	C-165
Dams	C-165
BUILDING BLOCK #6 - CHANNEL MODIFICATION	C-174
BUILDING BLOCK #7 - CHANNEL, DAM AND BRIDGE MODIFICATION	C-174
Building Block 7A	C-177
Building Block 7B	C-184
BUILDING BLOCK #11 - LEVEE/FLOODWALL	C-185
BUILDING BLOCK #13 - LEVEE/FLOODWALL, DAM AND BRIDGE MODIFICATIONS	C-185
Building Block 13A - 100 Year Levee/Floodwall	C-186
Building Block 13B - SPF Levee/Floodwall	C-194
BUILDING BLOCKS 17 AND 18 - EXISTING AND NEW RESERVOIRS	C-195
Early Screening	C-195
a. Screening Rationale	C-195
b. Early Screening Results	C-206
i. Ramapo River Subbasin	C-207
ii. Wanaque River Subbasin	C-207
iii. Pequannock River Subbasin	C-208
iv. Pompton River Subbasin	C-209
v. Rockaway River Subbasin	C-209
vi. Whippany River Subbasin	C-219
vii. Main Stem	C-210
c. Early Screening Summary	C-210
Formulation of Alternative Plans	C-210
a. Flood Damage Reduction: Potential Sites	C-211
b. Flood Damage Reduction: Existing Reservoirs	C-211
c. Water Supply	C-212
d. Hydropower	C-212
Results	C-212
a. Ramapo River Subbasin	C-213
b. Pequannock River Subbasin	C-217
c. Wanaque River Subbasin	C-219
d. Rockaway River Subbasin	C-223

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

Subject	Page
e. Whippany River Subbasin	C-230
f. Passaic Main Stem	C-230
Summary	C-232
BUILDING BLOCK 20 - PRESERVATION OF NATURAL STORAGE AREAS	C-232
Option 1(a) - Federal Acquisition	C-240
Option 1(b) - Section 404 Regulatory Program	C-241
Option 2	C-242
Option 2(a) - State of New Jersey Flood Hazard Regulations	C-243
Option 2(b) - State Acquisition	C-243
Option 2(c) - Local/Municipal Zoning	C-244
Option 2(d) - State Commission	C-244
Option 2(e) - State Moratorium/Legislation	C-244
Conclusion	C-244
BUILDING BLOCK 21 - AQUIFER RECHARGE	C-245
BUILDING BLOCK 23 - TUNNEL DIVERSIONS	C-247
General	C-247
Development of Alternatives: Technical Considerations	C-248
1. Hydrologic Considerations in Determining Inlet/Outlet Locations	C-248
2. Siphon vs. Hydraulic Grade Tunnels	C-258
3. Construction Techniques and Considerations	C-259
Screening of Tunnel Routes	C-263
Formulation of Tunnel Plans	C-273
Plan Components	C-273
Plan Development	C-275
a. Little Falls Inlet	C-275
b. Pompton River Inlet	C-279
c. Double Inlets	C-283
d. Two Bridges Inlet	C-286
e. Other Alternatives	C-286
f. Summary	C-287
"Building Blocks"	C-289
Building Block 23A	C-289
Building Block 23B	C-294
Building Block 23C	C-294
Building Block 23D	C-301
Building Block 23E	C-303

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

Subject	Page
Building Block 23F	C-309
Building Block 23G	C-311
BUILDING BLOCK 27 - TIDAL BARRIER	C-315
III - INTERMEDIATE PLANS	
INTRODUCTION	C-319
PLAN 5 - PERMANENT EVACUATION, FLOODPROOF/RAISING, DAM AND BRIDGE MODIFICATION	C-319
PLAN 8 - CHANNEL MODIFICATION, PERMANENT EVACUATION	C-322
PLAN 9 - CHANNEL MODIFICATION, FLOODPROOF/RAISING	C-322
PLAN 10A - CHANNEL MODIFICATION, FLOODPROOF/RAISING, PERMANENT EVACUATION	C-322
PLAN 10B	C-322
PLAN 12 - PERMANENT EVACUATION, LEVEE/FLOODWALL	C-323
PLAN 14A - LEVEE/FLOODWALL, NONSTRUCTURAL, DAM AND BRIDGE MODIFICATION	C-323
PLAN 14B	C-323
PLAN 15 - CHANNEL MODIFICATION, LEVEE/FLOODWALL	C-325
PLAN 15A	C-325
PLAN 15B	C-340
PLAN 16A - LEVEE/FLOODWALL, NONSTRUCTURAL, CHANNEL MODIFICATION PLAN	C-340
PLAN 16B	C-341
PLAN 16C	C-341
PLAN 19 - EXISTING AND NEW RESERVOIRS	C-341
PLAN 24 - RESERVOIRS, TUNNELS	C-344
PLAN 22/PLAN 25/PLAN 26 - AQUIFER RECHARGE, RESERVOIRS, TUNNELS	C-344
PLAN 28 - TUNNELS, PERMANENT EVACUATION, FLOODPROOFING/ RAISING	C-344
PLAN 28A	C-344
PLAN 28B	C-344
PLAN 28C1	C-346
PLAN 28C2	C-346
PLAN 28C3	C-346
PLAN 28D	C-346
PLANS 28E1, 28E2, 28E3	C-346
PLAN 28F	C-349
PLAN 28G	C-349
PLAN 29A-G - TUNNELS, CHANNEL MODIFICATION	C-349
PLAN 30A - TUNNELS, LEVEES/FLOODWALLS	C-349
PLAN 30B	C-353
PLAN 30C	C-353

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

Subject	Page
PLAN 30D	C-355
PLAN 30E	C-355
PLAN 30F	C-359
PLAN 30G	C-359
PLAN 31A-G - TUNNELS, LEVEE/FLOODWALLS, CHANNEL MODIFICATION	C-362
PLAN 32A-G - TUNNELS, NONSTRUCTURAL, CHANNEL MODIFICATION	C-362
PLAN 33A-G - TUNNELS, NONSTRUCTURAL, LEVEES/ FLOODWALLS	C-362
PLAN 34A-G - TUNNELS, LEVEES/FLOODWALLS, CHANNEL MODIFICATION, NONSTRUCTURAL	C-362
SUMMARY	C-369
SECTION 6 - EVALUATION AND SCREENING OF INTERMEDIATE STAGE ALTERNATIVES	
GENERAL	C-370
MAIN STEM PLAN FORMULATION REACHES	C-370
ARRAY OF INTERMEDIATE PLANS	C-371
Initial Screening	C-374
SEVEN BASIC INTERMEDIATE PLANS	C-377
PRESERVATION OF NATURAL STORAGE	C-379
EVALUATION OF INTERMEDIATE PLANS	C-379
Economic Assessment Summary	C-379
Environmental Assessment Summary	C-382
Evaluation Criteria	C-385
EVALUATION AND SCREENING OF INTERMEDIATE PLANS	C-387
SUMMARY OF STATE AND LOCAL INPUT	C-391
Impact of April 1984 Flood	C-392
NJDEP Public Involvement	C-393
Summary of Issues	C-393
State Selection of a Plan	C-396
ALTERNATIVES SELECTED FOR DETAILED PLANNING	C-398
SECTION 7 - PLAN FORMULATION-DETAILED STAGE	
DETAILED PLANNING INVESTIGATIONS	C-399
Establishment of Project Base Year	C-399
Finalizing of Without Project Conditions	C-399

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

Subject	Page
Refinement of Design and Cost Estimates	C-400
Hydraulics	C-400
Hydrology	C-401
Foundations and Materials Investigations	C-401
Screening of Incremental Elements	C-402
Incremental Degree of Protection	C-402
Incorporation of Preservation of Natural Storage	C-402
Incorporation of Other Plan Elements	C-403
Fish and Wildlife Mitigation	C-403
SIGNIFICANT PLAN REFINEMENT SUMMARY	C-404
Levee/Floodwall/Nonstructural/Channel Modification Plan (Plan 16A)	C-404
Beatties Dam Single Inlet Tunnel Diversion Plan Plan (Plan 30A)	C-404
Pompton/Passaic Dual Inlet Tunnel Diversion Plan Plan (Plan 30E)	C-406
SECTION 8 - OPTIMIZATION	
GENERAL	C-411
ANALYSIS OF INCREMENTAL DEGREE OF PROTECTION	C-411
Plan 16A - Levee/Floodwall/Nonstructural/ Channel Plan	C-412
Diversion Tunnels	C-415
Plan 30A	C-421
Plan 30E	C-422
DESIGNATION OF NED PLAN	C-422
FOCUS ON POMPTON - PASSAIC DUAL INLET TUNNEL DIVERSION (PLAN 30E)	C-427
Main Tunnel	C-427
Spur Tunnel	C-428
Tunnel Diversion Plan Element Last Added/First Added Summary	C-433
Surface Works Integral To Tunnel	C-435
a. Channel Modification	C-435
b. Levee/Floodwalls	C-436
Levee/Floodwalls Incremental To Tunnel	C-438
Preservation of Natural Storage	C-439
Fish and Wildife Mitigation	C-451
Nonstructural Measures	C-451

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

Subject	Page
SECTION 9 - EVALUATION AND COMPARISON OF DETAILED STAGE ALTERNATIVES	
GENERAL	C-453
PLAN 30E	C-453
PLAN 30A	C-461
PLAN 16A	C-466
EVALUATION OF DETAILED PLANS	C-469
National Economic Development	C-469
Response to Problem and Opportunity Statements	C-472
Evaluation Criteria	C-477
Environmental Quality	C-478
a. Terrestrial Resources	C-478
b. Aquatic Resources	C-478
c. Water Quality	C-496
d. Other Significant Resources	C-496
COMPARISON AND TRADE-OFF SUMMARY	C-496
RATIONALE FOR SELECTION	C-498
DIFFERENCES FROM PLAN SELECTED BY STATE	C-498
SECTION 10 - RECOMMENDED PLAN	
GENERAL	C-500
TUNNEL ELEMENTS	C-502
Pompton River Inlet	C-506
Two Bridges Inlet and Spur Tunnel	C-506
Tunnel Outlet	C-506
Alternate Outlet Locations	C-507
CHANNEL MODIFICATION INTEGRAL TO THE TUNNEL ELEMENT	C-507
Passaic and Pompton Rivers	C-507
Pequannock River	C-508
Wanaque River	C-508
Ramapo River	C-508
LEVEE/FLOODWALL SYSTEMS INTEGRAL TO THE TUNNEL ELEMENT	C-508
Induced Damages	C-508
Descriptions of Levee/Floodwall Systems	C-510
INCREMENTAL LEVEE/FLOODWALL ELEMENTS OF THE DUAL INLET TUNNEL DIVERSION PLAN	C-514
PRESERVATION OF NATURAL STORAGE UNDER THE DUAL INLET TUNNEL PLAN	C-518

//

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

Subject	Page
ENVIRONMENTAL EFFECTS	C-522
ENVIRONMENTAL ELEMENTS OF THE DUAL INLET TUNNEL PLAN	C-528
OPERATIONAL DETAILS OF THE TUNNEL	C-531
CONSTRUCTION OF THE DUAL INLET TUNNEL PLAN	C-538
OPERATION AND MAINTENANCE OF THE DUAL INLET TUNNEL PLAN	C-539
ECONOMICS OF THE SELECTED PLAN	C-539
Methodology	C-539
Estimate of First Cost	C-540
Estimate of Annual Charges	C-540
Estimate of Annual Benefits	C-540
a. Annual Flood Control Benefits	C-540
b. Traffic Delays	C-542
c. PATH Delays	C-542
d. Federal Flood Insurance Administration Cost Reduction	C-542
e. Residential Intensification	C-542
f. Industrial Content Growth	C-543
g. Annual Benefit Summary	C-543
Economic Justification	C-543
COST SHARING RESPONSIBILITIES	C-543
General	C-543
Federal Responsibilities	C-543
Non-Federal Responsibilities	C-545
Separable Cost-Remaining Benefits Analysis	C-545
RISK AND UNCERTAINTY	C-546

LIST OF TABLES

Table	Description	Page
C-1	WATER RESOURCES DEVELOPMENT ACT OF 1986	C-15
C-2	PASSAIC RIVER BASIN MUNICIPALITIES	C-17
C-3	EXISTING AND FUTURE CONDITIONS LAND USE EXTENT OF DEVELOPMENT	C-33
C-4	IMPACT OF LOSS OF CENTRAL BASIN NATURAL STORAGE AREAS	C-41
C-5	ACRES OF NATURAL STORAGE THAT ARE PROTECTED AND UNPROTECTED	C-44
C-6	PASSAIC RIVER BASIN WETLAND PARKLAND OR OPEN SPACE PROTECTIVE STATUS	C-45

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

LIST OF TABLES (CONT)

Table	Description	Page
C-7	HISTORIC AND FUTURE TREND OF IMPACTS ON CENTRAL BASIN NATURAL FLOOD STORAGE AREAS	C-53
C-8	FUTURE BRIDGE MODIFICATIONS	C-73
C-9	HISTORICAL FLOOD DAMAGES	C-88
C-10	EXISTING CONDITIONS DAMAGES	C-91
C-11	BASE CONDITION DEVELOPMENT FOR STUDY AREA	C-92
C-12	TOTAL EXISTING CONDITIONS EXPECTED ANNUAL DAMAGES	C-93
C-13	IMPACT OF FUTURE HYDROLOGY ON BASE YEAR WITHOUT PROJECT CONDITIONS	C-94
C-14	SUMMARY OF THE PROBLEMS AND NEEDS OF THE PASSAIC RIVER BASIN	C-102
C-15	MUNICIPALITIES INVESTIGATED AS PART OF THE MAIN STEM STUDY EFFORT	C-105
C-16	RESULTS OF MINOR TRIBUTARY STUDIES	C-108
C-17	STATEMENT OF PROBLEMS AND OPPORTUNITIES	C-116
C-18	MANAGEMENT MEASURES	C-121
C-19	CENTRAL BASIN FLOW ANALYSIS FOR EXISTING CONDITIONS 100 YEAR FLOOD	C-132
C-20	EMERGENCY AND LOCALLY IMPLEMENTABLE LAND MANAGEMENT MEASURES	C-138
C-21	STATUS OF ADOPTION OF FIA FLOODWAYS	C-147
C-22	PASSAIC RIVER BASIN FUTURE DEVELOPMENT PROJECTIONS AND HYDROLOGIC IMPACTS DUE TO URBANIZATION	C-149
C-23	SUMMARY OF PASSAIC RIVER BASIN BUILDING BLOCKS	C-156
C-24	BUILDING BLOCKS 1A, 1B AND 1C, PERMANENT EVACUATION	C-158
C-25	BUILDING BLOCK 1D PERMANENT EVACUATION, MAIN FLOOR FLOODING BY 10 YEAR EVENT	C-160
C-26	BUILDING BLOCK 1E PERMANENT EVACUATION, INCREMENTAL ANALYSIS	C-161
C-27	APPLICABILITY OF NONSTRUCTURAL MEASURES	C-162
C-28	SUMMARY OF BUILDING BLOCKS 3A, 3B AND 3C PERMANENT EVACUATION, FLOODPROOF/RAISE	C-166
C-29	BUILDING BLOCK 3A (10 YEAR LEVEL OF PROTECTION) ECONOMIC SUMMARY	C-167
C-30	BUILDING BLOCK 3B (50 YEAR LEVEL OF PROTECTION) ECONOMIC SUMMARY	C-168

TABLE OF CONTENTS

LIST OF TABLES (CONT)

Table	Description	Page
C-31	BUILDING BLOCK 3C (100 YEAR LEVEL OF PROTECTION) ECONOMIC SUMMARY	C-169
C-32	EFFECTS OF MODIFYING BEATTIES DAM	C-173
C-33	ECONOMIC ANALYSIS OF INTERMEDIATE STAGE ALTERNATIVES	C-178
C-34	BUILDING BLOCKS 7A AND 7B	C-179
C-35	BUILDING BLOCK 13A 100 YEAR LEVEE/FLOODWALL PHYSICAL FEATURES	C-187
C-36	EXISTING RESERVOIRS	C-196
C-37	UNDEVELOPED DETENTION SITES	C-200
C-38	DETENTION BASIN SCREENING DATA	C-203
C-39	DARLINGTON RESERVOIR - PHYSICAL FEATURES	C-214
C-40	DARLINGTON RESERVOIR - HYDROLOGIC EFFECTS	C-215
C-41	CHARLOTTEBURG RESERVOIR - PHYSICAL FEATURES	C-218
C-42	MONKSVILLE AND WANAQUE RESERVOIRS - PHYSICAL FEATURES	C-220
C-43	MONKSVILLE AND WANAQUE RESERVOIRS - HYDROLOGIC EFFECTS	C-221
C-44	LONGWOOD VALLEY - HYDROLOGIC EFFECTS	C-224
C-45	LONGWOOD VALLEY RESERVOIR - PHYSICAL FEATURES	C-224
C-46	WASHINGTON VALLEY RESERVOIR - PHYSICAL FEATURES	C-228
C-47	WASHINGTON VALLEY SITE - HYDROLOGIC EFFECTS	C-229
C-48	MYERS ROAD RESERVOIR - PHYSICAL FEATURES AND HYDROLOGIC EFFECTS	C-231
C-49	CENTRAL BASIN NATURAL STORAGE AREAS OF THE PASSAIC RIVER WATERSHED	C-235
C-50	IMPACT OF PRESERVATION OF CENTRAL BASIN NATURAL STORAGE AREAS	C-239
C-51	COMPARISON OF FLOOD STAGE REDUCTIONS FOR VARIOUS CENTRAL BASIN TUNNEL INLETS	C-252
C-52	INVERTED SIPHON VS. HYDRAULIC GRADE TUNNEL	C-261
C-53	DIVERSION TUNNEL ROUTES	C-264
C-54	SCREENING OF TUNNEL ROUTES	C-268
C-55	LITTLE FALLS TUNNEL BUILDING BLOCK FLOW ANALYSIS 100 YEAR FLOOD EVENT	C-277

TABLE OF CONTENTS

LIST OF TABLES (CONT)

Table	Description	Page
C-56	COMPARISON OF CENTRAL BASIN FLOOD STAGES RESULTING FROM TUNNEL AND CHANNEL IMPROVEMENTS 100 YEAR FLOOD EVENT	C-280
C-57	POMPTON RIVER TUNNEL BUILDING BLOCK FLOW ANALYSIS 100 YEAR FLOOD EVENT	C-281
C-58	DOUBLE INLET TUNNEL BUILDING BLOCK FLOW ANALYSIS 100 YEAR FLOOD EVENT	C-284
C-59	FORMULATION OF TUNNEL BUILDING BLOCKS	C-288
C-60	SUMMARY OF INTERMEDIATE PLAN FORMULATION	C-320
C-61	PLANS 15A AND 15B	C-328
C-62	SUMMARY OF PLAN SCREENING	C-373
C-63	SUMMARY OF PLAN FEATURES BY PLAN FORMULATION REACH - FINAL ARRAY OF INTERMEDIATE PLANS	C-378
C-64	ECONOMIC SUMMARY OF BASIC INTERMEDIATE PLANS	C-380
C-65	RELATIVE RANKING OF PLAN EFFECTS ON SIGNIFICANT ENVIRONMENTAL RESOURCES	C-386
C-66	SUMMARY OF INTERMEDIATE PLAN EVALUATION	C-388
C-67	SUMMARY RANKING OF INTERMEDIATE PLANS	C-389
C-68	INCREMENTAL DEGREE OF PROTECTION - PLAN 16A	C-413
C-69	INCREMENTAL DEGREE OF PROTECTION - DIVERSION TUNNELS	C-416
C-70	INCREMENTAL DEGREE OF PROTECTION - COMPREHENSIVE PLANS 30A AND 30E	C-423
C-71	DETAILED STAGE ALTERNATIVES - OPTIMAL SCALES OF DEVELOPMENT	C-426
C-72	SPUR TUNNEL OPTIMIZATION ANALYSIS	C-429
C-73	FIRST ADDED/LAST ADDED ANALYSES - DUAL INLET DIVERSION TUNNEL ELEMENT	C-434
C-74	ECONOMIC DATA FOR LEVEE/FLOODWALL SYSTEMS INTEGRAL TO DUAL INLET TUNNEL PLAN	C-437
C-75	DUAL INLET TUNNEL PLAN SEPARABLE ELEMENTS INCREMENTAL DEGREE OF PROTECTION TIDAL AND FLUVIAL LEVEE/FLOODWALL SYSTEMS	C-440
C-76	PRESERVATION OF NATURAL STORAGE INCREMENTAL DEGREE OF PROTECTION FIRST ADDED ANALYSIS WITHOUT DUAL INLET TUNNEL PLAN	C-447
C-77	CENTRAL BASIN NATURAL STORAGE IMPLEMENTATION TIMING SENSITIVITY	C-448

TABLE OF CONTENTS

LIST OF TABLES (CONT)

Table	Description	Page
C-78	PRESERVATION OF NATURAL STORAGE ANALYSES WITH AND WITHOUT DUAL INLET TUNNEL PLAN	C-450
C-79	DUAL INLET TUNNEL PLAN CHANNEL MODIFICATION PHYSICAL FEATURES	C-456
C-80	PLAN 30E - DUAL INLET TUNNEL PLAN - LEVEE/ FLOODWALL PHYSICAL FEATURES	C-457
C-81	PLAN 30A - SINGLE INLET TUNNEL PLAN - CHANNEL MODIFICATION PHYSICAL FEATURES	C-463
C-82	PLAN 30A - SINGLE INLET TUNNEL PLAN - LEVEE/ FLOODWALL PHYSICAL FEATURES	C-464
C-83	PLAN 16A - NONSTRUCTURAL MEASURES AND CHANNEL MODIFICATION PHYSICAL FEATURES	C-468
C-84	PLAN 16A - LEVEE/FLOODWALL PHYSICAL FEATURES	C-470
C-85	SUMMARY OF DETAILED PLAN EVALUATION	C-471
C-86	RESPONSE OF DETAILED PLANS TO PROBLEM AND OPPORTUNITY STATEMENTS	C-473
C-87	COMPARATIVE IMPACTS OF ALTERNATIVES	C-479
C-88	EFFECTS OF STAGE III PLANS ON AQUATIC AND WETLAND AREAS, AND MITIGATION, AND OTHER TECHNIQUES TO OFFSET EFFECTS	C-485
C-89	SUMMARY EVALUATION OF DETAILED PLANS	C-497
C-90	DUAL INLET TUNNEL PLAN REAL ESTATE REQUIREMENTS	C-503
C-91	INDUCED DAMAGES	C-509
C-92	PRESERVATION OF NATURAL STORAGE AREAS BY MAJOR WETLAND	C-520
C-93	PRESERVATION OF NATURAL STORAGE AREAS BY COMMUNITY	C-521
C-94	SIGNIFICANT EQ EFFECTS - DUAL INLET PLAN	C-523
C-95	DUAL INLET TUNNEL PLAN - PEAK FLOWS, PEAK STAGES AND VELOCITIES CORRESPONDING TO PEAK STAGES	C-533
C-96	ECONOMIC SUMMARY OF RECOMMENDED PLAN	C-541
C-97	COST APPORTIONMENT OF THE RECOMMENDED PLAN	C-544

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

LIST OF FIGURES

Number	Description	Page
C-1	STUDY AUTHORIZATION	C-3
C-2	BASIN MAP	C-4
C-3	CONGRESSIONAL GUIDANCE	C-6
C-4	INTERIM PROJECT AREAS	C-11
C-5	COUNTIES AND CONGRESSIONAL DISTRICTS	C-18
C-6	BASIN MUNICIPALITIES	C-19
C-7	TOPOGRAPHIC REGIONS	C-20
C-8	PASSAIC RIVER BASIN EXISTING LAND USE	C-32
C-9	PASSAIC RIVER BASIN 1990 LAND USE	C-35
C-10	PASSAIC RIVER BASIN 2040 LAND USE	C-36
C-11	NATURAL STORAGE AREAS OF THE CENTRAL BASIN	C-40
C-12	MAJOR TRANSPORATION ROUTES	C-70
C-13	SUPERFUND SITES IN 100 YEAR FLOODPLAIN AND CERCLA SITES OF CONCERN	C-76
C-14	MAJOR SURFACE WATER SUPPLIES	C-78
C-15	TRIBUTARY FLOOD PROBLEMS	C-107
C-16	PLAN FORMULATION APPROACH	C-122
C-17	DEVELOPMENT OF PLANS - "BUILDING BLOCK" APPROACH	C-124
C-18	PLAN FORMULATION REACHES	C-127
C-19	EXISTING CONDITIONS 100 YEAR, PASSAIC RIVER AT MOLLY ANN'S BROOK	C-130
C-20	DWOPER 100 YEAR HYDROGRAPH - PASSAIC AND POMPTON RIVERS	C-133
C-21	"DWOPER" HYDROGRAPH SIMULATION OF MAY 1968 EVENT	C-135
C-22	EXISTING FORECAST POINTS	C-140
C-23	RIVER FLOOD FORECAST SERVICE	C-141
C-24	FLASH FLOOD WARNING SERVICE	C-143
C-25	BEATTIES DAM	C-171
C-26	BUILDING BLOCK 7 CHANNEL MODIFICATION	C-176
C-27	BUILDING BLOCK 13 LEVEE/FLOODWALL	C-191
C-28	LOCATION OF EXISTING AND POTENTIAL DETENTION BASIN SITES	C-202
C-29	LONGWOOD VALLEY SITE	C-226
C-30	NATURAL STORAGE AREAS LOCATION MAP	C-234

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

LIST OF FIGURES (CONT)

Number	Description	Page
C-31	SIMULATION OF THE 100 YEAR FLOOD PASSAIC RIVER AT MOUTH	C-250
C-32	POTENTIAL DIVERSION INLET AND OUTLET LOCATIONS	C-251
C-33	BUILDING BLOCK 23A INLET AND OUTLET SKETCHES	C-254
C-34	BUILDING BLOCK 23C - INLET AND OUTLET SKETCHES	C-255
C-35	BUILDING BLOCK 23G - INLET AND OUTLET SKETCHES	C-256
C-36	PROFILES OF HYDRAULIC GRADE LINE AND INVERTED SIPHON TUNNELS	C-260
C-37	LITTLE FALLS DIVERSION TUNNEL ROUTES	C-270
C-38	CENTRAL BASIN DIVERSION TUNNEL ROUTES	C-272
C-39	BUILDING BLOCK 23A and 23B	C-290
C-40	BUILDING BLOCK 23A - PLAN AND PROFILE	C-292
C-41	BUILDING BLOCK 23C	C-295
C-42	BUILDING BLOCK 23C - PLAN AND PROFILE (1 OF 2)	C-296
C-43	BUILDING BLOCK 23C - PLAN AND PROFILE (2 OF 2)	C-297
C-44	BUILDING BLOCK 23D	C-302
C-45	BUILDING BLOCK 23E	C-304
C-46	BUILDING BLOCK 23E - PLAN AND PROFILE (1 OF 2)	C-305
C-47	BUILDING BLOCK 23E - PLAN AND PROFILE (2 OF 2)	C-306
C-48	BUILDING BLOCK 23E - POMPTON RIVER INLET AND OUTLET SKETCHES	C-307
C-49	BUILDING BLOCK 23E LITTLE FALLS INLET SKETCH	C-308
C-50	BUILDING BLOCK 23F	C-310
C-51	BUILDING BLOCK 23G	C-312
C-52	BUILDING BLOCK 23G - PLAN AND PROFILE	C-313
C-53	TIDAL BARRIER - BUILDING BLOCK 27	C-318
C-54	PLAN 14A	C-324
C-55	PLAN 15A	C-326
C-56	PLAN 15B	C-327
C-57	PLAN 16A	C-342
C-58	PLAN 16B	C-343
C-59	PLAN 28A and 28B	C-345
C-60	PLAN 28C	C-347
C-61	PLAN 28D	C-348
C-62	PLAN 28E	C-350
C-63	PLAN 28F	C-351
C-64	PLAN 28G	C-352

FLOOD PROTECTION FEASIBILITY

MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

LIST OF FIGURES (CONT)

Number	Description	Page
C-65	PLAN 30A and 30B	C-354
C-66	PLAN 30C	C-356
C-67	PLAN 30D	C-357
C-68	PLAN 30E	C-358
C-69	PLAN 30F	C-360
C-70	PLAN 30G	C-361
C-71	PLAN 33A and 33B	C-363
C-72	PLAN 33C	C-364
C-73	PLAN 33D	C-365
C-74	PLAN 33E	C-366
C-75	PLAN 33F	C-367
C-76	PLAN 33G	C-368
C-77	DETAILED FORMULATION REACHES	C-372
C-78	BEATTIES AND TWO BRIDGES DIVERSION OPTIMIZATION CURVES	C-418
C-79	DUAL AND POMPTON DIVERSION OPTIMIZATION CURVES	C-419
C-80	TUNNEL DIVERSION OPTIMIZATION CURVES	C-420
C-81	BEATTIES INLET COMPREHENSIVE PLAN OPTIMIZATION CURVE	C-424
C-82	DUAL INLET COMPREHENSIVE PLAN OPTIMIZATION CURVE	C-425
C-83	SPUR TUNNEL OPTIMIZATION CURVE	C-430
C-84	ANNUAL COST VS. ACRES ACQUIRED	C-442
C-85	ANNUAL BENEFITS VS. ACRES ACQUIRED	C-443
C-86	NET BENEFITS VS. ACRES ACQUIRED	C-444
C-87	DETAILED PLAN 30E	C-454
C-88	DETAILED PLAN 30A	C-462
C-89	DETAILED PLAN 16A	C-467
C-90	GENERAL PLAN AND INDEX MAP - RECOMMENDED PLAN	C-547
C-91	RECOMMENDED PLAN PASSAIC RIVER STA 0+00 TO STA 125+00	C-548
C-92	RECOMMENDED PLAN PASSAIC RIVER STA 125+00 TO STA 280+00	C-549
C-93	RECOMMENDED PLAN PASSAIC RIVER STA 280+00 TO STA 440+00	C-550
C-94	RECOMMENDED PLAN PASSAIC RIVER STA 440+00 TO STA 620+00	C-551

FLOOD PROTECTION FEASIBILITY

MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

LIST OF FIGURES (CONT)

Number	Description	Page
C-95	RECOMMENDED PLAN PASSAIC RIVER STA 620+00 TO STA 800+00	C-552
C-96	RECOMMENDED PLAN PASSAIC RIVER STA 800+00 TO STA 910+00	C-553
C-97	RECOMMENDED PLAN PASSAIC RIVER STA 910+00 TO STA 1090+00	C-554
C-98	RECOMMENDED PLAN PASSAIC RIVER STA 1090+00 TO STA 1270+00	C-555
C-99	RECOMMENDED PLAN PASSAIC RIVER STA 1270+00 TO STA 1370+00	C-556
C-100	RECOMMENDED PLAN PASSAIC RIVER STA 1370+00 TO STA 1510+00	C-557
C-101	RECOMMENDED PLAN PASSAIC RIVER STA 1510+00 TO STA 1610+00	C-558
C-102	RECOMMENDED PLAN PASSAIC RIVER STA 1610+00 TO STA 1760+00	C-559
C-103	RECOMMENDED PLAN PASSAIC RIVER STA 1760+00 TO STA 1940+00	C-560
C-104	RECOMMENDED PLAN PASSAIC RIVER OVERBANK STA 1760+00 TO STA 2240+00	C-561
C-105	RECOMMENDED PLAN PASSAIC RIVER STA 1940+00 TO STA 2080+00	C-562
C-106	RECOMMENDED PLAN PASSAIC RIVER STA 2080+00 TO STA 2240+00	C-563
C-107	RECOMMENDED PLAN PASSAIC RIVER STA 2240+00 TO STA 2420+00	C-564
C-108	RECOMMENDED PLAN PASSAIC RIVER STA 2420+00 TO STA 2580+00	C-565
C-109	RECOMMENDED PLAN PASSAIC RIVER STA 2580+00 TO STA 2760+00	C-566
C-110	RECOMMENDED PLAN PASSAIC RIVER STA 2760+00 TO STA 2900+00	C-567
C-111	RECOMMENDED PLAN PASSAIC RIVER STA 2900+00 TO STA 3080+00	C-568
C-112	RECOMMENDED PLAN POMPTON RIVER STA 0+00 TO STA 180+00	C-569

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

TABLE OF CONTENTS

LIST OF FIGURES (CONT)

Number	Description	Page
C-113	RECOMMENDED PLAN POMPTON RIVER STA 180+00 TO STA 357+35	C-570
C-114	RECOMMENDED PLAN PEQUANNOCK RIVER STA 0+00 TO STA 170+55	C-571
C-115	RECOMMENDED PLAN WANAQUE RIVER STA 0+00 TO STA 92+65	C-572
C-116	RECOMMENDED PLAN RAMAPO RIVER STA 0+00 TO STA 102+45	C-573
C-117	RECOMMENDED PLAN ROCKAWAY RIVER STA 0+00 TO STA 150+00	C-574
C-118	RECOMMENDED PLAN ROCKAWAY RIVER STA 150+00 TO STA 308+0	C-575
C-119	RECOMMENDED PLAN DEEPAVAAL BROOK STA 0+00 TO STA 100+00	C-576
C-120	RECOMMENDED PLAN DEEPAVAAL BROOK STA 100+00 TO STA 182+50	C-577
C-121	RECOMMENDED PLAN WHIPPANY RIVER STA 0+00 TO STA 180+00	C-578
C-122	RECOMMENDED PLAN WHIPPANY RIVER STA 180+00 TO STA 270+00	C-579
C-123	39 FT. POMPTON RIVER TO PASSAIC RIVER TUNNEL-PLAN AND PROFILE (1 OF 2)	C-580
C-124	39 FT. POMPTON RIVER TO PASSAIC RIVER TUNNEL, 22FT. SPUR TUNNEL-PLAN AND PROFILE (2 OF 2)	C-581
C-125	39 FT. POMPTON RIVER TO PASSAIC RIVER TUNNEL-INLET AND OUTLET SKETCHES	C-582
C-126	22 FT. SPUR TUNNEL - INLET, JUNCTION DETAILS	C-583
C-127	GREAT PIECE MEADOWS WEIR DETAILS	C-584
C-128	NATURAL STORAGE AREAS - BOG & VLY MEADOWS	C-585
C-129	NATURAL STORAGE AREAS - LOWER POMPTON VALLEY	C-586
C-130	NATURAL STORAGE AREAS - GREAT PIECE MEADOWS	C-587
C-131	NATURAL STORAGE AREAS - GREAT PIECE MEADOWS	C-588
C-132	NATURAL STORAGE AREAS - HATFIELD SWAMP	C-589
C-133	NATURAL STORAGE AREAS - TROY MEADOWS	C-590
C-134	NATURAL STORAGE AREAS - BLACK MEADOWS	C-591
C-135	NATURAL STORAGE AREAS - HATFIELD SWAMP SOUTH	C-592
C-136	NATURAL STORAGE AREAS - CANOE BROOK	C-593

2/

FLOOD PROTECTION FEASIBILITY
MAIN STEM PASSAIC RIVER

APPENDIX C - PLAN FORMULATION

SECTION 1 - INTRODUCTION

GENERAL

The formulation portion of this report involved identifying and screening the problems and needs of the Passaic River Basin; the translation of needs into problem and opportunity statements specific to this study; the development of a broad range of water resource management alternatives to address these problem statements; the screening, assessment and evaluation of these alternatives to determine which alternatives warranted more detailed study; the development and analysis of detailed plans; and the selection of the recommended plan.

ORGANIZATION

In the interest of clarity and organization, the formulation portion of this report is presented in 10 sections in this appendix:

Section 1 - Introduction

Section 2 - Without Project Conditions

Section 3 - Problem Identification

Section 4 - Plan Formulation Approach

Section 5 - Plan Formulation Results - Intermediate Stage

Section 6 - Evaluation and Screening of Intermediate Stage Alternatives

Section 7 - Plan Formulation - Detailed Stage

Section 8 - Optimization

Section 9 - Evaluation and Comparison of Detailed Alternatives

Section 10 - Selected Plan

This introductory section, presents background data regarding the authorization, classification, purpose and scope of the Passaic River Basin Phase I Study, discusses prior Corps' water resource reports and includes a summary of the basin's topography.

AUTHORIZATION

The Passaic River Study, a Phase I Advanced Engineering and Design Study, was accomplished under the authority of Section 101(a) of the Water Resources Development Act of 1976 (Public Law 94-587). Figure C-1 is an extract of the Phase I authorizing legislation. A map of the watershed is presented in Figure C-2.

STUDY CLASSIFICATION

The Passaic River Study is classified as a "Reformulation Phase I Study" based on the need for a review of alternate solutions stemming from the following: policy and criteria changes which have revised planning requirements and necessitate a reevaluation of benefits and costs; the need for an evaluation of the current needs and problems of the study area; changes in the physical conditions of the watershed; the need to appraise current public attitudes and update agency coordination; and in light of Congressional guidance specific to this study as discussed below.

PURPOSE

The purpose of the Passaic River Basin Study was to investigate the economic and environmental feasibility and the public acceptability of providing water management and flood control for the basin, and to recommend to the Congress the degree to which Corps and Federal participation in such plans is warranted. The Phase I Study was being accomplished in accordance with Corps' guidelines and procedures established for legislative Phase I AE&D studies involving reformulation of plans. These procedures and guidelines were established consistent with the intent of Congress in adopting a two-step authorization procedure for projects in Section 1 of the Water Resources Development Act of 1974 (Public Law 93-251).

The Passaic River Study began in October 1977 (Fiscal Year 78) and has continued through Fiscal Year 86. The purpose of this documentation is to present an evaluation of the problems and needs of the Passaic River Basin, to provide a description of the flood damage reduction plan formulation results for the mainstream Passaic River and to identify specific details of the selected plan. Plan development included consideration of the economic and environmental feasibility and the public acceptability of providing water management and flood control for the Passaic River Basin.

Study Authorization
Extract from Public Law 94-587

Public Law 94-587
94th Congress

An Act

Authorizing the construction, repair, and preservation of certain public works on rivers and harbors for navigation, flood control, and for other purposes.

Oct. 22, 1976
[S. 3823]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

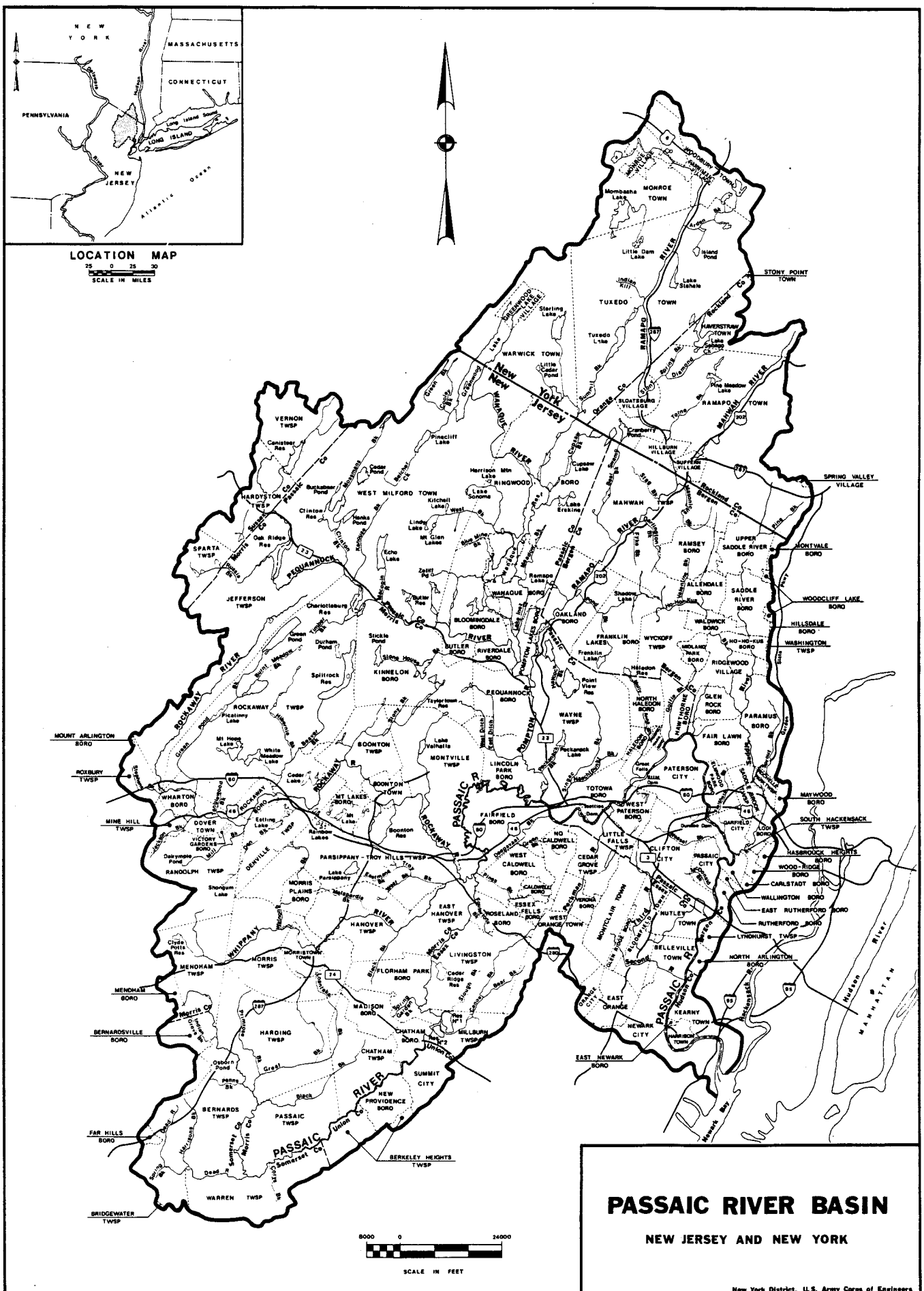
Water Resources Development Act of 1976.

SECTION 101. (a) The Secretary of the Army, acting through the Chief of Engineers, is hereby authorized to undertake the phase I design memorandum stage of advanced engineering and design of the following water resources development projects, substantially in accordance with, and subject to the conditions recommended by the Chief of Engineers in, the reports hereinafter designated.

PASSAIC RIVER BASIN

The project for flood control in the Passaic River Basin, New Jersey and New York: Report of the Chief of Engineers dated February 18, 1976, at an estimated cost of $12,000,000.

FIGURE C-1


LOCATION MAP
SCALE IN MILES
SCALE IN FEET
PASSAIC RIVER BASIN
NEW JERSEY AND NEW YORK
New York District, U.S. Army Corps of Engineers

C-4

FIGURE C-2

CONGRESSIONAL GUIDANCE

The Passaic River Basin Study is also being conducted under Congressional guidelines included in the U.S. House of Representatives Report No. 94-1702, the House Public Works and Transportation Committee's 27 September 1976 report on the 1976 Water Resources Development Act (See Figure C-3).

In House Report 94-1702, the Congress directed "...the reformulation of the plan for water management and flood control for the entire Passaic River Basin". The report stated: "Local opposition to any plan which relies upon extensive use of dikes, dams and levees such as those proposed in previous survey reports mandates that the following alternatives or any combination thereof shall be the only ones surveyed and considered:

1. A full range of nonstructural flood control alternatives to include land acquisition, floodplain mapping, floodproofing, developing early warning systems and relocation of buildings.

2. A tunnel diversion plan.

3. A system of tunnels addressing the needs of the entire basin.

4. Plans that combine local protection works where locally acceptable and nonstructural solutions including improvements to stream carrying capacity in accordance with different needs in the Lower Basin and in the Central Basin.

5. Evaluation of fulfilling water supply objectives together with flood control.

6. Aquifer recharge and underground storage.

7. Reservoir management in the headwaters."

Congress also directed that the Phase 1 Study include consideration of interim flood protection measures, and that recommendations as to such measures be made as soon as they are formulated, prior to completion of the Phase 1 Study.

SCOPE

The scope and level of detail employed in this plan formulation documentation is consistent with the requirements set forth in the Planning Guidance Notebook. The plan formulation results are based on detailed topographic mapping of

CONGRESSIONAL GUIDANCE

Extract from House Report 94-1702

PASSAIC RIVER BASIN, NEW JERSEY AND NEW YORK

The Phase I study shall include consideration of interim flood protection measures, and recommendations as to such measures are to be made to the Committee as soon as they are formulated, prior to completion of the Phase I study. Implementation of interim measures consistent with Public Law 92-500 and the National Environmental Policy Act, shall begin as soon as authorized and funded, and shall not await completion of the Phase I study.

Controversy revolves around a concern that conclusions reached by the Chief of Engineers Report of February 18, 1976, will be given priority to the exclusion of equal consideration of alternatives, and other objectives, including water management and attainment of water quality goals, pursuant to P.L. 92-500. Controversy over construction of the project emanates from many communities in Morris and Essex Counties that stand to lose substantial portions of their land to structural solutions; from conservation interests who seek non-structural solutions; from those who reject dams, dikes, and levees in their communities; from those who believe other forms of construction such as a diversion tunnel or a system of tunnels addressing the needs of the entire basin should be reevaluated; from those who believe water supply objectives should be met together with flood control.

In the Water Resources Development Act of 1974, the Congress adopted a new two-step authorization procedure for projects such as the Passaic River Basin project. The reasons for this new procedure, and a description of the items to be included in Phase I advanced engineering and design, are set forth in House Report 93-541 which accompanied H.R. 10203, and repeated in the introductory material in this report. These requirements and provisions apply to the Phase I study of the Passaic River Basin project.

The Committee directs the reformulation of the plan for water management and flood control for the entire Passaic River Basin. Said plan shall include a new environmental impact statement which is the subject of public hearings and formulation of a final environmental impact statement to be submitted to the Council on Environmental Quality.

Local opposition to any plan which relies upon extensive use of dikes, dams and levees such as those proposed in previous survey reports mandates that the following alternatives or any combination thereof shall be the only ones surveyed and considered:

1. A full range of non-structural flood control alternatives to include land acquisition, flood plain mapping, flood proofing, developing early warning systems and relocation of buildings.
2. A tunnel diversion plan.
3. A system of tunnels addressing the needs of the entire basin.
4. Plans that combine local protection works where locally acceptable and non-structural solutions including improvements to stream carrying capacity in accordance with difference needs in the Lower Basin and in the Central Basin.
5. Evaluation of fulfilling water supply objectives together with flood control.
6. Aquifer recharge and undergrounds storage.
7. Reservoir management in the headwaters.

Coordination with Federal, State and local agencies particularly the New Jersey Department of Environmental Protection in its efforts on flood control and management of the total water resource cycle including water supply and water quality, shall be carried out by the Corps of Engineers.

FIGURE C-3

approximately 105 square miles of floodplain, damage surveys of a representative sampling of the structures in the floodplain, a hydrologic model for the entire watershed, hydraulic water surface profiles from the mouth of the Passaic River at Newark Bay upstream to the Dead River in Warren Township, environmental studies for the watershed, real estate studies along the entire main stem Passaic River and major tributaries, foundations and materials data, construction cost estimates for specific flood control measures, and input received via the Public Involvement and Citizen Participation Program.

The plan formulation process, which has been completed, was iterative, with the level of detail increasing to reach the appropriate decision points during the course of the study. Early stages emphasized identifying and analyzing the full range of measures for addressing the problem and opportunity statements for the study. The formulation of plans for the Passaic River Basin was based on the "Building Block" approach in order to facilitate the plan formulation process. These basic management measures ("Building Blocks") as presented in Section 4 of this document act as major elements of plans which are responsive to the Congressional guidance for this study.

During the final stage in the planning process, studies focused on the evaluation and screening of the intermediate stage alternatives to identify those plans warranting detailed analysis, the development of detailed plans that more fully address the problem and opportunity statements, and the selection of the most desirable plan of protection.

The focus of this appendix is on the flood damage reduction need along the main stem Passaic River, including backwater along a number of tributary streams, since this is the primary objective of the study. Other water resource needs, such as water supply, which are also addressed as part of this study, are discussed in Section 3 of this appendix.

Separate studies have also been conducted for tributary flood problems and basin wide temporary measures which were previously identified as having potential as interim projects in accordance with Congressional guidance. The results of these studies are briefly summarized later in this section, while separate feasibility reports were prepared for those areas for which interim flood protection was found to be feasible. A discussion of report findings for the designated interim project areas is contained in the section on current study reports; however, plan formulation studies for these interim areas are not treated in this report since they were determined to be independent from the main stem study.

PAST CORPS OF ENGINEERS PLANNING

Under the River and Harbor Act of 10 June 1872, a navigation project in the Passaic River was authorized. This report published as Senate Executive Document No. 35, 42nd Congress, 2nd Session, recommended a channel varying from 50 to 200 feet wide and from 6 to 7-1/2 feet deep, from the Center Street Bridge in Newark to the Gregory Avenue Bridge in Passaic. Subsequently, several modifications have been made to this project.

Early Corps of Engineers flood control planning in the Passaic Basin included a preliminary examination report, which was completed by the New York District Engineer in December 1936. Based on the review of the preliminary report, a survey report was authorized and subsequently submitted to the Chief of Engineers in March 1939. Local interests in the Passaic Basin consumed considerable time in reviewing the report in attempting to resolve their differences, and in April 1945 it was returned to the District Engineer for updating of changed conditions. In October 1948, a revised report recommending favorable action on a modified plan was submitted. This report was returned to the District Engineer in March 1950 for further study because of the divergent views of local interests. In June 1962, the District Engineer submitted an updated and revised draft report recommending favorable action on an alternative plan. This draft report was also returned to the District Engineer in October 1962 for further study because of the divergent view of local interests and the apparent economic deficiencies of the recommended plans.

The most recent survey report prepared by the Corps of Engineers was issued in June 1972 and amended by a supplemental report in April 1973. The 1973 report provided the basis for authorization of this current Phase I Study by recommending a plan for the Passaic River Basin. This plan included a dry detention reservoir at Two Bridges, N.J., for flood control and recreation; diversions, channel modifications and local protection works on the Passaic and Pompton Rivers; and tributary local protection works on Molly Ann's Brook at Haledon, N.J.; Saddle River at Lodi, N.J.; Ramapo River at Oakland, N.J.; Mahwah River at Suffern, N.Y.; Nakoma Brook at Sloatsburg, N.Y.; and Rockaway River at Denville, N.J.

Subsequent to the completion of the supplemental report, development occurred on the site of the proposed dry detention reservoir. The large costs associated with the acquisition of these residential, commercial and industrial properties would result in a highly uneconomical plan. An alternative to the

acquisitions would be to extend the lengths and increase the heights of the proposed levees and floodwalls, along with providing additional interior flood control facilities, in order to protect existing land uses from the ponded waters of the detention reservoir during periods of flooding. However, this alternative was also determined to be prohibitively expensive, resulting in an economically infeasible plan. Furthermore, locals are opposed to the extensive dikes, dams and levees included in this plan for the main stem Passaic River. Therefore, this plan was eliminated from further consideration as part of the current study.

CURRENT STUDY REPORTS

The Plan of Study for this current Phase I AE&D Reformulation Study for the Passaic River Basin was completed in July 1979.

A Plan of Action Report which presented the status and formulation approach for achieving compliance with the Congressional mandate for consideration of interim measures was completed in January 1980 in conjunction with FY 81 budget testimony data. This report outlined the study and implementation responsibilities for potential interim flood damage reduction measures in the Passaic River Basin. Coordination of the report with the basin States (New York and New Jersey) was completed, and agreement reached regarding the division of study and implementation responsibilities between the Corps and State/local interests.

A Plan Formulation Status Report which summarized existing conditions studies and plan formulation results to date was completed in April 1982. An Intermediate Stage Report, which was completed in June 1983, documented the analysis of a full range of flood damage reduction measures for the main stem Passaic River. Subsequent to the coordination of this report with State and local interests, the State of New Jersey agreed to act as the non-Federal sponsor for a Passaic River Basin flood control project. As such, the State of New Jersey, in coordination with the affected communities, selected a plan for detailed study by the Corps. In January 1985 a Plan Formulation Rationale Report, which summarized the rationale used for evaluating and screening intermediate stage plans and identified those alternatives selected for detailed analysis, was completed. The findings contained in these reports were used as the basis for more recent plan formulation studies which are documented herein.

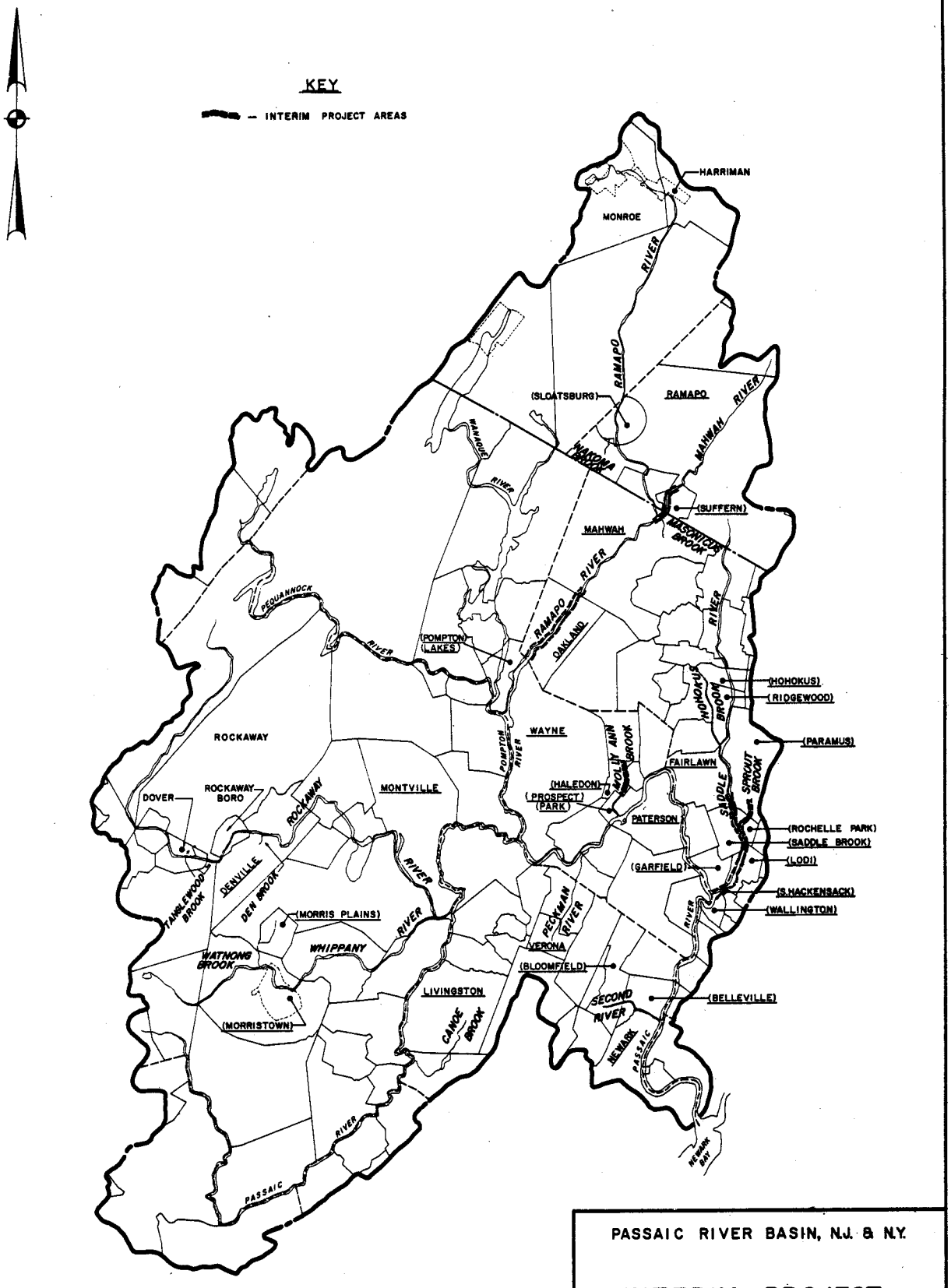
In September 1985, the Passaic River Basin Plan of Study was supplemented with documentation of the study approaches to be undertaken for the investigations remaining under the Passaic River Basin authority. These investigations include analyses of the flood problem in the Upper Rockaway River Subbasin and the Channel Clearing Study for the Passaic River and tributaries.

An Intermediate Stage Report, which documented the feasibility of channel clearing measures along the Passaic River and tributaries, was completed in February 1987. Channel clearing alternatives were approved by the North Atlantic Division in March 1987 as a partial solution interim to a basin-wide problem. Detailed planning studies for channel clearing measures are underway, and are scheduled for completion in FY88.

An Intermediate Stage Report for the Upper Rockaway River, which presented an array of economically feasible flood damage reduction plans, was completed in May 1987. The Upper Rockaway River Subbasin was approved as an interim project area by the North Atlantic Division in June 1987. Detailed planning studies for the Upper Rockaway River are currently ongoing and are scheduled for completion in FY88.

The findings for the designated interim project areas, for which feasibility studies have been completed, are summarized in the following paragraphs and the location of each area is shown on Figure C-4. In each case, the recommended plan is an effective solution to the water resources problems and needs in the project area and does not impact on or preclude an overall basin plan nor cause any significant adverse impact to other areas in the basin. Each project described below was authorized for construction under the Water Resources Development Act of 1986.

A Feasibility Report and an Environmental Impact Statement (EIS) for the Ramapo and Mahwah Rivers was completed in November 1983 under the Passaic River Study authority. The report recommendations were concurred in by the Board of Engineers for Rivers and Harbors in March 1984 and by the Chief of Engineers in November 1984. The report was submitted to Congress in January 1987. Continuation of Planning and Engineering studies were completed by the New York District in August 1987 for the recommended plan which consists of earthen channel modifications along the Ramapo and Mahwah Rivers, in addition to retaining walls along the Mahwah River. This plan has an authorized cost of $6,260,000.



PASSAIC RIVER BASIN, N.J. & N.Y.

INTERIM PROJECT AREAS

FIGURE C-4

A Feasibility Report and EIS for the Ramapo River at Oakland, Pompton Lakes and Wayne was completed in September 1984. This report, which was approved by the Board of Engineers for Rivers and Harbors in March 1985 and by the Chief of Engineers in January 1986, has been submitted to the Secretary of the Army for further processing. The plan recommended in this report consists of 6,800 feet of channel modification along the Ramapo River in conjunction with modifications to Pompton Lake Dam. The authorized cost of this plan is $6,450,000. Preconstruction engineering and design began in FY88.

The Feasibility Report and EIS for Molly Ann's Brook at Haledon, Prospect Park and Paterson, N.J. was completed in November 1984. The report recommendations were concurred in by the Board of Engineers for Rivers and Harbors in March 1985 and by the Chief of Engineers in December 1985. The recommended plan consists of 2.8 miles of channel modification along Molly Ann's Brook, the replacement of 10 bridges over the brook, and the removal of one building under which the brook flows through undersized culverts. The authorized cost of this plan is $21,600,000. The final report has been submitted to the Secretary of the Army for further processing. Preconstruction engineering and design is scheduled to begin in FY89.

The Feasibility Report and EIS for the Lower Saddle River Subbasin, Bergen County, N.J. was completed in August 1984 and was approved by the Board of Engineers and Rivers for Harbors in March 1985. The Chief of Engineers report was completed in January 1986 and the final report was then submitted to the Secretary of the Army for further processing. The recommended plan consists of 6.9 miles of channel modification along the Saddle River and Sprout Brook at an estimated cost of $36,500,000 at October 1985 price levels. Preconstruction engineering and design began in FY88.

RECENT SMALL PROJECT REPORTS

An Intermediate Stage Report under a separate study authority was completed for the Third River Basin in March 1980. An array of economically feasible flood damage reduction plans were presented. However, the studies indicated a possible plan formulation link with the Passaic River Study in relation to Passaic diversion tunnel plans. Therefore, the Third River investigation was incorporated into the Passaic River Study. Subsequent detailed studies ruled out the formulation link, and confirmed that the cost of Third River flood protection would be under the small project cost limit. The Third River investigations are continuing and project recommendations will be submitted under the Section 205 Small Project Authority.

The enhancement of the Passaic River's Flood Emergency Preparedness System was studied as part of the overall Passaic River Basin Phase 1 Study. However, for project implementation the Small Project Authority (Section 205 of the 1948 Flood Control Act) was selected over the Passaic River Phase 1 Authority, because of the low Federal first cost of the recommended plan and because the significantly shorter implementation period under the Small Project Program was more responsive to the need to mitigate the flooding threat in the Passaic River watershed.

The recommended plan included the establishment of local self-help programs, increased rain and stream gage density and automation, local flash flood warning system, improved computer software and hardware facilities, and enhancement of local response programs. The Detailed Project report for the preparedness system was approved by the Chief of Engineers in September 1984 and Plans and Specifications were subsequently completed by the New York District. The Secretary of the Army approved the recommended plan for construction and signed a Local Cooperation Agreement with the State of New Jersey on 30 October 1986. Installation began in 1987 and is to be completed in March 1988.

A Detailed Project report, which examined flood damage reduction measures along the Ramapo River at the Village of Monroe, N.Y., was completed in November 1985. The recommended plan consists of clearing and snagging the Ramapo River for a distance of 5,030 feet and removing a constriction on the right bank of the river. Plans and Specifications were initiated by the New York District in April 1986 and are expected to be submitted to the Office of the Chief of Engineers in FY88.

A favorable Expanded Reconnaissance Report for Emergency Streambank Erosion Control along Ho-Ho-Kus Brook at Waldwick, N.J. was completed on 31 October 1980 under Section 14 of the Flood Control Act of 1946, as amended. The project, which consisted of the construction of 84 feet of concrete retaining wall and the placement of 150 feet of riprap along the right bank of Ho-Ho-Kus Brook behind the Waldwick Middle School, was approved by the Chief of Engineers in June 1980. Plans and Specifications were approved by the North Atlantic Division in February 1981. Construction was completed by New York District in December 1981.

Unfavorable Detailed Project reports were completed for flood problems along the Ramapo River at Suffern, N.Y. (November 1979), and the Peckman River at Little Falls, West Paterson and Cedar Grove, N.J. (September 1981). Small local protection projects were not economically justified at these areas.

Unfavorable Reconnaissance Reports were completed under the authority of Section 205 of the 1948 Flood Control Act, as amended, for Canoe Brook at Livingston, N.J. in December 1980 and for Belchers Creek at West Milford, N.J. in February 1981. These reports concluded that there was no Federal interest in providing flood damage reduction measures to these areas.

REPORTS BY OTHERS

Several hundred reports on the development of water resources in the Passaic River Basin have been completed. These reports date back to Colonial times when the main emphasis of the studies was for irrigation of the Central Basin, and flood protection and navigation in the Lower Passaic River. The most comprehensive of these reports, published in 1931 by the New Jersey State Water Policy Commission, considered several alternative plans and made an inventory of the total flood control benefits which might be delivered within the Passaic River Basin from each plan.

WATER RESOURCES DEVELOPMENT ACT OF 1986

The Water Resources Development Act of 1986 (Public Law 99-662) contains several provisions which impact on the Passaic River Basin. PL 99-662 established revised cost-sharing requirements which are applicable to the plans developed as part of this study. The cost estimates presented later in this report conform to these requirements.

The Water Resources Development Act of 1986 also authorized several projects within the Passaic River Basin. These authorized projects, which are listed in Table C-1, would provide localized tributary or short-term flood protection, whereas the plans formulated in this study would provide long-term, Passaic River main stem flood protection. The authorized projects are discussed in pertinent sections of this report.

BASIN DESCRIPTION

The Passaic River Basin is a 935 square mile watershed, located in the States of New Jersey and New York in the Greater New York City Metropolitan Area. The Basin is roughly elliptical in shape, 26 miles wide and 56 miles in length, and encompasses 787 square miles (84%) in New Jersey, and 148 square miles (16%) in New York. The Basin has a wide variety of features ranging from heavily wooded, mountainous rural areas, to agricultural and suburban lowlands relieved by rolling hills, to densely populated, highly industrialized urban concentrations. It is located within a 35 mile radius of New York City.

TABLE C-1
WATER RESOURCES DEVELOPMENT ACT OF 1986
AUTHORIZATIONS FOR THE PASSAIC RIVER BASIN

SECTION		
401a	Flood Control Construction:	
	o Molly Ann's Brook	Tributary protection
	o Lower Saddle River	Tributary protection
	o Ramapo and Mahwah Rivers	Tributary protection
	o Ramapo River at Oakland	Tributary protection
401c	Flood Control Planning Engineering & Design:	
	o Upper Rockaway River Basin	Tributary protection
	o Third River	Tributary protection
	o Nakoma Brook at Sloatsburg	Tributary protection
602	Lakes Program:	
	o Removal of silt and stumps from Greenwood Lake and Belchers Creek	Tributary protection and lake restoration
603	Streambank Erosion Control:	
	o Bank stabilization and development, operation and maintenance of a recreation and greenbelt area along east bank Passaic River from Dundee Dam to Kearny Point	Localized, streambank protection and recreational development
607	Channel Clearing:	
	o Snagging, Clearing and channel rectification along Passaic River and tributaries	Short-term, interim and localized protection
	o Beatties dam flood control project	
914	Urban and Rural Flood Control	
	o Twenty-two tributaries potentially affected by new Federal interest criteria being developed by the Secretary of the Army	Tributary protection
1148	Acquisition of Floodprone Residential Structures:	
	o Passaic River Basin	Localized, interim protection

Occupying about 10.5% of the area of New Jersey, the Passaic Basin contains the greater portions of Bergen, Essex, Morris and Passaic Counties, and lesser portions of Hudson, Somerset, Sussex and Union Counties. Based on the 1980 Census, it is estimated that the basin's population was 2.5 million, roughly one-quarter of the State of New Jersey's total population, including 40% of the population of Newark, the State's largest city, and all of Paterson, the third largest city.

In New York State, the Basin occupies parts of Orange and Rockland Counties, and had an estimated 1980 population of more than 52,000.

The main stem Passaic River has its headwaters in Mendham Township, Morris County, N.J. and empties into Newark Bay at Newark, N.J. Its major tributaries include the Third River, Saddle River, Pompton River, Ramapo River, Pequannock River, Wanaque River, Rockaway River and the Whippany River. Figure C-2 is a map of the Passaic River Basin.

POLITICAL DIVISIONS

There are many levels of political jurisdiction which have an impact on water resources planning in the Passaic River Basin. The Basin includes portions of two states, 10 counties, and encompasses 132 municipalities. It comes under the jurisdiction of eight United States Congressional Districts in New Jersey and one in New York. Table C-2 lists the municipalities, and Figures C-5 and C-6 show these political boundaries.

TOPOGRAPHY

The Passaic Basin is topographically divided into three distinct regions, the Lower Valley, the Central Basin and the Highland Area, as shown in Figure C-7. (It is noted that the study area is also separated into three plan formulation reaches, Lower Valley, Central Passaic and Upper Passaic, as shown on Figure C-18. The Upper Passaic formulation reach lies within the Central Basin topographic region.)

Lower Valley. The Lower Valley, in the southeastern portion of the watershed, encompasses the most densely populated and heavily industrialized area of the basin. It contains an area of 173 square miles and extends from the Ramapo Fault in the north to the mouth of the Passaic River in Newark Bay. It is defined by the First Watchung Mountain and Campgaw Mountain to the west and the Hackensack River watershed to the east. The Lower Valley is part of the Triassic Lowlands Section of the Piedmont Physiographic Province.

TABLE C-2
PASSAIC RIVER BASIN MUNICIPALITIES

NEW JERSEY

BERGEN COUNTY

1. Allendale Borough
2. Carlstadt Borough
3. East Rutherford Borough
4. Elmwood Park Borough
5. Fair Lawn Borough
6. Franklin Lakes Borough
7. Garfield City
8. Glen Rock Borough
9. Hasbrouck Heights Borough
10. Hillsdale Borough
11. Hohokus Borough
12. Lodi Borough
13. Lyndhurst Township
14. Mahwah Township
15. Maywood Borough
16. Midland Park Borough
17. Montvale Borough
18. North Arlington Borough
19. Oakland Borough
20. Paramus Borough
21. Ramsey Borough
22. Ridgewood Village
23. Rochelle Park Township
24. Rutherford Borough
25. Saddle Brook Township
26. Saddle River Borough
27. South Hackensack Township
28. Upper Saddle River Borough
29. Waldwick Borough
30. Wallington Borough
31. Washington Township
32. Woodcliff Lake Borough
33. Woodridge Borough
34. Wyckoff Township

ESSEX COUNTY

35. Belleville Town
36. Bloomfield Town
37. Caldwell Borough
38. Cedar Grove Township
39. East Orange City
40. Essex Falls Borough
41. Fairfield Borough
42. Glen Ridge Borough
43. Livingston Township
44. Millburn Township
45. Montclair Township
46. Newark City
47. North Caldwell Borough
48. Nutley Town
49. Orange City
50. Roseland Borough
51. Verona Borough
52. West Caldwell Borough
53. West Orange Town

HUDSON COUNTY

54. East Newark Borough
55. Harrison Town
56. Kearny Town

MORRIS COUNTY

57. Boonton Town
58. Boonton Township
59. Butler Borough

MORRIS COUNTY

68. Chatham Borough
69. Chatham Township
70. Denville Township
71. Dover Town
72. East Hanover Township
73. Florham Park Borough
74. Hanover Township
75. Harding Township
76. Jefferson Township
77. Kinnelon Borough
78. Lincoln Park Borough
79. Madison Borough
80. Mendham Borough
81. Mendham Township
82. Mine Hill Township
83. Montville Township
84. Morris Township
85. Morris Plains Borough
86. Morristown Town
87. Mountain Lakes Borough
88. Mount Arlington Borough
89. Parsippany-Troy Hills Township
90. Passaic Township
91. Pequannock Township
92. Randolph Township
93. Riverdale Borough
94. Rockaway Borough
95. Rockaway Township
96. Roxbury Township
97. Victory Gardens Borough
98. Wharton Borough

PASSAIC COUNTY

99. Bloomingdale Borough
100. Clifton City
101. Haledon Borough
102. Hawthorne Borough
103. Little Falls Township
104. North Haledon Borough
105. Passaic City
106. Paterson City
107. Pompton Lakes Borough
108. Prospect Park Borough
109. Ringwood Borough
110. Totowa Borough
111. Wanaque Borough
112. Wayne Township
113. West Milford Town
114. West Paterson Borough

SOMERSET COUNTY

115. Bernards Township
116. Bernardsville Borough
117. Bridgewater Township
118. Far Hills Borough
119. Warren Township

SUSSEX COUNTY

120. Hardyston Township
121. Sparta Township
122. Vernon Township

UNION COUNTY

123. Berkeley Heights Township
124. New Providence Borough
125. Summit City

NEW YORK

ORANGE COUNTY

60. Greenwood Lake Village
61. Harriman Village
62. Monroe Town
63. Monroe Village
64. Tuxedo Town
65. Tuxedo Park Village
66. Warwick Town
67. Woodbury Town

ROCKLAND COUNTY

126. Haverstraw Town
127. Hillburn Village
128. Ramapo Town
129. Sloatsburg Village
130. Spring Valley Village
131. Stony Point
132. Suffern Village

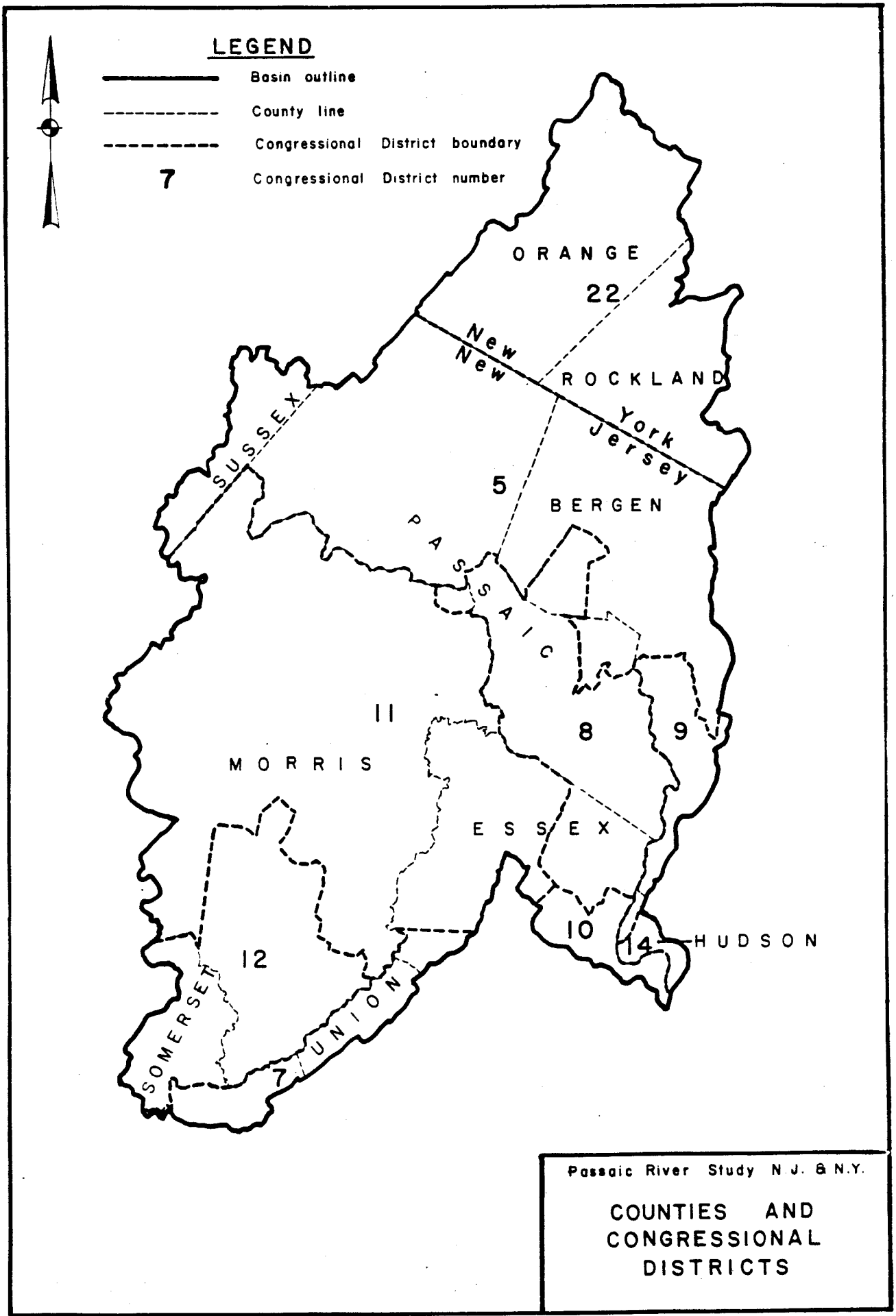
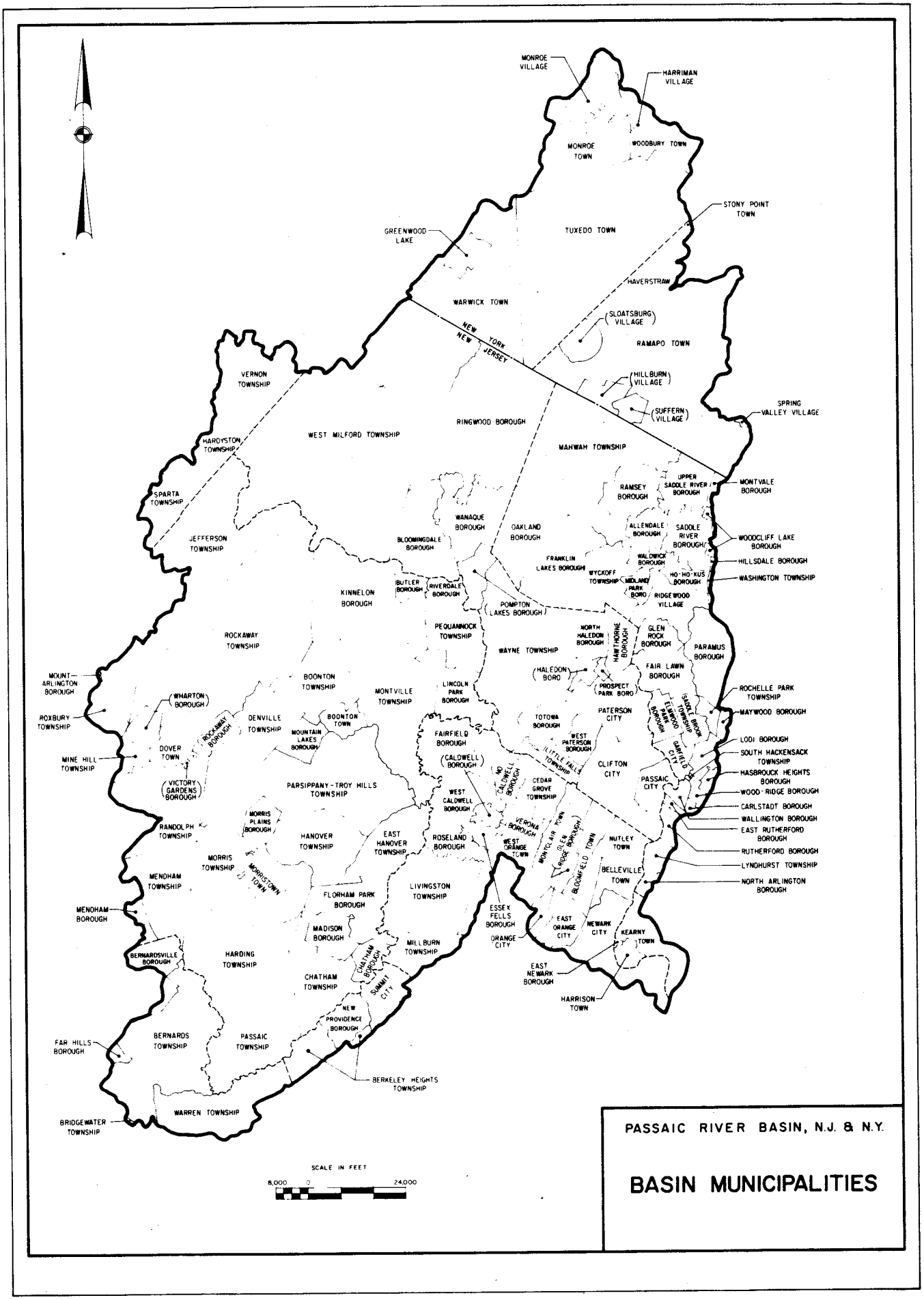

LEGEND
Basin outline
County line
Congressional District boundary
7
Congressional District number
ORANGE
22
ROCKLAND
New York
New Jersey
SUSSEX
5
BERGEN
PASSAIC
11
8
9
MORRIS
ESSEX
10
14
HUDSON
12
SOMERSET
UNION
7
Passaic River Study N.J. & N.Y.
COUNTIES AND CONGRESSIONAL DISTRICTS

FIGURE C-5



PASSAIC RIVER BASIN, N.J. & N.Y.

BASIN MUNICIPALITIES

FIGURE C-6

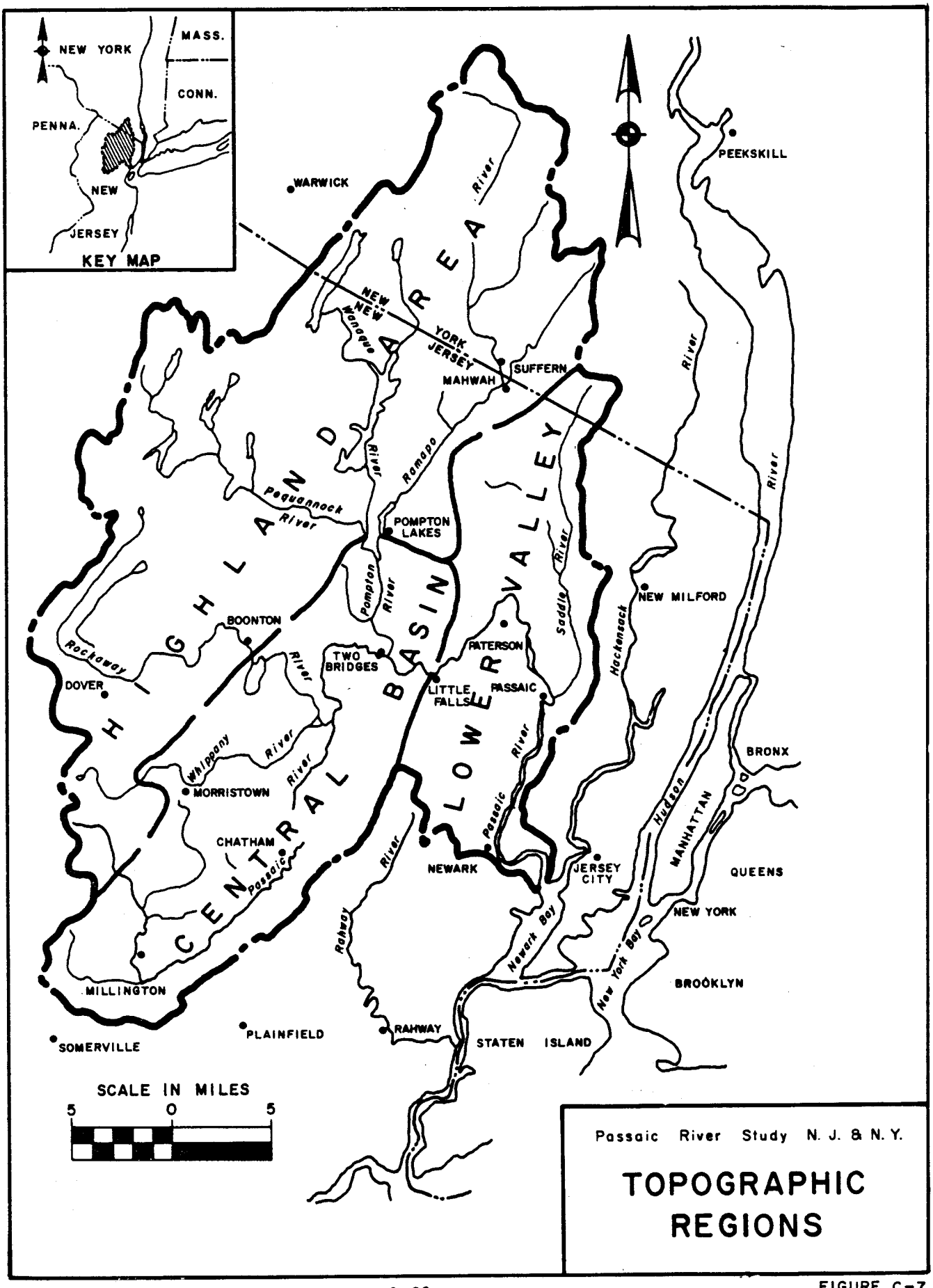

NEW YORK
MASS.
CONN.
PENNA.
NEW
JERSEY
KEY MAP
WARWICK
PEEKSKILL
NEW YORK
NEW JERSEY
SUFFERN
MAHWAH
POMPTON LAKES
BOONTON
DOVER
TWO BRIDGES
PATERSON
LITTLE FALLS
PASSAIC
NEW MILFORD
MORRISTOWN
CHATHAM
NEWARK
JERSEY CITY
BRONX
QUEENS
NEW YORK
BROOKLYN
MILLINGTON
SOMERVILLE
PLAINFIELD
RAHWAY
STATEN ISLAND
HIGHLAND AREA
CENTRAL BASIN
LOWER VALLEY
Wanaque River
Ramapo River
Pequannock River
Pompton River
Rockaway River
Whippany River
Passaic River
Saddle River
Hackensack River
Hudson River
Rahway River
Newark Bay
New York Bay
MANHATTAN
SCALE IN MILES
5 0 5
Passaic River Study N. J. & N. Y.
TOPOGRAPHIC REGIONS

FIGURE C-7

This roughly rectangular valley, which is about 8 miles wide and 26 miles long, is the result of the glaciation and later erosion of the Triassic sandstones and shales that exist between the underlying Palisades basalts that outcrop along the Hudson River to the east and the overlying basalts at the Watchung Mountain arcs to the west.

Elevation changes are quite modest in the Lower Valley, ranging only from 500 feet mean sea level (MSL) along the western edge to sea level at Newark Bay. This characteristic along with the proximity at this portion of the basin to Newark Bay and the New York Harbor have lent the Lower Valley easy access for urbanization. As such, it contains some of the oldest industrial and residential centers in the basin including Paterson, Passaic, and part of Newark. These communities had a tendency to be developed close to river banks due to the need for water sources for commerce and industry. This has resulted in many structures which are designated as being in floodplain areas.

Central Basin. The 262 square mile Central Basin is approximately 10 miles wide and 30 miles long, and extends in a northeast-southwest direction from south of Darlington Brook at the Ramapo River to the Second Watchung Mountain south of Millington. Located adjacent to and southwest of the Lower Valley, the Central Basin is bordered by the Ramapo fault to the west, First Watchung Mountain to the east as it swings north through Montclair, West Paterson, Hawthorne, and the ridge of Campgaw Mountain also to the east. Like the Lower Valley, the Central Basin is also a part of the Triassic Lowlands Section of the Piedmont Physiographic Province. Together, they form over one-half of the Passaic River watershed.

The landscape is characterized by low rolling hills, flat meadowlands and freshwater swamps. Elevations in the Central Basin vary from about 500 feet MSL along the southwestern rim of the Basin to 160 feet MSL at the northeastern edge. The diverse topography and surficial materials are the result of glacial Lake Passaic, the terminal moraine, the unglaciated areas, and various glacial land forms. Geologically, the Central Basin is the most complex of the three areas in the Passaic Basin.

The middle portion of the Central Basin is topographically low. This was the location of glacial Lake Passaic. The breaching of the eastern rim of the Central Basin by the Passaic River at Little Falls drained glacial Lake Passaic, leaving what is currently a vast area of wetlands covering much of the interior of the Central Basin. The terminal moraine crosses the

Central Basin from the west to southeast and divides the vast area of lakebed soils into two extensive wetland areas, including the Great Swamp to the south and Hatfield Swamp and the Troy, Great Piece, Bog and Vly, Long, and Black Meadows to the north. The total wetland area in the Central Basin is 38 square miles.

Of the three topographic regions in the watershed, the Central Basin is experiencing the most rapid growth in terms of suburban communities, commerce, and light industry. This development has created conditions in the watershed which adversely affect structures located in river floodplains in older communities downstream, as well as in some newer communities which have infringed on river floodplains and natural flood storage areas.

Highland Area. The largest geologic region of the Passaic River watershed is the Highland Area which contains 500 square miles. Approximately 13 miles wide and 38 miles long, this region comprises the north-west hold of the basin. The Highland Area borders both the Central Basin and the Lower Valley to the east along the Ramapo Fault. It is part of the geologically and topographically diverse section of the Reading Prong of the New England Physiographic Province.

The Highland Area is a heavily wooded, mountainous region characterized by a series of parallel northeast-southwest ridges and steep-sided, narrow valleys. Elevations in the region range from 1200 to 1400 feet mean sea level (MSL) at the westerly edge of the basin to 300 feet MSL in the valley at the eastern edge. The Passaic River's major tributaries originate in the Highland Area, which also contains numerous lakes and reservoirs with an aggregate water surface area of 22.9 square miles.

The Highland Area contains relatively sparse population and is largely devoted to recreational, rural residential, and public water supply purposes. Communities developed in this region are in the upper most areas of the Passaic River Basin. They tend to be newer and developed or expanded with flood damage protection measures in place. As such, communities in the Highland Area, although subject to flooding, are not impacted to the magnitude that exists in the Central Basin or Lower Valley.

SECTION 2 - WITHOUT PROJECT CONDITIONS

INTRODUCTION

This section presents the existing setting of the Passaic River Basin and discusses its most likely character over the next several decades. Based upon the projections of selected key indicators, such as total population, employment, future land use, wetland development and other environmental parameters the characteristics of the Basin's people, economy, environmental conditions and floodplain setting are depicted for the period through the year 2040. In addition, a number of Federal, State or local actions which are either committed for implementation or considered probable future actions were incorporated into the without project conditions and are also discussed in subsequent paragraphs.

HUMAN RESOURCES

The Passaic River Basin consists of 132 communities whose geographical area encompasses portions of Bergen, Essex, Hudson, Morris, Passaic, Somerset, Sussex and Union Counties, New Jersey; and Rockland and Orange Counties, New York. The outstanding changes in the basin between 1950 and 1980 were its overall growth, the dramatic population and employment increases in the newer suburbs and outlying areas and the decline of the older urban settlements, especially the central cities.

Demographic and Community Characteristics. In 1950, approximately 1.78 million people resided in the Passaic River Basin. Nearly one quarter of these people (439,000) lived in the City of Newark. The average community in the basin contained over 14,000 persons in 1950. Over the 30 year period from 1950 to 1980, the basin's total population increased by about 38% to 2.5 million (including a 0.5% decline in the last decade period), a gain of over 670,000 people. In 1980, only 14% of these people lived in Newark. During the same period, the population of the typical basin community also rose by 28% to approximately 18,500.

During the three decades, suburban areas and communities on the fringe of the basin experienced significant growth, while most of the older, central cities and built-up suburbs either lost population or remained relatively stable. The greatest absolute and percentage growth has been exhibited by rapidly developing communities in Morris and Rockland Counties and northern and western sections of Bergen and Passaic Counties. In Rockland County, Ramapo registered the largest absolute increase, 333%, to 89,100 people in 1980. At the other end of the spectrum, four of the five largest central cities in the

Passaic River Basin experienced declines in population; only one grew during this period. Newark, the most populous central city, underwent the largest decline in population, with a 25% decrease to 329,000 people in 1980. The other cities include Paterson (with a 1% decrease to 138,000 people), East Orange (with a 3% decrease to 77,000 people), and Passaic (with a 9% decrease to 52,500 people). By contrast, Clifton's population grew by more than 15% to 74,400 in 1980.

As the typical basin community's population grew, so did its average density. Population density in the mean community was over 3,745 persons per square mile (psm) in 1960, ranging from a minimum of 32 psm in Vernon Township, New Jersey to a maximum of 19,315 psm in East Orange. In 1980, the basin's mean community population density had grown to about 4,000 psm, ranging from 57 psm in Tuxedo, New York to 19,750 psm in East Orange. The greatest absolute and percentage increases in population density in the Passaic Basin between 1960 and 1980 occurred in Morris, Rockland, Bergen and Passaic County communities. Basin fringe communities generally contain the lowest densities.

The population density of a community exhibits itself in the character of the community, which is classified either rural, suburban, suburban/urban or urban. Based on 1980 data, the basin's communities are primarily "suburban" or "suburban/urban" in character. Of the 132 communities in the Passaic River Basin, 70 (or 53%) are classified "suburban" (150-2,500 psm). Over half of these are located in Bergen and Morris Counties. A total of 47 of the basin's municipalities are classified "suburban/urban" (2,500-10,000 psm) and are located primarily in Bergen, Essex and Passaic Counties. There are 13 "urban" communities (more than 10,000 psm) in the basin, including Newark, Paterson and Garfield. Only two communities, Tuxedo Town and Hardyston, are considered "rural" (less than 150 psm).

Personal and Family Economic Characteristics. In 1980, 1.5 million residents for the entire Passaic River Basin, or 60% of its population, were employed. Of the total available labor force, this represented 95% employment. The average basin community employed 11,200 residents. This contrasts sharply with 1960 in which 6,200 of the 16,600 residents in the typical basin community, or a 38% share, were employed. A few communities such as Newark, Orange and East Orange experienced declines in residential employment due to changes in their demographic structure and loss of industrial jobs. On the other hand, rapidly growing communities in Morris County, for example, recorded the largest residential employment gains due to a shift of opportunities from central cities to new jobs in outlying areas.

The median family income for the 132 basin communities in 1980 was $28,892, well above the New York, New Jersey or national medians. Among all basin communities, median family income ranged from a maximum of $49,484 in affluent Mountain Lakes, Morris County, to a low of $10,118 in Newark.

Per capita income is another major indicator of economic conditions within the basin. Based on data available for the basin communities in 1980, per capita income for the mean community was approximately $9,735, higher than New York State ($7,498), New Jersey ($8,127) and the nation as a whole ($7,298). The highest per capita income of $24,270 was recorded in Harding Township, Morris County. Mountain Lakes, which reported the highest 1980 median family income, had the tenth highest per capita income in 1980 ($14,470) due mainly to the large percentage of its population which was under 18 years of age.

Future Socioeconomic Profiles. The most important conclusion that can be drawn from the projections of future socioeconomic conditions in the Passaic River Basin is that the future will essentially be an extension of the last three decades. With some variations, the major trends that have been formative since the end of World War II and were first measured in 1950 are expected to continue.

As in the past, the single most important indicator of the changes that can be expected in the basin over the coming decades is total population. Between 1980 and the year 2040, the basin is also expected to add over eight hundred thousand people, but this time the augmentation will take 60 years. The rapid deceleration in population growth over the next six decades was heralded in the 1970's, through which was evidenced a 0.5% population decline (in 1980, the basin population registered almost 2.5 million).

To a large degree, the central conclusion that the future of the basin will be a continuation of the previous thirty years is a result of the projected scale of change. By the year 2000, nearly 2.8 million people are expected to reside in the Passaic River Basin. By 2040, the basin's population will reach approximately 3.2 million. The growth of approximately seven hundred thousand people between 1980 and 2040 translates into an annual growth rate of less than 0.5%, less than one half of the annual rate that was sustained in the preceding thirty years. Not only will net growth slow down enormously, but the combination of large and concentrated net growths in people and jobs and the decline of the older centers which produced massive changes during the 1950's and 1960's will abate, and in some cases be reversed, as the older centers regain some of their strength. Population declines in the cities of Newark and East Orange, for example, are expected to reverse themselves by the year 2000.

The projected striking deceleration in the basin's rate of population growth after 1980, to a point below that of natural increase, will be the product of several factors. The most important will be the declining rate of economic growth, indicated by a slowdown in the rate at which new jobs will be added to the basin's employment base, compared to the preceding 30 years. Another restraint on population growth will be the continued high cost of new housing and the decline in the construction of rental housing in response to the rising cost of home sites, high interest rates and market factors.

Between 1980 and 2040, population growth in the basin will occur in the same counties that experienced high rates of growth in the preceding three decades. Thus, the older, more populous and built-up counties that are all or partly in the basin (Union, Essex, Hudson, and the central and southern portions of Bergen Counties) will either remain fairly stable, or grow moderately by between ten and twenty percent. On the other hand, the less developed counties that exhibited high growth rates in the 1950's and 1960's, such as Morris, Somerset and Sussex Counties in New Jersey, and Rockland and Orange Counties in New York, will continue their strong growth, increasing by about two-thirds in population and, in the case of the last three counties, by over 100% through the year 2040.

Population density in the basin will, of course, rise in direct proportion to the changes in total population, with both indicators rising by about 33% in the sixty years between 1980 and 2040. The overall density in the basin will grow from 4,000 persons per square mile in 1980 to approximately 4,600 in the year 2000 and to over 5,300 in 2040.

Changes in density will directly mirror changes in the distribution of the population. Population density in the older, more built-up counties will either stabilize or grow modestly. For example, Hudson and Bergen Counties will sustain relatively modest increases in density over the next six decades, about 12% and 23%, respectively. The density in Essex County, the only county in the basin that is projected to lose population between 1980 and 2040, shrinking by about 3% will decline by a similar proportion.

On the other hand, the largest increases in density will be sustained in the same counties that experienced major population growth between 1950 and 1980 and where there are large supplies of vacant land. Since the older counties of Essex, Hudson and lower Bergen have already developed at densities above the 1980 mean for the entire basin (4,000 persons per square mile), growth will occur primarily in other counties with lower densities and developable land within reach of the recently

expanded highway network, such as in Morris, Somerset, Passaic and Rockland Counties. In addition to the new growth occurring in the older central cities and suburbs, the future growth will also take place towards the margins of the basin on land accessible from the regional highway network and near the new jobs that will have been created in these areas.

The densities at which new housing is built may be higher than the densities that prevailed in the 1950's and 1960's. As a result of rapidly rising land and construction costs and recent state court decisions that have required communities to increase densities in some residential zones, much of the new single-family housing will be on smaller sites and take the form of townhouses.

Based on a distinction of communities by density, the basin should remain predominantly "suburban" and "suburban-urban" in character through the year 2000. As in 1980, approximately one-half of all communities will retain a "suburban character". Meanwhile, as towns in northwestern Bergen and Morris Counties continue to develop, the number of "suburban-urban" municipalities is expected to increase slightly by the year 2000, accounting for some 40% of all communities. As in 1980, the number of "urban" communities will remain unchanged, accounting for about 10% of all the basin's communities in the year 2000.

As the population continues its outward expansion, the number of "suburban-urban" and "urban" communities will increase at the expense of "rural" and "suburban" municipalities to the point where approximately 45% of all communities will be "suburban-urban" in character by 2040. Communities joining the urban ranks by 2040 will include Morristown, Belleville, Harrison, Maywood, Hackensack, Hasbrouck Heights and Elmwood Park. For the most part, communities whose densities are expected to surpass 2,500 persons per square mile, becoming "suburban-urban", sometime between 2000 and 2040 are concentrated in Rockland and Orange Counties. By the year 2040, there will be no more "rural" communities in the basin.

Another important indicator of the future status of the basin is the anticipated number of jobs, especially the ratio of jobs to total population. The percentage of employment population in the basin is projected to be about 44% in the year 2000 and about 48% in the year 2040.

Per capita income projections for areas in the Passaic River Basin were obtained for standard metropolitan statistical areas (SMSA). Geographic divisions that overlap the Basin are: 1) New York, New York-New Jersey SMSA, which includes Bergen County, New Jersey, and Orange and Rockland County, New York; 2)

the Newark, New Jersey SMSA, which covers Essex, Morris, Somerset and Union Counties; 3) the Paterson-Clifton-Passaic SMSA which includes Passaic County, New Jersey; and 4) the Jersey City New Jersey SMSA which covers Hudson County, New Jersey.

Per capita income for these four SMSA's from 1980 Census data, are $7,905; $8,680; $7,214; and $6,476, respectively. The SMSA show less than moderate increases in per capita from 1980 to 1990, with the New York-New Jersey SMSA projection of 3%, Paterson showing 4%, Newark with -0.6% and Jersey City with the highest at 14%. Figures for the year 2030 indicate that the New York, New York-New Jersey and the Jersey City, New Jersey SMSA's will have the largest increases in per capita income from 1990 to 2030, increases of about 110% each. The remaining areas are as follows: Newark, New Jersey (109%), and Paterson-Clifton-Passaic, New Jersey (108%).

LAND USE

The pattern of development and land use distribution in the Passaic River Basin is a product of the post-World War II trend of suburbanization in interaction with the natural physical characteristics of the area. From the urban City of Newark in the Lower Valley to the rural western perimeter of the Highland Area, the Passaic River Basin displays all the degrees and stages of development caused by the suburban trend. These development patterns radiate from the core central city of the metropolitan area, New York City, as well as from the secondary urban centers such as Hudson County, Newark, Paterson, Passaic and Morristown.

Prior to World War II, most of the northeast's population, hence, industry, commerce and jobs, were located in the cities. But the post-war baby boom and limited urban housing combined with an expanding highway system made it both necessary and convenient to relocate to outlying areas, thus triggering suburban sprawl through northeastern New Jersey. This development typified suburban growth away from the urban centers and along major highways. Concurrently, the cities and older suburbs have undergone varying degrees of decline and/or redevelopment towards higher density land uses. Suburban development in the Passaic River Basin is characterized by low density residential land use representing the major portion of developed land in the suburbs.

Existing Development. The Lower Valley is the oldest and most densely developed portion of the basin, containing and receiving the primary influence of its older urban areas, the core City of Newark and the secondary centers of Passaic and Paterson. High density multifamily housing predominates with low income and minority groups comprising a large proportion of these cities' populations.

The southern portion of the Lower Valley between Newark and Paterson is almost completely developed. It contains urban communities, such as Bloomfield, East Orange and those in lower Bergen County, which have high densities of 10-20 dwelling units per residential acre (d.u./res. acre) and substantial multifamily housing. Suburban communities such as Montclair have median densities of 5-10 d.u./res. acre and primarily single family homes.

North of Paterson, the residential patterns range from a mixture of dense, older suburban and newer subdivisions near the City of Paterson to almost exclusively newer subdivisions and larger lot private homes in the far north near Suffern. The northern Bergen County municipalities within the Lower Valley may be characterized as outer suburban with densities of 2-4 d.u./res. acre. This northern area contains most of the vacant land in the Lower Valley.

Commercial patterns in the Lower Valley tend to be represented by central and neighborhood business districts in the major cities and by strip development along major roads outside of these cities. Uniquely, near the mouth of the Passaic River, large areas are devoted to port facilities for the transfer of goods and materials. This has resulted in a substantial number of petroleum off-loading facilities and truck terminals in the Newark-Kearny area, and the development of heavy and light industry along the Passaic River.

Vehicular transportation consists of many limited access and multiple lane highways, an intricate network of secondary highways, and local streets. Freight and passenger rail transportation is centered on the Newark-Kearny area where several lines converge from all directions on two large railyards. Airports servicing the basin include: Newark International, Teterboro, Caldwell and Morristown Airports.

Open space is at a minimum in the southern portion of the Lower Valley, containing few city parks, but this increases to the north. Even use of the floodplain of the lower main stem Passaic River and many of the smaller tributaries is dominated by high density commercial, industrial and residential development, principle recipients of periodic flood damages.

The Central Basin can be characterized as almost completely suburban. Densities range from 2-4 d.u./res. acre, in the outer suburban eastern rim and older towns, such as Morristown and Boonton, to less than 2 d.u./res. acre in the rural-suburban western section, where zoning ranges from one-half acre to ten acres. The predominant housing type is the single family house. However, garden apartments have increasingly appeared along major automobile routes while the eastern towns of Wayne, Livingston, and others contain several large apartment complexes.

In addition to shopping centers, each of the communities has its own local business district and industrial park (or park containing predominantly light industries and service industries. Highways which pass through and link the communities are also lined with strip development. The trend of business and industry to move out of the city has resulted in the relocation of several large corporate headquarters, research facilities and office complexes into the suburbs, as seen in the Whippany/Morristown area.

Other large land holdings in the Central Basin belong to institutional users, including hospitals, state and county facilities, large consolidated secondary schools with attendant athletic facilities, and public and private residential and commuter colleges. Rock quarries, and sand, gravel and clay pits are also found in the Central Basin.

Transportation services for the Central Basin include major, primary and secondary highways, local street networks, a few rail lines, two large general aviation airports in Morristown and Caldwell and several small airports.

Open land in the Central Basin is dominated by the wetlands; however, large areas of other types of open land are found throughout the region. These include: forests, local, state and Federal parks, golf courses, horseback riding areas, and ski areas, all of which have recreational value. The wetlands account for more than 15 percent of the Central Basin (see Appendix B - NATURAL RESOURCES). They are valuable habitat for various flora and fauna, and provide large natural storage areas for floodwaters, lessening the amount of flooding downstream, but remain under intense pressure for development because they are the only large expanses of level land still undeveloped. Several wetlands have already been filled for housing developments, shopping centers, and industry.

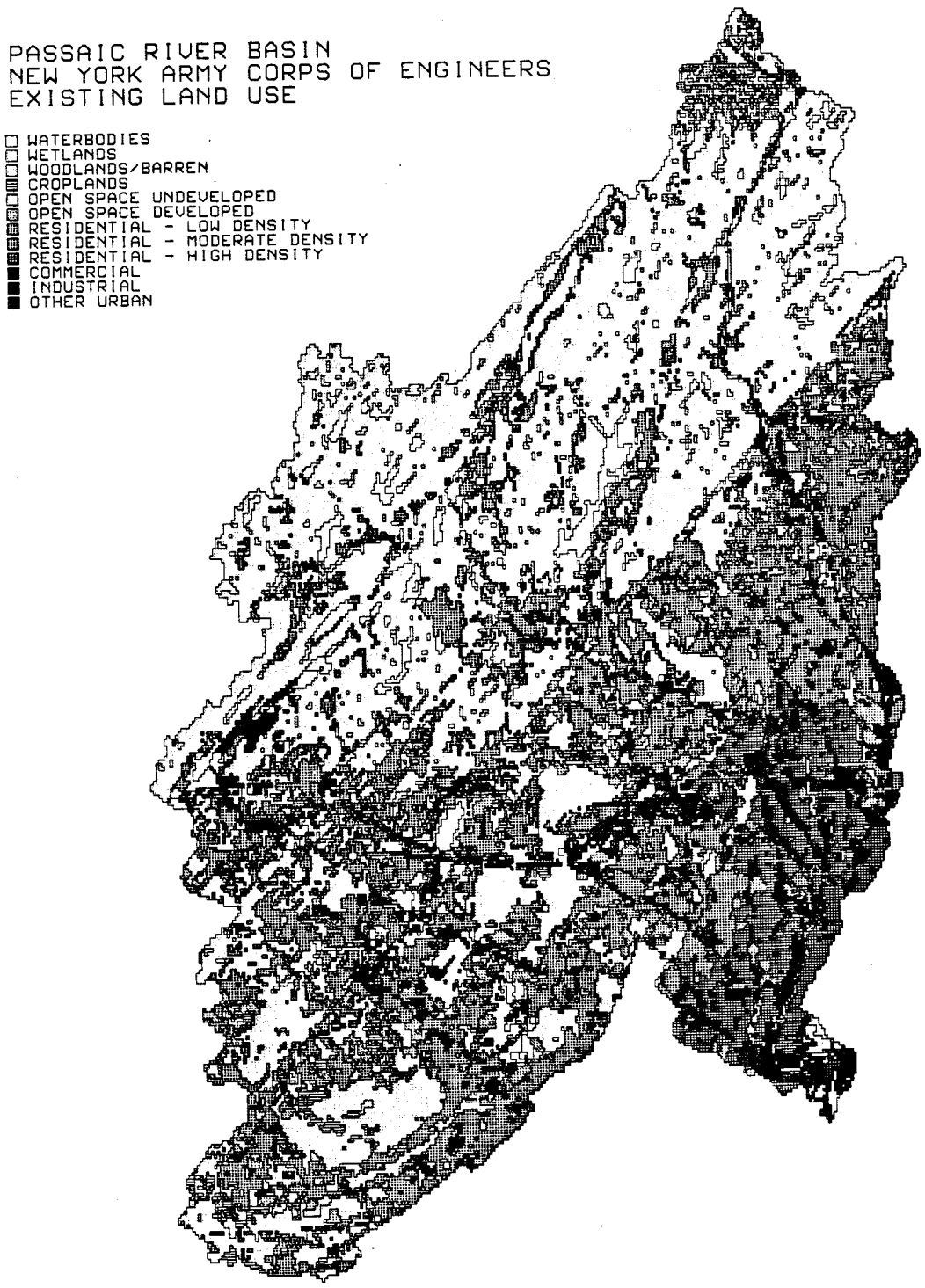
Due to its distance from the urban center, its often rugged topography, and poor highway access, most of the Highland Area has so far been spared from any significant impact of suburbanization. All but a few towns within this area have densities of less than 2 d.u./res. acre. Residential development is sparse and scattered; one acre (and more) zoning and single family homes predominate. Much of the land is given over to parks and reservations as well as to agriculture. Commercial facilities are confined primarily to community core and highway strip development. Outside of the built-up areas, the Highlands are dominated by forests and lakes which attract vacation and recreation oriented business.

Only a very small portion of the main stem floodplain lies in the Highland Area. Parts of Pequannock Township and Pompton Lakes Borough near the junction of the Wanaque and Pequannock Rivers and part of the Borough of Oakland along the lower reach of the Ramapo River constitute the main part of the Highland Area floodplain.

Figure C-8 shows existing development while Table C-3 lists the quantities of developed acres for each county in the Passaic River Basin.

Future Land Use Changes. Several factors influence future land use, including utilities, services, transportation, and the national and local economic climates; but the two fundamental socioeconomic variables, population and employment, were used in the analysis for this study. Requirements for future residential development are based on population projections, while future industrial, commercial and other land use needs are based on the respective employment projections in each municipality. Refinements to produce actual development projections and locations in each municipality include assessment of the acres available for future development, incorporation of predetermined expansion patterns and coordination of the results with the local interests.

In this study, the target years selected for future land use projections are 1990 and 2040. The most probable future land use conditions without a flood control project include consideration of urbanization, wetlands and natural storage acquisition plans and major redevelopment plans in the Passaic River Basin.



C-32

FIGURE C-8

TABLE C-3
EXISTING AND FUTURE CONDITIONS
EXTENT OF DEVELOPMENT
PASSAIC RIVER BASIN COUNTIES

COUNTY	TOTAL ACRES IN BASIN	ACRES DEVELOPED 1/ 1978	1990	2040
BERGEN	74,130	51,821	53,006	55,666
ESSEX	56,729	43,274	45,676	47,728
HUDSON	4,215	3,037	3,422	3,422
MORRIS	201,290	82,610	93,936	96,051
PASSAIC	121,714	51,480	55,205	57,767
SOMERSET	24,214	10,403	13,003	14,252
SUSSEX	14,648	703	3,303	4,214
UNION	7,603	4,916	4,928	5,233
ORANGE	59,863	8,864	17,280	31,326
ROCKLAND	35,741	11,282	15,532	24,985
TOTAL	600,147	268,930	305,291	340,644

1/ DEVELOPED AREAS INCLUDE:
RESIDENTIAL, COMMERCIAL, INDUSTRIAL AND
OTHER URBAN AND INSTITUTIONAL LAND USAGE

Urbanization. The results of the future land use analysis are consistent with the future characteristics of the basin as a whole. Since the land use projections are an outgrowth of population and employment projections, areas currently consisting of lower levels of development, such as in the Highland Area, are those which are expected to experience the greatest increases in land development. Though population and employment trends show increases for the years 1990 through 2040, the explosive growth which occurred during the years 1950 through 1970 will not recur and, accordingly, land use projections reflect this. Figures C-8, C-9 and C-10 illustrate the existing magnitude of development, and land use projected in 1990 and 2040. Table C-3 shows the number of acres developed under existing conditions (1978), 1990 and 2040 by county. Approximately 35,350 acres are projected to be developed between the years 1990 and 2040. Compared to historical growth in the Passaic River Basin, the future acreage projected to be developed is relatively small. It should be noted that though comparatively more acres were developed in the past than are projected for the 1990 to 2040 period, the incremental effect on frequent flooding and the extension of floodplain areas could be more significant. The following discussion focuses on land use projections only for those portions of counties lying partly or wholly within the Passaic River Basin. The Economics Supporting Documentation presents additional detail on the land use in these counties.

Bergen County has approximately 16,500 acres available for future development, approximately 22% of the total acreage in the county. The greatest amount of vacant land is located in the Highland Area. The greatest increase in development through 2040 will be for urban and institutional usages consisting of approximately 1,500 acres; however, this is less than a 1% increase from the total developed acres under existing conditions. Other increases by 2040 include residential (1,100 acres), commercial (1,000 acres) and industrial (200 acres) development.

Essex County is densely populated and extensively developed, functioning as the industrial and financial center for north-eastern New Jersey. The increase in residential development by the year 2040 is projected to be less than 1% of total existing development. Commercial development will increase by 1,500 acres. No additional industrial development is projected for 2040.

Hudson County, characterized as an older high density urban area, has little vacant land available in the county. Only 400 additional acres (50 residential, 200 urban/institutional and 150 commercial acres) are expected to be developed by 2040. This represents less than 10% of the total basin acreage.

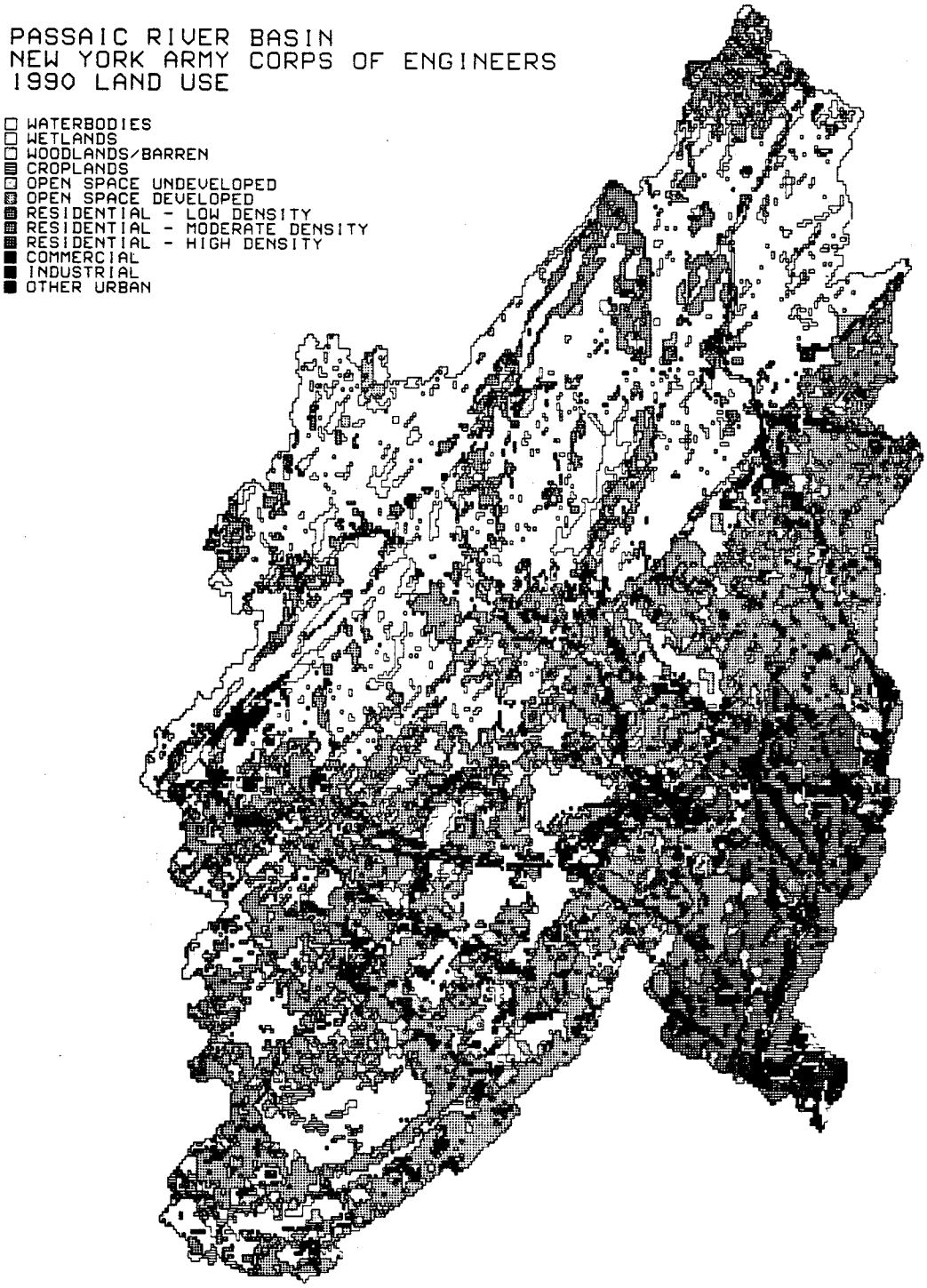

PASSAIC RIVER BASIN
NEW YORK ARMY CORPS OF ENGINEERS
1990 LAND USE
WATERBODIES
WETLANDS
WOODLANDS/BARREN
CROPLANDS
OPEN SPACE UNDEVELOPED
OPEN SPACE DEVELOPED
RESIDENTIAL - LOW DENSITY
RESIDENTIAL - MODERATE DENSITY
RESIDENTIAL - HIGH DENSITY
COMMERCIAL
INDUSTRIAL
OTHER URBAN

FIGURE C-9

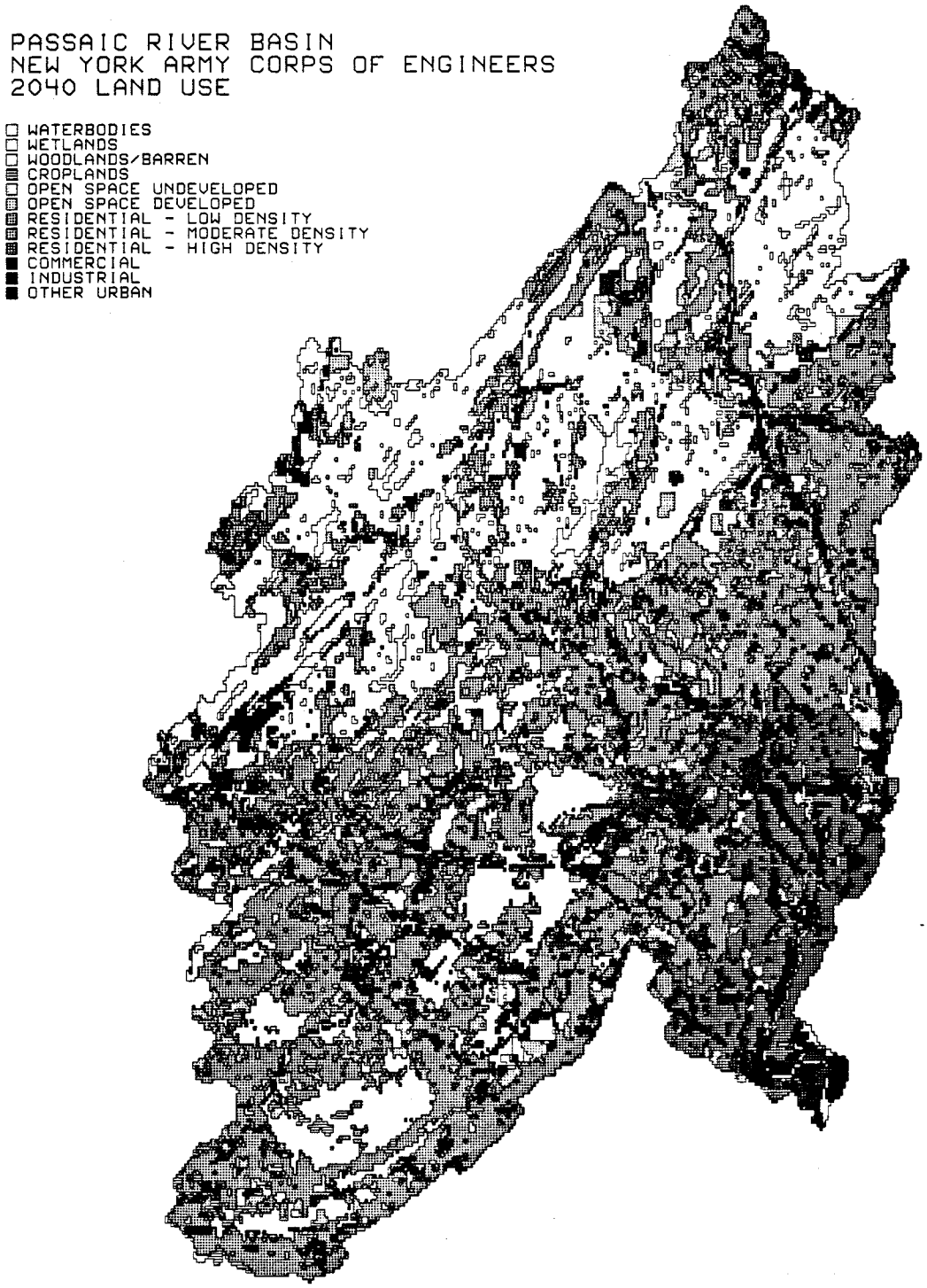

PASSAIC RIVER BASIN
NEW YORK ARMY CORPS OF ENGINEERS
2040 LAND USE
WATERBODIES
WETLANDS
WOODLANDS/BARREN
CROPLANDS
OPEN SPACE UNDEVELOPED
OPEN SPACE DEVELOPED
RESIDENTIAL - LOW DENSITY
RESIDENTIAL - MODERATE DENSITY
RESIDENTIAL - HIGH DENSITY
COMMERCIAL
INDUSTRIAL
OTHER URBAN

FIGURE C-10

Morris County, one of northeast New Jersey's least developed counties, is expected to develop an additional 11,300 acres by 1990 and a total of 13,400 acres through 2040. Over 75% of the projected development will be residential, with the balance being commercial, industrial and urban/institutional.

Passaic County's land use ranges from urban and dense suburban in the Lower Valley, or southeastern portion, to mixed uses in the Central Basin, and low density residential in the Highlands Area or northwestern portion of the county, where most of the vacant land exists. Development projections of approximately 6,300 additional acres by 2040 represent about 3% of the county's basin acreage. Most of this will be residential and commercial development. No industrial development is anticipated in Passaic County while it is projected that over 1,180 additional acres will be used for urban and institutional purposes.

The primary land use in Somerset County is residential development. Strong growth is anticipated in this county, indicated by the large areas of open land, about 9,500 available acres. Approximately 3,100 residential, 500 commercial and 175 urban/institutional acres are projected for development by 2040. No development of additional industrial land use is expected by 2040.

Of all the counties in the basin, Sussex County currently has the highest proportion of undeveloped acres relative to total acreage, approximately 95%, due in part to the limited highway access and its rugged terrain. The majority of existing land use consists of residential development. A total of 3,500 acres will be developed by 2040 or approximately 20% of the county's total basin acreage. This includes 2,100 residential acres, 500 commercial acres, 900 acres for urban and institutional uses and no industrial development.

Union County is a densely settled area with approximately 65% of its total area currently developed. Union County has less than 400 acres available for future development. Based on population and employment trends for the county, 20 residential acres, 140 commercial acres, and 160 acres for urban and institutional uses are expected to be developed by 2040. No additional industrial development will occur.

Growth has been dynamic in Orange County. The majority of new development has taken place in the unincorporated towns. Orange County has over 39,000 acres available for future development. Population and employment trends indicate that additional development through the year 2040 will include about

15,700 acres for residential use, 400 acres for industrial usage, 1,900 acres for commercial usage and over 4,400 acres for urban and institutional uses, totalling over 35% of the county's total basin acreage.

Rockland County has felt the pressure of urbanization and suburbanization in recent years. The surge of development has been spurred by the proximity of the N.Y.S. Thruway. Approximately 8,100 residential, 900 commercial, 800 industrial and 3,900 urban/institutional acres are projected for development through the year 2040. This represents about 38% of the county's total basin acreage.

The existing conditions in the Passaic River Basin and the most probable future conditions are reflective of the historical socioeconomic characteristics of the area. The favorable climate for economic growth that historically existed in the basin is still strong in the majority of the basin's service area counties. Almost half the basin's communities will be described as suburban-urban by 2040.

The projected continual growth is important in light of future flood conditions which would increase current expected annual damages due to worsening flood conditions. Probable increases in expected annual damages are due to future land development in the basin drainage area in both upland and floodplain areas (see FLOOD DAMAGES in this section for quantification of existing and most probable future conditions flood damages in the basin). It should be emphasized that little significant future development of vacant land is projected in existing floodplain areas since much of the floodplain is already developed, while other largely undeveloped tracts lie in wetland areas which are protected by various Federal and non-Federal interests or regulatory measures. The impact of development in these wetland areas was incrementally tested as part of the analysis of preserving the natural storage areas, discussed below.

Central Basin Wetlands and Natural Flood Storage. All of the major wetlands in the Central Basin act as natural flood retention areas during periods of high flows in the source rivers. During the balance of the year, they provide habitats for a great diversity and large numbers of reptiles, amphibians, birds and mammals. Although a natural function of wetlands is to attenuated flood flows through storage, variability in flooding has intensified due to development throughout the entire Passaic River Basin. Upland development has resulted in increased runoff and river flows, while continued encroachment along the periphery of the wetlands has reduced the area available for natural attenuation. Seasonal flooding is

reaching higher levels for longer periods of time. This causes damages to human property and also affects the less tolerant plant species, wildlife habitats, and overall productivity of the wetlands.

Currently, approximately 24,485 acres of natural flood storage exist in the Passaic River Central Basin. The storage areas largely consist of wetlands, with 24,100 acres of the total natural storage acreage classified as wetlands. This natural flood storage is concentrated primarily in eleven major Central Basin Wetland groups (see Figure C-11). These include: Great Piece Meadows, Troy Meadows, Hatfield Swamp, Hatfield Swamp South, Black Meadows, Bog and Vly Meadows, the Great Swamp, and unnamed systems along the Lower Pompton River, Canoe Brook, Upper Passaic River and the Dead River. (Note that additional Central Basin wetlands such as Lee and Long Meadows do not serve as significant natural storage areas because of their location, elevation or encroached upon nature, although they are wetlands).

Central Basin flood storage areas would store up to 200,000 acre-feet of water for a flood with a 500 year recurrence interval. Natural flood storage provided in these areas for the 10, 50 and 100 year events total in excess of 65,000, 110,000, and 135,000 acre-feet, respectively, in the Passaic River Central Basin (See Table C-4 which includes data for flood storage conditions expected for the year 1990).

The without project future conditions, in terms of natural storage, includes a projection of what storage areas are likely to be developed, at what rate they would be lost, and the resulting impact on expected annual damages. Future conditions were projected based on available planning data and information obtained from various Federal, State and local offices. The years 1990 and 2040 were the target years for projecting future development.

In addition, it was acknowledged that recent legislation designed to protect environmental attributes will alter development towards patterns of growth that minimize adverse impacts and maintain the viability of the natural environment rather than a continuation of past and current approaches. Specifically, environmental legislation will, to a certain degree, further control the use of wetlands and floodplains.

Based on the foregoing, the general changes in the physical setting of the Passaic River Basin were forecast. It is assumed that the basic physiography and geology of the basin will remain unaltered in the future. Natural storage acreage (which includes but is not limited to wetlands) is expected to decline in the future. The extent of acreage lost in the future will,

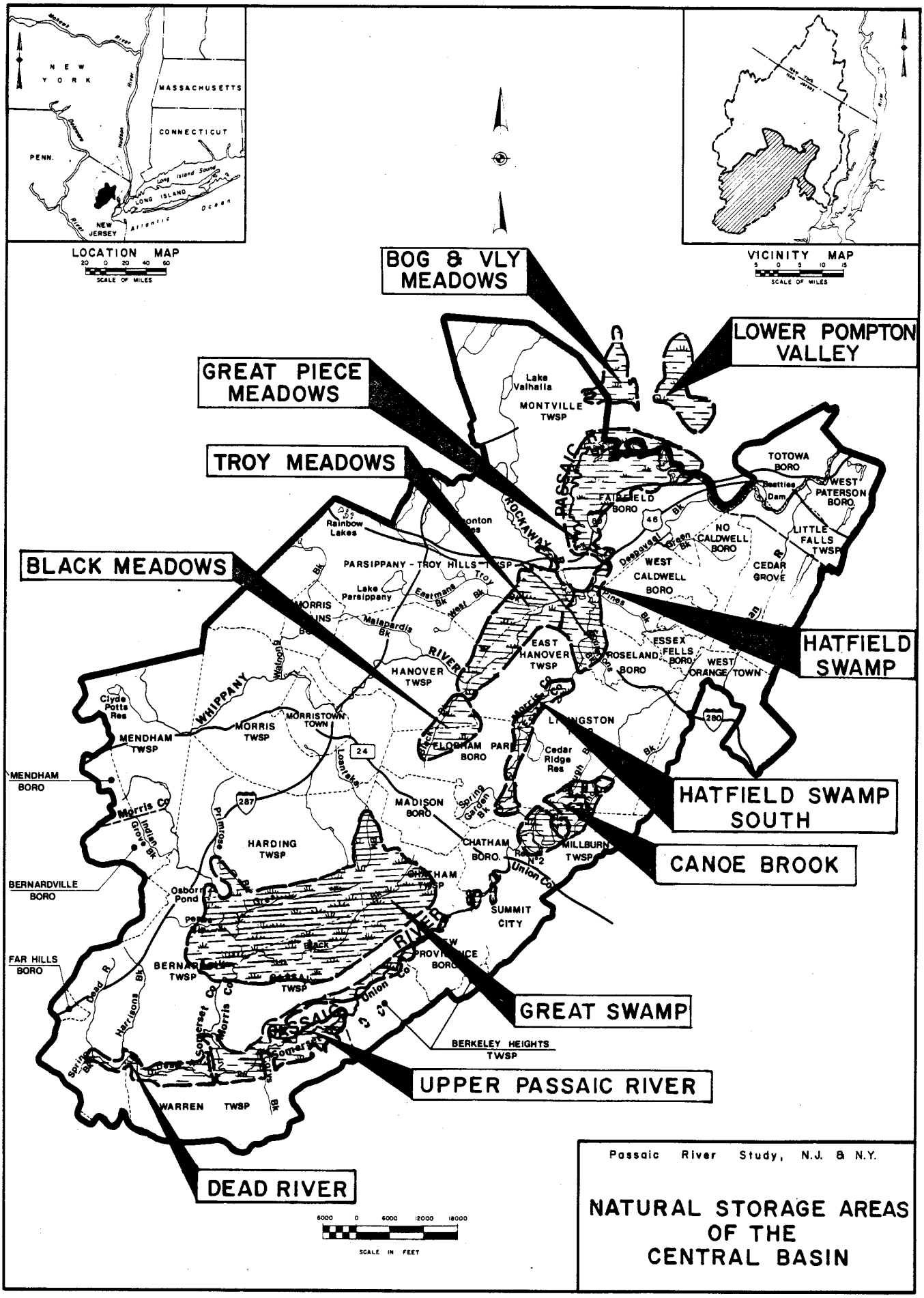


FIGURE C-11

61

TABLE C-4
IMPACT OF LOSS OF CENTRAL BASIN NATURAL STORAGE AREAS

CENTRAL BASIN FLOOD STORAGES (ACRE-FEET)

CONDITION	10YR	50YR	100YR	500YR
1990 WITHOUT PROJECT	66,600	113,000	136,000	203,900
2040 WITHOUT PROJECT	57,100	85,300	104,700	165,200

PEAK DISCHARGES AT LITTLE FALLS (CFS)

CONDITION	1YR	10YR	50YR	100YR	500YR
2040 WITHOUT LOSS OF ANY NATURAL STORAGE AREAS	6,153	14,159	23,583	28,156	45,201
2040 WITH PROJECTED LOSS OF NATURAL STORAGE AREAS	6,232	15,323	27,416	33,053	51,565

however, depend on several factors. These include historic trends, Federal floodway designation, parkland or open space zoning, non-Federal regulatory actions implemented by the State of New Jersey, and Federal regulation under Section 404 of the Clean Water Act.

Historic Trends. The historical loss of natural flood storage is difficult to estimate directly due to lack of data. However, historic mapping and photogrammetry data do exist for wetlands. Although, not precisely equal to natural storage, aerial photographs were used to determine the amount of wetland acres that were lost historically. Aerial photographs of the Passaic Basin taken in 1940 were compared with those taken in 1978 as part of this study. Based on these aerial photographs it was determined that in 1940, the Central Basin wetlands covered about 35% of the area or about 30,500 acres. Since then, the 1978 photographs indicate that many sections of wetlands, particularly around the fringes, have been filled or drained. Based on the 1978 aerial photographs, it is estimated that wetland acreage has dwindled to about 25,300 acres, a loss of 5,200 acres since 1940. Much of this loss took place in the last 20 years as development was accelerated due to highway expansion into the Central Basin. Additionally, between 1940 and 1978 approximated 7,500 acres of wetlands in the Passaic River Lower Valley were lost. Thus, a total of 12,700 acres of wetlands in the Passaic watershed were destroyed during this period.

A significant portion of the historical Central Basin loss took place in the major wetland groups. In the Upper Passaic region of the Central Basin, the Great Swamp has diminished somewhat, although most of these wetlands are now included within the Great Swamp National Wildlife Refuge and should be safe from further direct reduction. Between 1940 and the present, much of the Black Meadows were filled to accommodate Morristown Airport. The construction of Interstate Highways 80, 280 and 287 in the early 1970's put once remote areas within easy commuting range of New York City, spurring a building boom, and a further decline in the periphery of wetlands. The northern section of Troy Meadows have also been lost to development. North of Hook Mountain, the municipalities of Montville and Lincoln Park have greatly infringed on the Bog and Vly Meadows, reducing this freshwater swamp to about one third of its former size.

To determine the extent of development of the remaining wetland acreages between 1978 (the basis for existing conditions analytical models) and present conditions (1984), a review was made of recent floodplain encroachment applications and known land use changes. It was determined that between 1978 and 1984 approximately 1,200 additional acres were lost to wetland

filling, leaving approximately 24,100 acres of wetland areas remaining in the Central Basin. The total remaining natural storage acreage is estimated at 24,485 acres, which include 24,100 acres of wetlands and 385 acres of intermittent, low-lying, mixed use, open development.

The most probable future of the remaining 24,485 acres of natural storage lands was projected, with consideration to the likely protective status of these areas based on FEMA floodway designations, location of existing and future parkland, zoning regulations, non-Federal legislative and regulatory actions implemented by the State of New Jersey, and regulations under Section 404 of the Clean Water Act, as amended. The consideration of these factors is discussed in the following sections.

a. Lands Contained Within Floodway Delineations. Floodways have been adopted throughout most of the Passaic River Basin. The major exceptions, however, are along the Rockaway and Whippany Rivers in East Hanover, Hanover, and Parsippany-Troy Hills, which encompasses the important storage areas of Hatfield Swamp, Troy Meadows, and Black Meadows. The floodways in these areas are expected to be adopted by the end of 1987. The amount of natural storage acres that would be protected via Federally designated floodways were determined by a technical review of the actual delineations on NJDEP/FEMA mapping for the communities in which they have been adopted, and by review of NJDEP estimates of what the final delineations will be, where they have not been adopted. Based on such delineations it was determined that approximately 6,380 acres of natural storage will be protected via floodway designations as presented in Table C-5.

b. Parkland or Open Space Zoning Designation. The consideration of this factor involved determining which natural storage areas, lying between the floodway delineations and flood hazard limits, are currently and will continue to be preserved due to the nature of their parkland or open space ownership or zoning designation. Lands designated as parklands were deemed to be protected and future development would, therefore, be precluded. Those areas identified as such were then coordinated with local municipalities to verify their status. The evaluation determined that 9,485 natural storage acres would be preserved through programs or ownership controlled by local interests or government agencies. A breakdown of the 9,485 acres protected in the flood fringe according to wetland areas is summarized below and detailed in Table C-5. Additional data regarding the storage areas protected via parkland or open space use is displayed on Table C-6.

TABLE C-5
ACRES OF NATURAL FLOOD STORAGE THAT ARE PROTECTED AND UNPROTECTED 1/
(1984 Conditions)

STORAGE AREA NAME	ACRES	ACRES 2/ PROTECTED BY FLOODWAY DELINEATIONS	ACRES 3/ PROTECTED AS PARKLAND OR OPEN SPACE	TOTAL ACRES PROTECTED	PERCENT PROTECTED	REMAINING DEVLOPABLE ACRES	DEVELOPABLE 5/ ACRES PROTECTED WITH FHAR	ACRES LEGALLY 6/ SUSCEPTABLE TO FILL
Great Piece Meadows	4125	2185	220	2405	58%	1720	945	775
Troy Meadows	2390	805	315	1120	47%	1270	700	570
Canoe Brook	1245	745	140	885	71%	360	200	160
Upper Passaic River	2200	675	930	1605	73%	595	330	265
Hatfield Swamp	1775	1045	205	1250	70%	525	290	235
Black Meadows	1300	40	0	40	3%	1260	695	565
Great Swamp	8500	0	7500	7500 4/	88%	1000	550	450
Dead River	850	180	0	180	21%	670	370	300
Bog & Vly Meadows	650	205	0	205	32%	445	245	200
Hatfield Swamp (South)	605	220	175	395	65%	210	115	95
Lower Pompton	845	280	0	280	33%	565	310	255
TOTAL	24,485	6,380	9,485	15,865	65%	8,620	4,750	3,870

1/ Storage areas are not always analogus to wetland designations.
2/ Approximate acreage protected by floodway delineations.
3/ Approximate acreage protected consists of those areas in public ownership expected to remain as parkland or open space.
4/ The Great Swamp National Wildlife Refuge/Lord Sterling Park protects 7500 acres.
5/ Developable acres estimated to remain as open space due to the Flood Hazard Area Regulations limitation on fill placement in flood fringe.
6/ Developable acres estimated to be filled under the Flood Hazard Area Regulations.

TABLE C-6

PASSAIC RIVER BASIN WETLAND PARKLAND OR OPEN SPACE PROTECTIVE STATUS

Name of Area	Acres Designated As Protected (Parks or Open Space)	Land Use	Brief Definition	Status
Great Swamp/Lord Sterling Refuge Park	7500	National Wildlife Refuge/ County Park (Passaic - Harding Twps. and Somerset County Park)	Great Swamp is dedicated to migratory birds and wildlife conservation; Lord Sterling Park is nature education and recreation (horseback riding).	Great Swamp is protected by Federal Regulation. Lord Sterling Park is protected as a county park.
Upper Passaic River	930	Morris Co. and Green Acres Parkland	Lands dedicated to open space.	Protected as Morris Co. parkland and by State's Green Acres program.
Troy Meadows	315	New Jersey Green Acres	Lands dedicated to open space.	Protected under State's Green Acres Program.
Great Piece Meadows	220	Parkland	Lands dedicated to open space.	Will remain protected.
Hatfield Swamp	205	Parkland West Essex Co. Park (Several Communities)	Lands dedicated to open space.	Will remain protected.
Canoe Brook	90	Conservation District (Milburn)	Lands dedicated to open space and to protect water supplies.	Township expects most of this acreage to remain under current zoning.
	25	Parkland (Florham Park)	Lands dedicated to open space.	Will remain protected.
	25	Parkland (Chatham)	Lands dedicated to open space.	Will remain protected.
Hatfield South	85	Parkland (Roseland)	Lands dedicated to open space.	Will remain protected.
	90	Parkland (Livingston)	Lands dedicated to open space.	Will remain protected.

The Great Swamp is a Federal national wildlife refuge dedicated to providing habitats for migratory birds and refuge for wildlife. Lord Sterling Park is an environmental education center and recreation area for horseback riding. Within the Great Swamp Refuge/Lord Sterling Park complex, 7,500 acres will remain protected in the future.

Troy Meadows in Parsippany-Troy Hills Township contains approximately 315 acres of land, outside of the expected protection of the floodway, which is currently under the control of the Green Acres program preventing active development and preserving open space. Great Piece Meadows has 220 acres of parkland. Hatfield Swamp further upstream contains about 205 acres of land which is protected as parkland by the Essex County Parks Commission. In addition, approximately 175 acres located in Hatfield Swamp South is designated as parkland. In the Upper Passaic River area, 930 acres are protected as parkland.

The Canoe Brook area contains surface and groundwater potable water supplies. Therefore, approximately 90 acres have been set aside as conservation district land to preserve these water sources. The Township of Millburn has indicated that most of this land will remain as is, however, some peripheral highway land which is now zoned conservation district may be sold by the owners. An additional 50 acres in the Canoe Brook area will be protected as parkland.

In addition to park lands, approximately 1,400 acres of wetlands, mostly in Troy and Great Piece Meadows, are owned by a private wildlife organization, which has, to date, protected these lands. the future of these lands, however, as well as other wetland areas that have been zoned by municipalities as recreational, conservation, and/or agricultural areas, is far from certain. Developmental pressures have resulted in the continued encroachment at the periphery of Troy and Great Piece Meadows. Ongoing development, which has adversely affected the value of these areas as wildlife habitat, is causing the private wildlife organization to consider the sale of its lands in order to buy other wetlands (not necessarily in the Passaic Basin) believed to be of higher quality. Additionally, municipal zoning is subject to revision with changes in local administrations and increased developmental pressure. In view of the risks and uncertainty associated with assuming the continued protection of these lands, such areas in private ownership were evaluated on a case-by-case basis and were generally treated as unprotected.

Therefore, of the 24,485 acres of natural flood storage lands available as of 1984, approximately 6,380 acres are afforded protection via floodway delineations, and about 9,485

acres are protected as parkland (approximately 7,500 acres of which comprise the Great Swamp Refuge and Lord Sterling Park), leaving 8,620 acres of natural flood storage areas not covered by these programs. This total includes 8,480 acres of wetlands and 140 acres of non-wetland natural storage lands.

c. Section 404 of the Clean Water Act (PL 92-500). The Corps' regulatory program processes permit applications for development under 404 jurisdiction after permission to build is given by municipal zoning ordinances (or waivers), and by the State of New Jersey's stream encroachment program. The Section 404 program, although not absolutely prohibiting development in wetlands (i.e. potential natural storage areas), requires that all discharges comply with 404 (b) (1) guidelines. Most 404 permits currently issued by the Corps in wetland areas require the applicant to mitigate for lost wetlands, and this would work in conjunction with the State's Flood Hazard Area Regulations discussed below to limit the loss of natural storage areas within the overall risk pool of 8,620 acres.

d. Non-Federal Regulatory Action. The State of New Jersey has taken a number of nonstructural actions in conjunction with the selection of a comprehensive flood control plan in order to implement an overall watershed management approach to addressing the flood problem in the Passaic River Basin.

One of these measures is the enactment of new Flood Hazard Area Regulations (FHAR) to control construction and filling in the floodways. The regulations became effective May 21, 1984 and are fully discussed later in this section under NON-FEDERAL FLOOD CONTROL PROGRAMS. These regulations, in effect, limit the amount of natural storage areas which can be lost since only 20% of the total volume between the ground surface and the flood hazard design elevation can be filled in, while the lowest floor of new structures still must be a minimum of one foot above the design flood elevation.

The remaining 8,620 natural storage acres, therefore, would be affected by the NJDEP fill regulations adopted in 1984. The net fill that could be placed in the flood fringe area (equal to 20 percent of the total volume between the natural ground surface and the flood hazard design elevation) would be sufficient to fill in approximately 45% or 3,870 acres out of the 8,620 acres of remaining unprotected natural storage areas (see Table C-5). (Note that the 20% fill volume translates geometrically to approximately 45% areal extent based on the topography of the Central Basin).

The 3,870 acres is considered a minimum estimate of potentially filled natural storage acreage since it does not reflect iterations of resale of unfilled land that would again be subject to incremental filling as portions of the property are developed. Although such iterations are possible, it is considered that both the State's Flood Hazard Area Regulation program and Federal Section 404 regulatory requirements will limit such additional filling beyond the approximately 3,870 acres. Therefore, the estimate of approximately 3,870 acres of future natural storage loss is considered most probable.

The continued limitation of "no net fill" placement in the Central Passaic Basin does impose a more stringent requirement in the study area; however, there is no way to quantify the effects of this regulation on future hydrology. The limitation would not preclude the filling of the more valuable storage areas (as they relate to flood detention capabilities) to the 20% volume limit and replacing them with storage areas at points where the reduction of downstream flows would be much less significant. While the effects of such "swaps" of storage cannot be predicted prior to designation of specific borrow areas, the "no net fill" rule is considered an important component in the State of New Jersey's efforts to protect natural storage areas.

In order to maximize the effectiveness of the Flood Hazard Area Regulations, not only the State government but also County and Municipal governments must participate in their application. The State of New Jersey has, therefore, developed a series of training seminars to familiarize all levels of government in New Jersey with the new and strengthened regulations and their application. In addition, a group of private organizations has instituted a floodplain watch which reports the placement of illegal fill in storage areas.

e. Recent Non-Federal Actions. Although it was hoped that the new and strengthened regulations would have the effect of further restricting development in wetlands, there has been significant concern that current development pressures have resulted in an unabated loss of wetlands. On June 8, 1987 the Governor of New Jersey declared a moratorium on development within the State's remaining unprotected freshwater wetlands. This action by the Governor recognized that wetlands are being developed, that there is a need to stop this loss and that the existing regulations are inadequate to prevent such losses. The moratorium was to remain in effect until November 1988 or until the New Jersey State Legislature passed a bill that would further regulate wetlands development.

On July 1, 1987, the Governor of New Jersey signed into law new restrictions on development in and around wetlands in the State. Under the Freshwater Wetlands Protection Act, Chapter 156, Public Laws of 1987, except under exempted circumstances, most development on wetland is forbidden and building in "buffer zones," lands adjoining swamps and marshes, is sharply limited. The bill retains local controls over wetlands until the effective date of the legislation, a year from the bill's enactment. The effects of this bill are expected to be beneficial to preserving natural flood storage in the Passaic River Basin, although what constitutes the permitted exempted circumstances where wetland construction is allowed remains to be determined by State officials. One concession to developers was the provision allowing "grandfathering" of projects in wetlands for which preliminary site plans or application have received preliminary site plans or application have received preliminary approvals from local authorities prior to the act.

Further complicating the issue is the recent U.S. Supreme Court decision of First English Evangelical Lutheran Church of Glendale vs County of Los Angeles, 85-1199. In that case, the Court ruled that property owners must be compensated when they are deprived of all or substantially all use of their property, even temporarily, by land use regulations.

f. Future Natural Storage Losses. Based on the foregoing discussion, the remaining 8,620 acres are considered to be at risk of losing their natural flood storage potential and are legally vulnerable to environmental filling and development. Approximately 3,870 acres out of the available pool of 8,620 acres of natural storage could be directly lost due to filling. Of course, it cannot be predicted with certainty which lands would be lost first, although development has historically proceeded inward from the flood fringe. It is too early to determine the effectiveness of the new State legislation on wetland construction, in view of both the "exempted circumstances" caveat and the Supreme Court decision in First English. State regulations to enforce the law remain to be developed, and amendments to the law which would accommodate a range of exceptions to be permitted, are currently being debated in the State legislature. Therefore, the probable rate of development expected for the remaining 8,620 acres of unprotected natural storage areas is uncertain to some degree at this time. However, the recent actions taken by the Governor and State legislature confirm that even the more stringent 1984 Flood Hazard Area Regulations were not an effective wetland protective measure.

Based on the potential loss of storage associated with planned projects and the current inability to project the effectiveness of the new legislation in light of existing and proposed exemptions, emphasis was placed on examining the historical trend, as modified by the 1984 Flood Hazard Area Regulations and planned highway projects in determining the most probable future rate of the loss of natural storage in the Passaic Central Basin.

As noted previously, based on historical wetland losses and permit applications of development which have occurred between 1978 and 1984, a basin-wide total of approximately 12,700 acres of wetlands have been lost in the 38 years between 1940 and 1978, with an additional 1,200 acres lost between 1978 and 1984. Of this total, approximately 6,400 Central Basin acres have been lost in the 44 years between 1940 and 1984 (5,200 acres were lost between 1940 and 1978 and 1,200 acres were lost between 1978 and 1984). The basin-wide loss rate during the entire 44 year period is approximately 315 acres per year, while the average rate of Central Basin natural storage loss is approximately 145 acres per year over the entire 44 year period. The average rate of loss between 1978 and 1984 was 200 acres per year in the Central Basin.

While the 1940-1984 and 1978-84 Central Basin rates of 145 and 200 acres per year, respectively, most certainly will not continue in the future, several factors indicate that losses which will have a measurable effect on natural storage capability will take place. Such losses would reflect the 1984 FHAR 20% fill rule, the Section 404 program, and additional, yet to be determined, constraints imposed by the Freshwater Wetlands Protection Legislation. Property values in northern New Jersey, including the Central Basin, have skyrocketed in recent years. Even homes severely damaged in the April 1984 flood have seen dramatic increases in value. These high real estate prices only add to the pressure to develop available areas. In addition, the completion of state and county highways, will provide greater access to more wetland areas. Interstate I-78 has just been completed and opened for use, allowing access to natural storage areas along the Upper Passaic and Dead Rivers. This route links to I-287 which is not yet completed but is planned for completion by the early 1990's. This is quite likely to spur development in the Black Meadows and Bog and Vly Meadows. State Route 24 is proposed to pass through the southern portion of Black Meadows and will almost assuredly cause complete development of this area, now zoned for industry. Eisenhower Parkway located in western Essex County, which is scheduled for completion in the early 1990's will open portions of Hatfield Swamp to development.

Since 1984 a yearly average of approximately 50 nationwide and 12-15 individual Section 404 permits have been issued in areas within the Passaic River Central Basin natural storage lands. This trend is expected to continue in the future with 45-55 nationwide permits and 6-8 individual permits projected annually over the next ten years. Highway projects, usually processed as individual Section 404 permits, make up approximately 75% of the individual permit total.

In light of these planned projects and other potential exemptions to the State's wetlands legislation, it is considered that a natural storage conversion rate of 70 acres per year is probable for the without project conditions. This forecast implies that the natural storage loss of 3,870 acres would take place gradually, through the year 2040, subject to the additional, yet to be determined impact of the State's Freshwater Wetlands Act. Such a natural storage loss rate is considered reasonable since it is equal to approximately one-fifth of the 1940-1984 basin-wide rate, one-third of the recent short term Central Basin rate, and one-half of the long term (1940-1978) Central Basin rate which was only significantly accelerated by highway construction during the latter half of the period. This loss projection does not reflect resale iterations of unfilled land that could again be subject to incremental filling. It is considered that both the State FHAR, and 404 regulatory and associated mitigation requirements will limit such losses.

The areas filled would lose both natural flood storage capability and environmental value. The future projections recognize that natural storage areas could be altered by development (i.e. natural cover areas removed and lawns planted) and still function as storage areas. Flood storage is considered to be lost only when lands are filled. Wetland characteristics, however, are lost or diminished not only when filled, but also when altered or indirectly impacted by development without filling. In this latter situation, these impacted wetlands would still retain their natural storage ability. A portion of the remaining natural storage areas may also be developed, without being filled, thus retaining their storage capability, but losing much of their habitat value, with impacts ranging from alterations to create roads, lawns and landscaping, to more indirect losses of wildlife values. Therefore, an acreage total beyond the 3,870 acres of natural storage areas projected to be directly lost could experience a significant loss of environmental character.

A summary of the historic and projected impact on the Central Basin's natural storage areas is contained in Table C-7. The 6,400 acres of wetlands lost between 1940 and 1984 resulted from the filling of these lands as displayed in Table C-7. Since the regulations during that period did not effectively limit the volume of fill placed in the floodplain, the loss of natural storage was assumed to be equal to the loss of wetlands, based on filling 100% of the floodplain volume.

The 20% volume limit on filling the floodplain, established by New Jersey's 1984 Flood Hazard Area Regulations, could result in potentially different conversion rates for wetlands and natural storage areas for the years 1984 through 2040, as reflected by footnote 2 on Table C-7.

Based on the natural storage loss rate of 70 acres per year, it is estimated that approximately 430 natural storage acres would be lost between 1984 and 1990, and that 3,870 natural storage acres, out of the total 8,620 acres expected to remain at risk, would be lost by 2040. Note that since the hydrologic and hydraulic existing conditions models are based on a natural storage condition as of 1978, the total change in storage from 1978 to 1990 would be 1,630 acres filled.

The total potential wetland acreage impacted by future development plans includes both those natural storage lands that would be filled and those that would be altered or indirectly impacted without filling. Between 1984 and 1990, a maximum of 945 acres of wetlands could be impacted by development plans, while between 1990 and 2040, a maximum of 7,535 acres of wetlands could be impacted.

Central Basin Future Natural Flood Storage Summary. Based on the above, the most probable future without project conditions for the Central Basin natural storage areas for the years 1990 and 2040 are as follows:

a. As of 1984 approximately 24,485 acres of natural storage exist in the Passaic River Central Basin, of which 24,100 acres are classified as wetland.

b. With the adoption of floodway delineations, it is expected that approximately 6,380 of the remaining 24,485 acres of developable natural storage areas would be protected.

c. The Great Swamp National Wildlife Refuge/Lord Sterling Park complex will protect approximately 7,500 acres of wetlands.

TABLE C-7

HISTORIC AND FUTURE TREND OF IMPACTS ON CENTRAL BASIN NATURAL FLOOD STORAGE AREAS

YEAR	CENTRAL BASIN WETLAND ACRES	CENTRAL BASIN NATURAL STORAGE ACRES	INCREMENTAL NATURAL STORAGE ACRES LOST	CUMULATIVE NATURAL STORAGE ACRES LOST
1940	30,500	30,500 [1/]		
			5,200	5,200
1978	25,300	25,300 [1/]		
			1,200	6,400
1984	24,100	24,485		
	[2/]		430	6,830
1990	23,670	24,055		
			3,440	10,270
2040	20,230	20,615		

1/ For historic purposes, wetlands and natural storage areas are assumed interchangeable although it is recognized that there would be at least 385 acres more of natural storage than of wetlands.

2/ This reflects the potential wetland acreage directly impacted by future projected development, i.e., filled (20% of the volume, which represents about 45% of the areal extent based upon geometric determination) or altered without filling (natural cover removed and lawns planted, etc.). Indirect impacts without filling (isolation, flow regime changes) based on total potential lands included in development plans could bring the total wetland acres converted to 945 acres between 1984 and 1990, and 7,535 acres between 1990 and 2040.

d. State, county, and municipal entities have protected an additional 1,985 acres located outside of the floodway boundaries as parkland or open space.

e. A remaining 8,620 acres of natural storage areas are at risk of being partially lost due to filling. The total consists of approximately 8,480 acres of wetlands and 140 acres of non-wetland natural storage. The extent of filling would be limited by the State's Flood Hazard Area Regulations and further limited by the recently enacted Freshwater Wetlands Protection Act. However, the extent to which the Wetlands Act will further limit the loss of natural storage cannot be determined until State regulations are developed and implemented.

f. Based on the Flood Hazard Area Regulations, the limitations on the amount of fill that could be placed within the floodway and flood hazard boundaries would most probably allow an additional estimated 3,870 acres to be filled and another undetermined acreage up to 4,750 acres to be included in development plans, but not filled.

g. Therefore, of the initial 24,485 natural storage acres available in the study area, approximately 3,870 acres within an identifiable risk pool of 8,620 acres are likely to be lost subject to further restrictions by the State's new Wetlands Law.

h. It is projected that 430 acres of natural storage will be lost by the year 1990. Combined with the 1,200 acres lost between 1978 and 1984, this would result in a total natural storage loss of 1,630 acres between the existing conditions (1978) and the 1990 levels. Based on the natural storage loss rate of 70 acres/year, the filling of the remaining 3,440 acres would occur by 2040.

i. The projected filling and development of 3,870 acres of Central Basin lands would result in the accompanying loss of natural flood storage. Table C-4 presents Central Basin flood storage data for the 10, 50, 100 and 500 year events under conditions for the years 1990 and 2040. The filling and development of 3,870 acres would result in the loss of approximately 9,500 acre-feet of flood storage for the 10 year event, while storage losses for the 50, 100, and 500 year events would total about 27,700, 31,300 and 38,700 acre-feet, respectively.

j. The loss of this natural flood storage to development would increase flood flows in the Central Basin and Lower Valley. Table C-4 also presents the natural storage loss impact on flood flows at Little Falls for the year 2040. The Little Falls location, which is the Passaic main stem outlet of

the Central Basin, reflects typical flow changes associated with natural storage losses and is a good indicator of changes elsewhere in the Central Basin and Lower Valley. The effect of natural storage losses is not significant for frequent events, while the impact on flood discharges is more significant for events greater than the 10 year flood. The 2040 flood discharge at Little Falls would increase only by 79 cfs for the 1-year event, while the 100 year event would increase from 28,156 cfs to 33,053 cfs. Average annual equivalent damages would increase by approximately $5,000,000 (October 1985 price levels) without preservation of natural storage areas.

Acquisition Plans. The Federal Emergency Management Agency (FEMA) is involved in floodplain evacuation plans in several communities in the Central Passaic Basin. Currently, six municipalities are participating in the FEMA program, as follows: Pequannock, Riverdale, Montville, Fairfield, Wayne and Lincoln Park.

In Pequannock, a FEMA buyout program approved the acquisition of 40 homes. The owners of 28 of these homes agreed to the sale. To date, 8 structures have been acquired and demolished. Currently, six structures in Riverdale and nine in Montville are under consideration for inclusion in an acquisition program. In Fairfield, 103 structures were considered for acquisition. A total of $736,000 was approved to acquire 24 of these structures. In Wayne, $1,814,000 was approved for buying 49 of the 117 structures investigated. In Lincoln Park, 58 structures have been declared eligible and $2,219,000 was approved for the acquisitions. Only 16 of the structures' owners, however, have applied for the Lincoln Park program. This again points up to escalating real estate prices in the Central Passaic Basin, which places additional development pressures on natural storage areas as described above.

The State of New Jersey, through NJDEP, is also pursuing the acquisition of frequently flooded properties on a limited scale. The N.J. State Legislature has appropriated $5,000,000 for the acquisition of such properties. While there is some overlap with the areas being considered by FEMA, NJDEP has identified eight neighborhoods in Wayne, Pequannock, Oakland, Lincoln Park, and Fairfield for possible evacuation. The areas being considered include Hoffman Grove in Wayne, four neighborhoods in Pequannock (including the northern and eastern sections of Pequannock Avenue, the eastern site of Riverside Drive, and Harrison Road), the Island Terrace Area of Oakland the Two Bridges neighborhood of Lincoln Park, and the Camp Lane area of Fairfield. The latter two areas have not yet been officially included but are under NJDEP consideration. As of August 1987, 13 structures have been acquired and five of these have already been demolished. The acquisition of an additional 12 structures is expected to be completed in the near future and value appraisals are underway for several more structures.

While coordination amongst the State, municipal governments and local residents is ongoing, the same problem encountered by FEMA in Lincoln Park could arise for the State; that is purchase prices approved under the program cannot keep pace with the market prices of structures even highly susceptible to flood damage. For the purposes of this study, however, structures either previously acquired or projected for acquisition have been accounted for in the future without projected conditions for the Passaic River Basin. The structure inventory file used with the future flood damage model for the basin has been updated to reflect those homes that have already been acquired. In addition, based on available information from local interests, the most likely remaining areas to be evacuated are also reflected in the without project conditions. These latter structures include the Camp Lane are in Fairfield.

City of Passaic Redevelopment Plans. On September 2, 1985, the eastern section of Passaic City was destroyed by fire. The affected area included the triangular portion of land bounded by South Street, 8th Street and the Passaic River. Also, a very large industrial complex opposite to this triangular portion of land, on the west side of 8th Street, between South and Market Streets, was totally destroyed. In all, 22 structures were destroyed by the fire. Of these, 16 were residential, 2 were commercial, and 4 were industrial structures. The total market value of the destroyed structures was approximately $133 million (October 1985 price levels).

All of the structures destroyed were in the floodplain, so that redevelopment plans will reflect current Flood Hazard Area Regulations by NJDEP. Coordination with the Department of Planning Association of North Jersey indicates that the redevelopment plan for the area would include townhouses and multifamily dwellings; retail and service establishments; banks; industrial uses; and outdoor recreation facilities. The City expects to request proposals from interested developers for specific redevelopment which would address the broad objectives established for the site.

For the purposes of the future without project conditions, it is projected that the redevelopment value will likely approach, if not exceed, the market value of the destroyed structures. The major difference in the development will be that, in accordance with the Flood Hazard Area Regulations, the first floors of the newly constructed building will correspond to an elevation one foot above the FEMA 100 year design flood. Such changes in the City of Passaic damage reaches have been reflected in the computation of expected annual damages for the without project conditions and the benefits for flood control alternatives.

BIOLOGICAL RESOURCES

Diversity of wildlife and the quality of wildlife habitat in the Passaic River Basin is limited by development. Development has increasingly reduced the amount and the value of terrestrial habitat necessary to support the variety of species which historically inhabited the basin. The basin's aquatic environment has also suffered, as it does not support a well balanced fishery. Despite the continuous trend to urbanize the undeveloped natural areas in the basin, environmental awareness on both local and national levels is making strides to protect some of the more significant basin habitat (primarily the wetlands), to maintain open space (such as the riparian corridors), to protect wildlife species, and to improve the surface water quality in the basin.

The following is a discussion of the terrestrial and aquatic resources: water quality of the Passaic River and its major tributaries; and the rare, threatened and endangered species which currently exist in the Passaic River Basin, and projections as to their status under future without project conditions.

Terrestrial Resources. The terrestrial setting, including vegetative cover types and wildlife in the Passaic River Basin varies appreciably as one proceeds from the Lower Valley to the Central Basin, upstream along the Passaic River or its tributaries, and from the older urbanized centers to the more rural uninhabited spaces.

Despite the preponderance of urban and industrial land uses in the Lower Valley, some habitat types still remain to enhance otherwise limited urban wildlife resources. The few remnant riparian (riverside) and upland habitat areas and linear riverside parks that remain are particularly important as these are the last areas capable of supporting some urban wildlife species and of providing contrast to the biologically homogeneous natures of the surrounding cityscape. The habitat diversity in the ravine at Little Falls, which is provided by the riverine uplands and transitional vegetation, contributes to the species' richness of the Lower Valley. Similarly, the riverbanks that extend for about half a mile above and below Great Falls also add to the habitat diversity and variety of different species in the Lower Valley. Finally, the estuarine and riverine wetlands near the mouth of the Passaic river provide habitat for spawning anadromous fish, which are known to occur in the Passaic River over a distance of about 17 miles above the mouth.

Lower Valley Flora and Fauna. Since most of the land in the Lower Valley is used for urban activities, most of the vegetation that exists is classed as upland cover types of an urban nature. Only a small amount of native natural vegetation remains in the Lower Valley. Since 1940, 8,000 acres of mixed habitat, mostly farmland, and 4,000 acres of open areas have been lost to urban land cover types. Upland forested areas are concentrated in parks outside the potential project area.

Wetlands, once commonly found in the Lower Passaic River floodplains, are almost all gone. Over 7,500 acres have been filled and developed in the Lower Valley since 1940. Only a few remnant pockets of wetlands, usually only several feet wide, may be found along the river's course, particularly below Dundee Dam. Most of the remaining wetland habitats are located in the floodplains along tributaries such as the Third River, Henderson, Goffles, and Molly Ann's Brooks, and the Peckman River, although most of the area along these streams has also been heavily developed. General lack of terrestrial habitats in the Lower Valley has changed the composition of the wildlife from indigenous fauna to more human-tolerant species found in urban settings. The limited nature of the wetlands in the Lower Valley has also reduced its habitat value. Wildlife such as the raccoon, eastern gray squirrel, eastern cottontail rabbit, and oppossum still exists through use of the remaining wetlands and riparian corridors, but the species numbers are very low, with tolerant species present in disproportionately high numbers. The river, however, still provides migratory stopover habitats for certain species of waterfowl such as canvasback, redhead, bufflehead, mallards, and black duck.

Urbanization's encroachment into the Lower Valley floodplains has also severely affected both amphibians and reptiles. Loss of ground cover destroys the moist microclimate habitat and food sources that amphibians need to survive. Birds consist mainly of species such as starlings, grackles, house sparrows, cardinals, crows, doves, and bluejays. Species that require more seclusion and special habitats have been nearly eliminated. Large mammals, such as the white-tailed deer, that require multiple cover types, large quantities of food and freedom from human harassment have also been virtually eliminated from the planning area within the Lower Valley.

Central Basin Flora and Fauna. The dominant terrestrial features of the Central Passaic River Basin are the wetland areas. They constitute an important set of habitats whose plant and animal communities are quite different from the more typical upland areas of northern New Jersey. At nearly 13,000 acres, these wetlands represent about 57% of the ground cover in the Central Basin. The most significant wetlands include Great

Piece Meadows, Hatfield Swamp, Hatfield Swamp South, Troy Meadows, Black Meadows, Bog and Vly Meadows, lower Pompton River, and Canoe Brook. Great Piece, Black, and Troy Meadows are the most productive wetlands based on the number of wildlife species observed.

Other vegetation in the Central Basin includes 1,025 acres of upland cover on 4% of the region. The balance of the region is developed area (8,846 acres) which, over the last 40 years, has replaced much of the natural vegetation. Vegetation existing in the developed areas are dominated by grass, shrubs and shade trees.

Wildlife in the Central Basin is abundant and diverse, owing largely to the presence of extensive wetlands. Surface water is a general requirement of wildlife species, so basin-wide wildlife populations diminish away from the major wetlands. Within the project area, suburban development is continuing to encroach on the wetlands, changing their habitat characteristics and lowering their carrying capacity. This in turn adversely affects species composition.

Amphibians and reptiles are found in all of the seven major Central Basin wetlands. Their widespread distribution throughout the wetlands suggests a healthy stock. A substantial number of bird species also inhabit these wetlands, including both breeders and migrators. The species lists for these wetlands indicate that they are valuable refuges for endangered, threatened, and declining birds species. Mammals, such as the white-tailed deer and chipmunk, exist in the wetlands but are sensitive to habitat changes; so it is feared that these numbers may be reduced substantially if development continues. Raccoons and other small mammals can be more adaptable, coexisting with man in suburban settings. Wildlife associated with upland ground cover in the Central Basin varies in species richness and diversity between the natural upland sites and suburban sites, and also with the age and density of the tree stand. The greatest number and species richness for birds, the most common wildlife found, is encountered in the Pompton River Subbasin near Bog and Vly Meadows. With the exception of species like the white-tailed deer, rabbit and oppossum, few upland mammals are encountered.

Upper Passaic River Terrestrial Resources. The Passaic River reach upstream of Chatham contains approximately 11,600 acres of wetlands including about 8,500 acres of both protected and unprotected wetlands in the Great Swamp Refuge/Lord Sterling Park complex. Although outside of the project area, these wetlands attenuate flood flows and provide some measure of flood control to the Central Basin by storing the flood waters.

Future Conditions of Terrestrial Resources. The continuing trend toward development of upland and wetland areas in the Passaic River Basin will reduce the quantity of terrestrial habitat available for all plant and animal species except those that tolerate the habitats created by residential or industrial development. The availability of natural areas will be more restricted to parks and other areas preserved by legislation, or to areas where development is prohibitively costly (e.g., low-lying wetlands). The continued growth of the regional population and service facilities will heighten the demand for developable land.

The vegetative cover types that characterize the Passaic River Basin range from almost none in urban areas to upland forests, old fields, and a variety of wetland plant communities in rural areas. Development of the existing upland areas is likely in the near future, resulting in the replacement of existing upland vegetative communities with urbanized areas. In addition, some areas of wetland plant communities will be filled for development; the floodplain areas (frequently wetland palustrine forest) are likely to be areas where development will occur. The exaggeration of the natural flooding regime in the remaining wetland areas, resulting from increased flooding being concentrated in smaller areas of wetlands, will impact the remaining palustrine forest and favor the water-loving plant communities dominated by cattails and sedges.

Many sections of Passaic River Basin wetlands, particularly around the borders, have been filled or drained. Based on historic trends, wetland acreage is expected to continue to decline in the future. Continued eradication of the wetlands will cause increased losses of wetland habitats, particularly for state endangered species.

As of 1984, about 24,100 acres of wetland and 385 acres of intermittent low-lying, mixed use, open development remained in the Central Basin. About 6,380 acres are protected by floodway delineation, another 9,485 acres are protected as parkland. The vast majority of parkland is the Great Swamp National Wildlife Refuge/Lord Sterling County Park complex located upstream of the potential project area. The remaining 8,620 acres were determined to be at risk to be developed.

It should be noted that New Jersey Flood Hazard Area Regulations (effective May 21, 1984) limit to 20% the total volume of fill allowed to be placed in these natural storage areas. Taken into consideration with the average slope in the Passaic River Basin, this would allow fill to be placed over approximately 45% of the area in question. Therefore, of the 8,620 acres of developable wetland and other storage areas

remaining in 1984, about 3,870 acres could be filled for development, while the balance could be altered without fill (e.g., with lawns, etc.) or indirectly impacted by development without fill (e.g., lower productivity). At the current estimated rate of natural storage loss of 70 acres per year, it is most probable that about 430 acres would be filled (equivalent to 960 acres included in development plans) by 1990, and the total 3,870 acres filled (equivalent to 8,620 acres included in development plans) by 2040. (Refer to the discussion on Wetlands and Natural Storage, earlier in this section, for further information regarding loss of natural storage areas).

Increasing development of these wetland areas will also reduce wildlife species richness as the total area of wetland habitat is reduced and the remaining area is subject to more perturbation from infringing development. The quality of the remaining habitat will change as fluctuations in water level are exaggerated, and as local land management measures (e.g., ditching) alter the community structure of the wetland habitats. Those species that flourish in grassy areas may find more available habitat, while species preferring poorly drained areas find habitat areas more restricted. Faunal richness and abundance are expected to decline in response to these trends.

Aquatic Resources and Water Quality. The Passaic River is physically and biologically different throughout its 87 mile length from Mendham Township to Newark Bay. As one of the most urbanized river basins in New Jersey, the Passaic River Basin and its waters are subject to many competing uses. Although the river system is used for some recreational and agricultural purposes in the headwater areas, its principal use is as a source of public and industrial water, and as a vehicle for the disposal of municipal and industrial wastewaters. Consequently, water quality of the Passaic River and its major tributaries generally gets poorer in their lower reaches where the aquatic communities show biological changes (losses of pollution-intolerant species) that corresponded with diminished water quality. The following discussion highlights the aquatic characteristics of the Lower Valley and Central Basin, the principal planning reaches for alternative basin-wide flood control solutions. Emphasis is placed on Passaic main stem and tributary reaches that could possibly be impacted by proposed project works.

Lower Passaic River. Both the freshwater and tidal reaches of the Lower Valley (above and below Dundee Dam, respectively), are considered to have poor water quality due to the 10 million gallons per day (MGD) of domestic and processed water discharged by wastewater treatment facilities, the poor quality water

flowing from upstream, and due to the runoff from non-point sources. The fishable and swimmable Federal goals are not met due to low dissolved oxygen (DO), high nutrients and ammonia, and high fecal coliform counts.

Benthic macroinvertebrate species that are tolerant of heavy organic pollutant loads are characteristic of the Lower Passaic River. Species numbers among macroinvertebrates are low; they decline upstream away from tidal influences.

The freshwater portions of the Lower Passaic River and its tributaries contain a warmwater fishery consisting principally of carp, goldfish, white sucker, American eel, and killifish. These pollution-tolerant fish are indicative of the heavy organic loading in this lower reach. Some game fish such as the large mouth bass, however, still persist. The tidal reach possesses a lower Hudson River type fishery (e.g., Atlantic tomcod, red and silver hake, and northern pipefish), estuarine marsh species (e.g., mummichogs, and Atlantic silversides), and several anadromous fish species (e.g., alewife, shad, herring, striped bass, and white perch). Dundee Dam blocks the movement of anadromous fish further upstream along the Passaic River.

The anadromous fish (species that migrate from saline waters to fresher waters to spawn) are supported by the Hudson River/New York Bay estuary in connection with the Lower Passaic River, its principal tributaries and the fresh or nearly freshwater habitats at the northern end of this reach. The existence of adult and juvenile anadromous fish in the Lower Passaic River and its tidal tributaries has demonstrated the successful spawning of American shad, alewife, blueback herring and white perch; striped bass also use the area on a limited basis, although spawning has not been confirmed. Poor water quality, however, is probably the principal factor limiting the success of anadromous herring spawning. Warm weather drops in DO levels also block emigration out of the spawning reach. Although the possibility of establishing a limited sport fishery for anadromous species exists if water quality and habitat conditions improve, dioxin contamination of the aquatic community and sediments has resulted in the placement of restrictions on the sale and consumption of all fish and shellfish taken from the tidal Passaic River.

Central Passaic River. Water quality of the Central Passaic River reach is considered poor. In general, the fishable and swimmable goals are not met due to low DO and high biological oxygen demand (BOD), nutrients, ammonia, and fecal coliforms.

The relatively higher quality water of the Pompton River improves the water quality of the main stem at the confluence, but the lower portions of the reach (downstream of the Pompton River) are degraded by point sources. The flow from these sources (14-15 MGD on average) is significant compared to low flow conditions.

The benthic invertebrate community of the Central Passaic River reach is poor in species representation and species abundance. A warmwater fishery regime of very low diversity exists in the Central Passaic River consisting of carp, golden shiner, pumpkinseed, white sucker, black crappie, spottail shiner, goldfish and silvery minnow. The Central Passaic lacks significant numbers of predatory game fish, indicative of a stressed aquatic ecosystem.

Pompton River. The Pompton River flows through a relatively flat and largely developed suburban area. Water quality is considered fair to good. Point source discharges into the river from industrial and municipal institutional users average 6 MGD and are primarily responsible for nitrogen, phosphate and BOD loadings. The Pompton River waters are generally above state standards as they are able to assimilate these discharges. The Pompton River is considerably cleaner than the Passaic at the confluence of the two rivers.

The limited fishery indicates a warmwater fishery regime dominated by spottail shiner and panfish, but the species composition of rough fish, forage fish, panfish, and game fish is better balanced than in the main stem Passaic River. The Pompton River is designated as "non-trout water," although the NJDEP maintains a trout stocking program in this river.

Pequannock River. The Pequannock and Ramapo Rivers join to form the source of the Pompton River. Only the lower 3 miles of the Pequannock River fall within the potential project area. The water quality of the Pequannock is among the best in the overall basin. On average 3-4 MGD of effluent for the length and 2-3 MGD for the study area are discharged into the river by point sources, resulting in raised BOD and ammonia levels and lowered DO; however, the river meets fishable and swimmable standards. For most of its length, the Pequannock River has a balanced warmwater fishery, however, within the study area an unbalanced warmwater fishery including white sucker, spottail shiner, creek chub and panfish is observed in the Pequannock River. Trout, usually found only in coldwater, exist in the Pequannock River (a trout maintenance area) upstream of the immediate study area. The benthic macroinvertebrate community is moderately rich in species.

Ramapo River. Water quality in the Ramapo River downstream of the Pompton Lake Dam is considered generally good with a few problems resulting from non-point source pollution. Average effluent discharge is 1-3 MGD in the subbasin, and less than 0.1 MGD in the study reach. Water quality standards appear to be met in this study area reach except for fecal coliform levels. A relatively balanced fishery has been observed on the Ramapo River near Pompton Lakes although species numbers were lower than on the Wanaque River. This area is deemed significant based on its use by New Jersey's fish stocking program.

Wanaque River. The Wanaque River, tributary to the Pequannock, flows through a sparsely developed basin of hills, valleys, brooks and lakes, with population concentrated around the lakes. Water quality is generally above state standards due to the limited development and small point source contribution (average 1-2 MGD). Fishable and swimmable goals are also met. Fish species in the Wanaque are dominated by spottail shiner and white sucker, with panfish and predatory game fish also present. Although possessing a warmwater fishery regime, the Wanaque is stocked with trout by New Jersey.

Rockaway River. Water quality in the Rockaway River downstream of Boonton Reservoir (including the study area) is moderately polluted. In the study area, the average point source discharge is insignificant (less than 0.18); however, occasional contravention of the minimum DO standard has been measured at the Pine Brook Station, while fecal coliform levels generally exceed the standard. A warmwater fishery is observed in this reach, which is designated "non-trout water." The moderately rich array of species is dominated by white suckers, spottail shiners, golden shivers, and panfish. The benthic macroinvertebrate community in the lower Rockaway River consists of organisms tolerant of organically enriched waters.

Whippany River. Water quality is fair to poor for the study area reach of the Whippany River below Morristown. This reach does not meet Federal fishable and swimmable goals. Point source discharges are responsible for a significant percentage of the river flow during low flow and are a principal source of BOD, nitrogen and phosphorous loadings. DO standards are periodically violated while fecal coliform levels are significantly above standard. Fish sampling in the lower reaches (designated "non-trout waters"), reflects a warmwater fishery dominated by white sucker, carp, spottail shiner, golden shiner, and panfish.

Future Conditions of Aquatic Resources and Water Quality. In the future, some water quality characteristics (e.g., dissolved oxygen, BOD, nutrient levels) may show localized improvement due to more complete control and treatment of municipal wastes; however, continued residential and commercial development of land areas in the watershed will increase the transport of sediments and contaminants into the Passaic River system from non-point sources. The development of land areas will also increase the magnitude of flooding events; in areas that persist as retention basins, the duration of flooding events will also increase. Effects of flooding events include the resuspension, transport, and deposition of sediments into the floodplain. This stresses the fisheries through poorer water quality and overbank stranding.

Overall quality of municipal wastes discharged into the Passaic River is expected to improve in the future; continued development of the area, however, will be responsible for an increase in non-point source loads to the study area, negating improved treatment.

The lower reaches of the Passaic River are currently used largely by pollution-tolerant fish species; species that require better water quality will continue to be excluded from these lower reaches. The upper reaches and tributaries to the Passaic River, however, are inhabited by a variety of fish species that could extend their ranges back into the Passaic River main stem only if water quality in the main stem improves; at the current rate of development, this will not occur.

Anadromous fish species are reported to be returning to the Passaic River in increasing numbers, and the establishment of a limited sport fishery for anadromous species is a possibility in the future, dioxin contamination notwithstanding. The principal factor limiting success of reproduction of these anadromous species is apparently poor water quality, particularly low DO levels (both seasonal and short term), primarily related to natural variations and not as much to point and non-point sources.

In the absence of additional effluents to degrade water quality, the warmwater fisheries characteristics of the Pompton River will persist, maintaining a moderately rich assemblage of rough, forage, game, and panfish species. Continued development in the Pompton River area will likely result in the loss of some riverbank forest, resulting in warmer water temperatures and decreasing the already marginal suitability of this river for coldwater fish species. As development along the Pequannock River continues in the future, the degree of shading by river-bank vegetation will decrease. The resulting increases in water

temperatures should not affect the richness of the present warmwater fishery, but the river will become less suitable for coldwater fish such as trout. The decommissioning of the Bulter-Bloomingdale sewage treatment plant by 1987 will improve water immediately downstream of the plant.

The Wanaque River, which has water quality characteristics and a fish community similar to those of the Pequannock River, is likely to maintain the warmwater fishery, but the coldwater fish habitat is not likely to be maintained.

The Ramapo River watershed will experience little development in the future, as most of the land outside of the floodway is currently developed. Therefore, little change in this reach of the river is foreseen.

As for the Rockaway River, future increases in the quality of point source inputs will be offset by the increase in non-point source runoff. However, the warmwater characteristics of the fishery will persist.

It is not likely that improvements in the quality of municipal effluents entering the Whippany River can offset the future increases in runoff inputs.

Endangered and Threatened Species. No Federal or New Jersey designated or nominated threatened or endangered species of vegetation are known to exist in the Lower Valley. With the exception of incidental occurrences associated with the migratory patterns of the bald eagle and peregrine falcon, there are no Federally designated threatened or endangered animal species known to inhabit the Lower Valley subbasin. One fish species, the American shad, which the State of New Jersey classifies as threatened, is found in the Lower Valley.

In the Central Basin, searches have yielded no plant species which are designated endangered or threatened by Federal listings. New Jersey listings indicate that two rare species of plants, one each in Great Piece and Troy Meadows may exist. Their locations are such that they are not in areas of structural works or areas where they would be adversely affected by project induced water fluctuations. With the exception of the bald eagle and peregrine falcon, which use the study area during their migratory movements, the same is true for wildlife by Federal listings. On New Jersey listings, in addition to migratory stopovers by the peregrine falcon and bald eagle, seven endangered wildlife species are known or believed to exist in the Central Basin. They include the blue-spotted salamander, Tremblay's salamander, bog turtle, pied-billed grebe, Cooper's hawk, northern harrier, and the sedge wren. Only five of these State-endangered species (the blue-spotted salamander, pied-billed grebe, Cooper's hawk, northern harrier and sedge wren)

87

were found in the Central Basin during recent field searches. New Jersey threatened species found during the survey include the wood turtle, great blue heron, red-shouldered hawk, barred owl, osprey, bobolink, and Savannah sparrow. In addition, there are other animals in need of protection, whose status is uncertain, or in the declining category.

By virtue of New Jersey's endangered species legislation, institutional significance is attached to the Great Piece, Troy and Black Meadows, and Hatfield Swamp. Bog and Vly Meadows are also deemed institutionally significant since three endangered or threatened wildlife species occur in this wetland.

CULTURAL RESOURCES

Prehistoric Sites and Density Distributions. The State Archaeologist, working through the New Jersey State Museum, has researched existing cultural resource data for the Passaic River Basin. No data exists on prehistoric sites for most of the project area from the mouth to the Third River. In this area, the development of most of the land disturbed potential sites, thereby precluding subsurface testing for prehistoric resources.

Low density of prehistoric sites exists around Great Falls, medium density near Dundee Dam, and high density in the Third River, Lincoln Avenue Bridge, and Route 46 areas. These areas are mostly developed. Where they are not developed and preserved by institutional means, they are likely to be developed in the future, disturbing any prehistoric sites which are present.

The Central Basin is an area which offers a high probability for the occurrence of archaeological sites. Substantial areas within the Central Basin possess a high probability for containing prehistoric sites, including South Orange Avenue to Route 10, the Rockaway/Passaic River confluence, Troy and Black Meadows. Moderate density of sites are expected along most of the Passaic River, and high densities are expected between Route 10 and Eagle Rock Avenue, from Route 46 to Route 80, the Two Bridges area, the entire Pompton River, and the Pequannock River from its confluence to Riverdale Avenue. Areas which have been built upon by man have decreased the likelihood of some expected sites remaining intact. Additionally, sampling in conjunction with the Passaic River flood control project failed to reveal new sites. Where areas with high potential for sites are not protected by institutional recognition, development will disturb these sites.

Historic Sites and Density Distributions. Many historic sites and districts remain throughout the Lower Valley including National Historic Districts at Great Falls and Paterson, and Morris Canal in Little Falls and West Paterson. In the future, the sites are expected to remain intact and many may be placed in the National Register of Historic Places, although some of those not protected by institutional recognition could be lost.

The Central Basin has a known average density of 1.39 sites per square mile. Over 10 sites per square mile are recorded for some places, particularly at the confluences of rivers.

There is a high potential for National Historic Districts along older north-south roadways such as Passaic Avenue, Walnut Street, Hanover Neck Road, and Eisenhower Parkway; as well as along east-west roads such as Orange Avenue, Route 10, and Eagle Rock Avenue. In addition, the entire area around Route 46 has a high potential for nomination to the National Register of Historic Places. Suburban settlements are likely to contain only isolated sites. Marsh areas which are presently unsettled have a low potential for containing historic sites.

To the west, historic sites are likely especially along long established routes such as Routes 24, 10 and 46, and Columbia Turnpike. Today these areas are extensively developed. Black Meadows is expected to have isolated historic sites, while Troy Meadows is expected to have low sensitivity. On the Pompton River, Route 202 was a Revolutionary War road; the Morris Canal is also in the vicinity of Route 202. Two National Historic Districts are already recognized in this area: the Morris Canal and the Pompton Iron Works. The Pompton Iron Works is located in the area of the Paterson-Hamburg Turnpike and the Pompton Lakes Dam.

These and other sites where protected by institutional mechanisms will remain. Other sites are likely to be affected in the future by development.

TRANSPORTATION

Existing and Future Facilities. The Passaic River Basin has a large and intricate transportation network. This network of highway routes, rail lines, port facilities and airport centers handles the flow of traffic to and from the densely developed New York metropolitan area and the outlying regions of northern New Jersey.

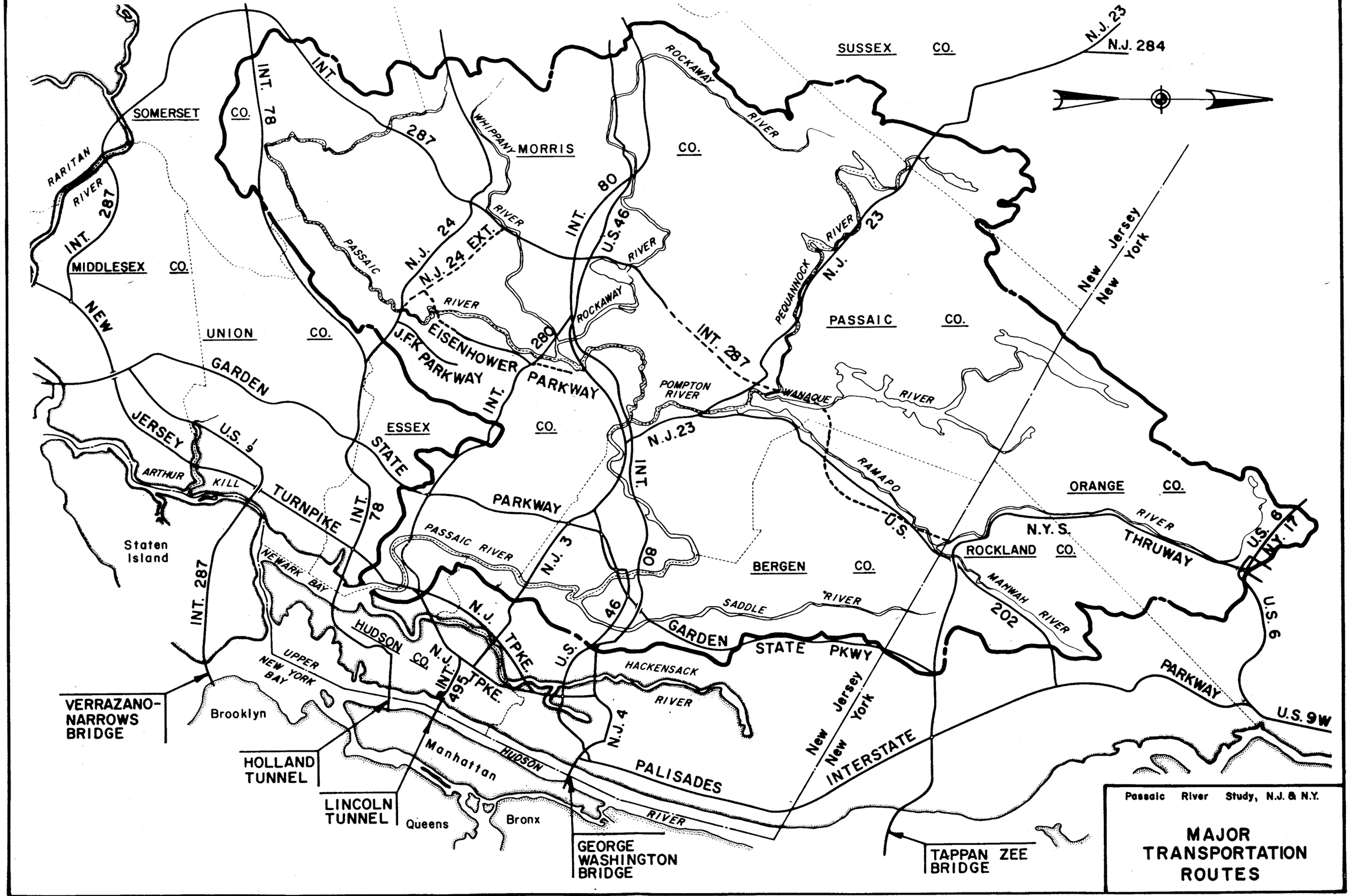
The Lower Valley contains the most densely developed system of transportation routes in the basin. Limited access and mutliple-lane super highway routes traversing the Lower Valley include: the New Jersey Turnpike, US 109, I-280, NJ 21, NJ 3, Garden State Parkway, I-78, I-80, NJ 17 and US 46 (see Figure C-12). Several other primary and secondary routes along with the extensive local street network complete the system. At present, the highway systems operate near or beyond capacity especially during peak traffic hours. Inevitably as traffic volumes through the Lower Valley increase due to the continuing development in the New York-New Jersey area, expansion of the highway system will be necessary. At present, the only plans are the addition of lanes to the New Jersey Turnpike and localized road improvements. Any new systems would be constrained by the highly urbanized nature of the area.

Rail transportation within the Lower Valley is also extensive. Rail transportation is centered on the Newark-Kearny area where several lines converge from all directions on two large railyards. From here, only a few tracks leave for the tunnels to New York City. The major function of the rail lines is freight, although commuter and long distance passenger service is also provided. Both commuter and freight lines carry large volumes of people and goods. Rail traffic through the Passaic River mouth region is especially heavy since most of the industrial areas from Newark to Paterson are serviced by rail lines or spurs.

Commercial navigation on the Passaic River has declined considerably in recent years with only a few port facilities remaining in service along the lower part of the river. Recreational boating on the lower Passaic has become increasingly popular. The Passaic River Restoration Project, an effort designed to enhance the lower Passaic, proposes the development of recreational boating facilities.

The Central Basin also contains several super highways. These include: US 202, NJ 10, NJ 24 and the Eisenhower Parkway. Other major routes in the Central Basin include the continuation of several of the routes found in the Lower Valley. They include: I-80, I-78, I-280, US 46 and US 23. These highways along with other primary and secondary routes service the rapidly growing Central Basin.

Expansion of the highway network is occurring in pace with the continued development of the region. Extensions or modifications of routes currently in progress or planned for the future include I-78, NJ 23, NJ 24 and the Eisenhower Parkway. A section of NJ 23 was recently widened to carry traffic more efficiently. The proposed NJ 24 extension from Chatham to Morristown will cut through the southern portion of the Black



Passaic River Study, N.J. & N.Y.

MAJOR TRANSPORTATION ROUTES

C-70

FIGURE C-12

Meadows in Florham Park. The highway will divide approximately 300 acres of the wetland. It is expected that the highway will foster development through the area. The recent completion of I-78 will make more accessible the upper Passaic region and add to development pressures there. The proposed Eisenhower Parkway expansion skirts the southern portions of Hatfield Swamp and may bring increased development in that area.

In addition to the highway network, there are several small airports located in the basin. Airports such as: Morristown Municipal Airport, Essex County Airport, Lincoln Park Airport and others are handling greater volumes of traffic. Expansion of these facilities is highly probable in the future, though no plans exist at this time.

The outlying reaches of the Passaic River Basin also contain several highway systems. In addition to the continuation of routes already mentioned, the New York State Thruway, I-287 and the John Kennedy Parkway are others which traverse the outlying basin region. Expansion of I-287 through the Pompton Lakes region and skirting the Bog and Vly Meadows will bring greater accessibility to the region and will probably spur development there.

At the present time flood conditions have severe impacts on the transportation network in the basin. Many of the highways and commuter rail lines, such as the Port Authority Trans Hudson (PATH) system in the Lower Valley, are subject to flooding. Flooded highways, bridges, rail lines and airfields cause impacts on the region ranging from inconvenience and delays to costly damages and dangerous conditions in the transportation infrastructure. Conditions in the future without a flood control project are expected to worsen. Continued development made accessible by the expanding transportation network, most notably in the upper watershed, will cause increased frequency flooding and worsening of the effects of flood events on transportation. Unless attenuated, flooding will continue to cause damages and delays throughout the basin's transportation network.

Bridges. Three bridges were recently reconstructed and an additional two bridges are scheduled to be modified before the year 2000, the base year for the proposed Passaic River main stem project. Of these latter two bridges, one will be removed and the other will be reconstructed. The recent and scheduled bridge modifications are discussed in the following paragraphs.

The Hillman Street bridge in Paterson is to be demolished in the near future. It will not be replaced. Its removal will not have a significant impact on the river hydraulics. Although a date for its removal has not been set it is expected to occur before the year 2000.

The Conrail Railroad bridge across the Passaic River between the cities of Garfield and Passaic has been rebuilt. The wooden trestle bridge was replaced in 1980 by a concrete and steel structure. The impact on the hydraulics of the river was found to be insignificant.

The Ackerman Avenue bridge across the Passaic River between the cities of Clifton and Garfield has been reconstructed. Due to its proximity to Dundee Dam, any hydraulic effects from its reconstruction will be minor.

The Route 23 bridge across the Pompton River between the Townships of Wayne and Pequannock is being reconstructed. The deck is being replaced. Additional work is also being done on the piers. The change between the old and new bridges in terms of hydraulic effects is negligible.

The Passaic Avenue bridge over the Deepavaal Brook in the Borough of Fairfield is scheduled to be reconstructed within the next three years. The new bridge will have hydraulically similar effects to the old bridge with minor channel and structural differences.

In addition, several other bridge alterations are proposed, but no definitive plans have been made as to when the alterations will occur. Table C-8 lists both the scheduled and proposed bridge modifications. None of these bridge modifications will have a significant impact on the existing and the future without project hydraulic and economic conditions.

RECREATION

The diversified nature of the Passaic River Basin allows for a wide variety of recreational uses. At present numerous facilities exist which serve both the passive and active demands of the public's recreational desires, but these facilities are not adequate. The major problem areas as identified by the New Jersey Statewide Comprehensive Outdoor Recreation Plan (SCORP) are the lack of recreational opportunities for large segments of the population and the need to preserve more open space. The need for additional open space becomes evident by examination of conditions in Hudson County. The Hudson County "Open-space Acquisition Plan," for example, recommends that by 1990, the county should have 2,659 acres reserved for open spaces and recreation purposes. If these acquisition plans are met, there will still be a deficit of 1,070 acres.

Besides the need for additional open space, the high demand for very popular activities such as bicycling, swimming, jogging and picnicking is greater than the supply of facilities for these activities. The demand deficits for these and other activities are expected to grow in the future and continue to

TABLE C-8 FUTURE BRIDGE MODIFICATIONS

River	Bridge	Municipality	Remarks
Proposed Modifications			
Passaic River	Rutgers St.	Belleville/Kearny/ North Arlington	Proposed rehabilitation
"	Kingsland	Nutley/Lyndhurst	Proposed rehabilitation
"	Union Ave.	Passaic/Rutherford	Proposed rehabilitation
"	Gregory-Main Ave.	Passaic/Wallington	Proposed rehabilitation
"	Maple Ave.	Paterson/Fair lawn	Proposed rehabilitation
"	Straight St.	Paterson	Under feasibility study for rehabilitation or reconstruction
"	Arch St.	Paterson	Under feasibility study for rehabilitaiton or reconstruction
Wanaque River	Wanaque Ave.	Pompton Lakes	Proposed Reconstruction
Rockaway River	Vail Road	Montville/ Parsippany-Troy Hills	Proposed rehabilitation
Scheduled Modifications			
Passaic River	Hillman St.	Paterson	To be removed
"	Conrail Railroad	Garfield/Passaic	Reconstructed
"	Ackerman Avenue	Clifton/Garfield	Reconstructed
Pompton River	Route 23	Wayne/Pequannock	Reconstructed
Deepavaal Brook	Passaic Avenue	Fairfield	To be reconstructed

contribute to the problem of the lack of recreational opportunities. Although the potential for the development of recreational sites exists in many areas of the basin, pressure to develop these areas to meet the needs of the expanding population and economy also exists. In helping to achieve an acceptable balance and reduce recreational deficits, a dual purpose may be served in that the preservation of additional presently undeveloped sites for outdoor recreational purposes can also serve to lessen future increases in flood conditions by utilization of the natural storage which exists at these sites.

The Central and Upper Passaic Basins contain the most potential in terms of future development of new recreational sites. The numerous wetlands, woodlands and streams provide natural areas for outdoor activities. Fishing, hunting and camping are among the available activities. Other recreational sites are currently located within local, state and Federal parks and refuges. Two major sites are the Great Swamp National Wildlife Refuge/Lord Sterling Forest Complex and the Morristown National Historic Park. There is a need for more sites and this is reflected by reaction to the demands in one Central Basin county. Morris County has proposed the addition of 2,200 acres to its park system to meet its needs by 1990. This represents 50% of the county requirements for additional park acreage.

The Lower Valley has less potential for future development of new recreation sites due to its highly developed nature. Existing facilities consist mainly of urban parks. Many of these sites are in riparian corridors adjacent to the Passaic River and its tributaries. Industrialization along the Passaic River has degraded many of the park sites. There exists a need to upgrade many of these sites so that they are more desirable to the public. The Passaic River Restoration Project, an effort designed to restore the lower Passaic riverfront, is attempting to do just that. In conjunction with the Passaic River Coalition and a grant through the New Jersey Department of Environmental Protection to the lower Passaic municipalities, a restoration committee has developed a master plan which suggests the re-zoning of all or parts of the riverfront to a mixed use zone. Several projects recommended by the committee, including a multipurpose hiking/biking trail, parks, and boating facilities, would enhance the recreational character of the lower Passaic River.

HAZARDOUS SUBSTANCE SITES

The Passaic River Basin lies in the heavily industrialized northeastern section of New Jersey. Each year the counties that contain the Basin in New Jersey generate 200 million pounds of hazardous substances. These wastes have been either placed in drums and stored in warehouses, dumped without containment in

landfills and other dump sites, or illegally dumped elsewhere. Unregulated dumping in such areas has resulted in the leaching of hazardous substances into certain wellfields. The Environmental Protection Agency has identified five hazardous substance sites within the 100 year floodplain of the Passaic River Basin for "Superfund" remediation. Forty-five other Comprehensive Environmental Response Compensation, and Liability Act of 1980 (CERCLA) hazardous substance locations not included on EPA's National Priority List have also been identified along the main stem and its tributaries. Of the 50 Superfund and CERCLA sites, only eight CERCLA sites are of concern in formulating flood damage reduction plans. Figure C-13 depicts the locations of the Superfund sites within the 100 year floodplain and the eight CERCLA sites of concern.

Two of the five Superfund sites on the main stem Passaic River are located in the Lower Valley communities of Kearny and Newark. Dioxin has been found in the Lower Valley's river sediments as well as in fish and shellfish. In addition, the eight CERCLA hazardous substance sites of concern are located in the Lower Valley (1987 data).

In the Central Basin, two Superfund sites lie in the immediate study area in Fairfield and Parsippany-Troy Hills. A third site, an asbestos dump, exists in Passaic Township upstream of the study area.

Known hazardous substance sites that may be affected by fluvial and/or tidal floodwaters warrant special attention as they pose the potential hazard of contaminating floodwaters and spreading the hazardous substance over larger areas. The hazardous substances identified in the 50 Lower Valley and Central Basin main stem sites include the following: PCB's, toluene, benzene, carbon tetrachloride, phenol, chloroform, and lead. These substances have been implicated in a range of serious health ailments, including cancer.

The increasing concern expressed by regulatory agencies and the public regarding hazardous substance sites within the Passaic River Basin, particularly within the 100 year floodplain, could lead to identification of more sites than are currently on either the Superfund or CERCLA lists. Future sites will be added to the appropriate lists and will require investigation and remedial action.

NJDEP is committed to the total remediation of the Superfund site at 80 Lister Avenue, Newark by the year 2000. As such, this variable does not enter into the evaluation of proposed plans. The other superfund sites are also undergoing remediation planning, but are at earlier planning stages. Sites going

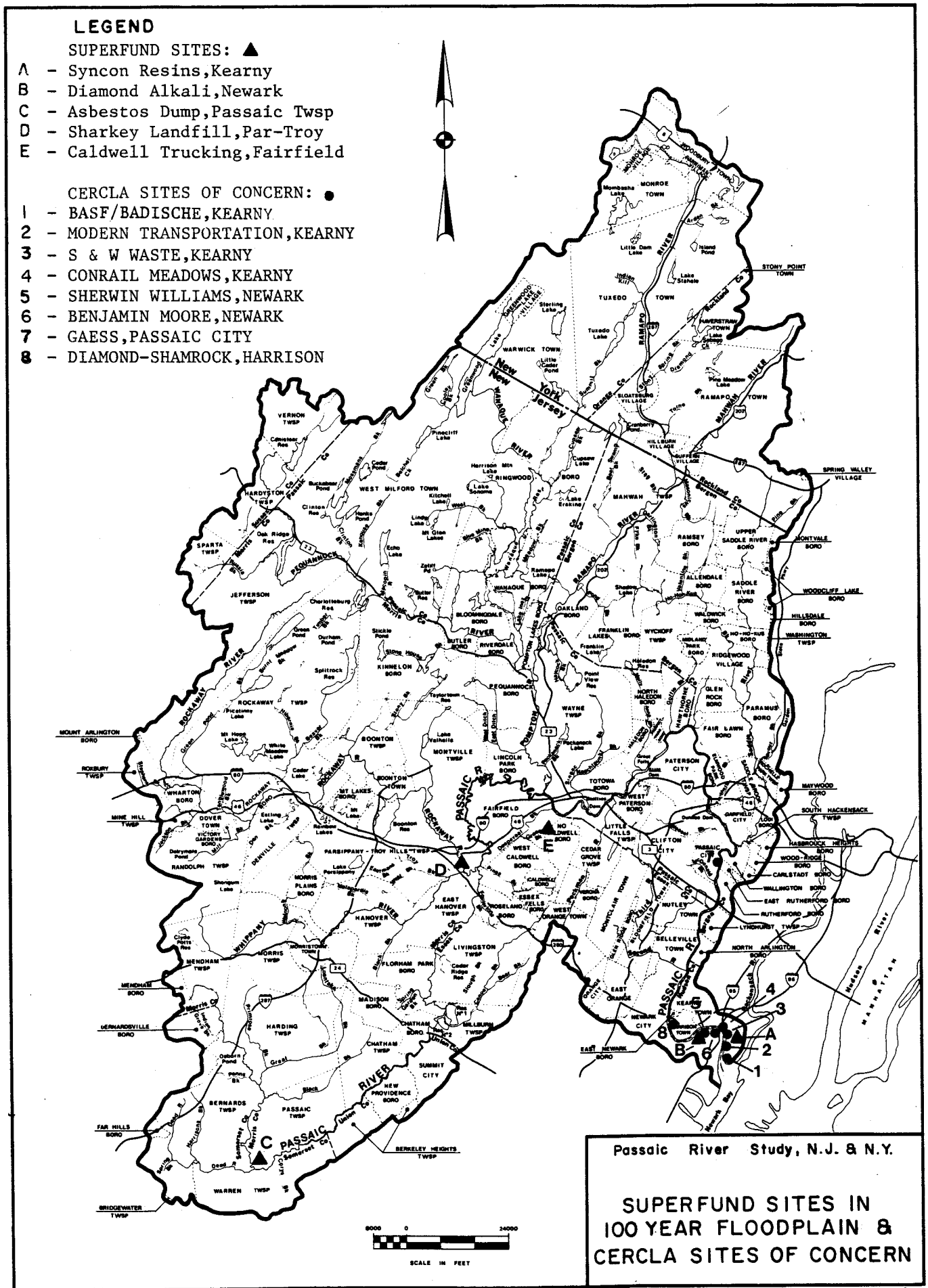

LEGEND
SUPERFUND SITES: ▲
A - Syncon Resins,Kearny
B - Diamond Alkali,Newark
C - Asbestos Dump,Passaic Twsp
D - Sharkey Landfill,Par-Troy
E - Caldwell Trucking,Fairfield
CERCLA SITES OF CONCERN: ●
1 - BASF/BADISCHE,KEARNY
2 - MODERN TRANSPORTATION,KEARNY
3 - S & W WASTE,KEARNY
4 - CONRAIL MEADOWS,KEARNY
5 - SHERWIN WILLIAMS,NEWARK
6 - BENJAMIN MOORE,NEWARK
7 - GAESS,PASSAIC CITY
8 - DIAMOND-SHAMROCK,HARRISON
New York
New Jersey
SCALE IN FEET
Passaic River Study, N.J. & N.Y.
SUPERFUND SITES IN 100 YEAR FLOODPLAIN & CERCLA SITES OF CONCERN

FIGURE C-13

untreated are expected to yield conditions similar to the present, with or without a project in place. This includes riverbottom scouring with subsequent re-release of dioxin into the water column and related contamination of sediments and structures in the floodplain.

WATER SUPPLY

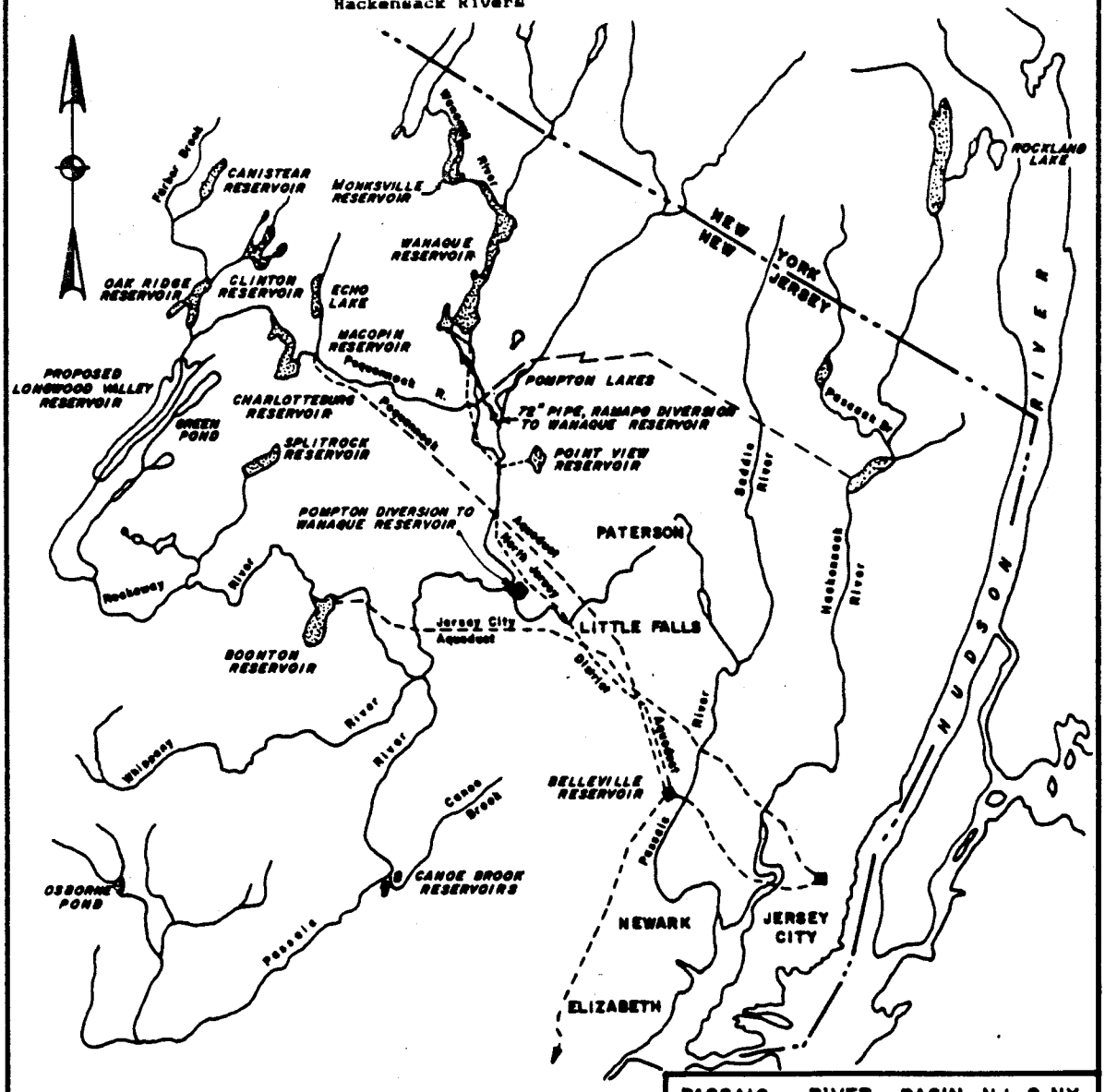
Existing Water Supply Systems. The Passaic River Basin has already been extensively developed for water supply. The water supply study area extends beyond the basin's boundary because of the seven large water purveyors that service northeastern New Jersey, and includes the Passaic, Hackensack and Raritan River Basins.

Development of the surface waters supply systems began in the 1800's when cities experienced groundwater contamination and heavy surface water contamination of local sources; large quantities of pure water were required and even greater quantities were anticipated for the future. As a result, upstream tributaries were developed for the municipal water systems, primarily in the Lower Valley, far removed from their sources. These systems were developed and have grown to their large existing sizes over the years. The Hackensack Water Company, for example, while draining most of its water from the Hackensack River, also draws water from the Saddle River, and has recently participated with the North Jersey Water Supply Commission in the construction of the Wanaque South Project and Monksville Reservoir. It has a service area that includes 60 communities in Bergen and Hudson Counties. Jersey City, located to the southeast of the basin, draws its supply from the Rockaway River and serves some communities in the basin. Newark, which also owns a large share of the North Jersey District Water Supply Commission, draws from the Pequannock River in a similar manner. Typically this water is impounded in the headwaters of rivers that are tributary to the Passaic and transmitted via pipeline to the center of demand. The purveyors are interrelated directly through many interconnections with each other and with several smaller companies. Figure C-14 displays the major surface water supply systems in the Passaic River Basin.

Groundwater is the primary source of water supply in the Highland Area and Central Basin for potable water supply, as the surface water supplies have been largely developed for export from these areas. It provides 75% of the potable water used above Little Falls, but represents only 16% of the total developed water supply upstream of Little Falls. The publicly supplied potable water demand of the area is estimated at 61 million gallons per day (mgd). Approximately 45 mgd of this amount is taken from public wells, the remainder from surface supplies. The largest diversions of groundwater from the

MAJOR SURFACE WATER SUPPLY SYSTEMS

OPERATOR	BASIN	SUPPLY
City of Newark	Pequannock River	Canistear, Oak Ridge, Clinton, Echo Lake, Macopin & Charlotteburg Reservoirs, NJDWSC
Jersey City	Rockaway River	Boonton, Splitrock and Longwood Valley Reservoir
North Jersey District Water Supply Commission	Wanaque & Ramapo Rivers	Wanaque and Monksville Reservoirs, pumped diversion from Ramapo and Pompton Rivers
Passaic Valley Water Commission	Passaic & Pompton Rivers	Diversion from Passaic River and Little Falls, pumped diversion from Pompton River to Point View Reservoir & North Jersey District Water Supply Commission
Commonwealth Water Co.	Passaic R. & Canoe Brook	Osborn Pond Reservoir, pumped diversion from Passaic River, Canoe Brook
Hackensack Water Co.	Wanaque, Ramapo, Pompton, Saddle and Hackensack Rivers	Monksville Reservoir, pumped diversion from Pompton River, diversion from Saddle River



PASSAIC RIVER BASIN, N.J. & N.Y.

MAJOR SURFACE WATER SUPPLIES

FIGURE C-14

Central Basin and Highland Area include the Commonwealth Water Company (12.5 mgd), the City of East Orange from Millburn (8.8 mgd), Morristown (5 mgd), the Parsippany-Troy Hills Water Department (5 mgd), and a number of municipal wells. In addition, approximately 50,000 private wells in the Basin are used for domestic water needs. Much of this groundwater comes from an important source of groundwater known as the Buried Valley Aquifer. The aquifer was formed in a system of former river valleys that have been filled with glacial material. Two segments of the Buried Valley Aquifer have been designated as "sole source aquifers" by the U.S. Environmental Protection Agency.

The aquifer is located under much of Morris County, the western portions of Essex and Union Counties, and under northern Somerset County. Within the Passaic River Basin study area, the aquifer extends beneath the Passaic, Rockaway and Whippany Rivers and Deepavaal Brook.

The section of the aquifer underlying the Great Piece Meadows tends to be formed by a relatively thin layer of sand and gravel (about 20 feet thick,) overlain by deposits of silt and clay ranging in thickness up to 130 feet. In fact, the area from northern East Hanover to Two Bridges is dominated by this consolidated silt and clay and generally does not contain a significant sand gravel/aquifer. There is, however, a productive tributary valley in Fairfield and Caldwell. There is some question as to how the aquifer under the Great Piece Meadows is recharged; however, there are sufficient indications that the recharge comes from higher surrounding elevations and not from the area adjacent to the Passaic River.

While not so well defined, a significant aquifer is located in the Pompton River Valley and possibly underneath the lower Pequannock and Wanaque Rivers as well. These aquifers are believed to be directly recharged both from the rivers and surface runoff. At this time, adjacent communities are served primarily by surface supplies.

As for the Lower Valley, the Passaic River below Little Falls is not used as a source of potable water supply. It is used, however, as an industrial water source, for navigation and to transport waste materials. The Saddle River is used as a small surface water supply source by the Hackensack Water Company, which transfers this water into the Hackensack Basin.

The existing water supply systems in the Passaic River Basin are operating near or above safe yield (the amount of water which could be supplied under repetition of the drought of record). The 1960's record drought, during which rainfall fell to two-thirds of the annual average, caused a deficit in groundwater recharge and has resulted in the reevaluation of water supply source yields which had been based on the previous drought of record that occurred in the 1930's.

Range of Deficits. Two studies reveal the significant water supply needs of the Passaic River Basin for the immediate future. The projections of the State of New Jersey's Water Supply Master Plan for Region 1, which includes the Passaic River Basin, show deficits of 72 mgd through year 2020 and 124 mgd through 2030. The Corps' Northeastern U.S. Water Supply Study (NEWS) projects 241 and 671 mgd, respectively. The differences can be accounted for in the basic assumptions regarding population and employment projections, public versus private systems, and the extent of water intensive technologies in use at the time.

The reported deficits have been reduced by the inclusion of the Wanaque South Project which is scheduled to go into operation this year. An incremental yield of 79 mgd will be supplied to the region from this project. Wanaque South consists of upgraded pumping capacity, additional aqueduct connections, a new Pompton River intake at Two Bridges capable of pumping 250 mgd to the Wanaque Reservoir, and the new Monksville Reservoir on the Wanaque River.

The State of New Jersey's Master Plan has developed alternative solutions for the projected water supply deficits only through the year 2020. Beyond this date, long term concepts are discussed, but the focus is clearly on the immediate future. If the forecasted levels of population and economic activity beyond 2020 are realized, however, the need for additional water supply will be even greater.

For the immediate future, emergency actions during drought events include the use of Greenwood and Hopatcong Lakes as potential water supply sources. Diversions from the Pompton and Passaic Rivers at Two Bridges and from the Ramapo River at Pompton Lakes have also been approved for the North Jersey District Water Supply Commission and Hackensack Water Company. Plans currently being considered include the proposed Washington Valley Reservoir on the Whippany River for the Morris County Municipal Utility Authority.

Future Water Supply Needs. The development of projections for future water supply needs takes into consideration critical variables such as population, economic activity, future water supply requirements and potential supplies from local sources. Based on these, it is projected that deficits remaining in the Passaic River Basin after implementation of the Water Supply Master Plan will be 6.6, 12.7 and 37.2 mgd for the years 2000, 2020, and 2040, respectively.

WASTEWATER

Sources of water pollution occurring by discharging into the Passaic River and its major tributaries can be distinguished as "continuous point source" dischargers and "non-point and intermittent point source" dischargers. Point sources are generally continuous discharges from municipal/institutional treatment plants (including hospitals, schools, and general municipal sanitary wastes), or from industrial wastewater treatment facilities (i.e., process water, cooling water, and/or sanitary wastes). Non-point and intermittent point sources include agricultural runoff, direct land runoff, construction runoff, spills, runoff from septic tanks, storm sewers, combined sewers (during overflow periods), etc. The non-point and intermittent point sources are generally discontinuous over time and are not traceable to specific points.

Point Source Discharges. It is estimated that nearly 200 municipal/institutional wastewater treatment facilities discharge effluent into the rivers of the Passaic River Basin study area. These point source discharges comprise an estimated average flow of approximately 170 mgd. The greatest number and major dischargers of point source effluent are industrial.

On the Lower Passaic River, four municipal/institutional facilities within the study area possess average discharges between 1 and 2 mgd. Industrial discharge flow rates are dominated by the high flow rates listed for Public Service Electric & Gas Company facilities (95 mgd for the Newark facility, 7 mgd for the Harrison facility, 3 mgd for the Paterson facility). Eighty-six other industrial point source dischargers have been identified for this section of the Passaic River; however, the average flow rates are estimated to be approximately 12 mgd.

In the Central Basin, the largest numbers of point sources in the study area occur on the Passaic and Whippany Rivers. On the Passaic River, nine municipal/institutional sources account for an average of approximately 12-13 mgd of effluent. Although there are 20 industrial sources, the estimated volume of effluent is only 2-3 mgd. On the Whippany River, discharges within the study area are predominantly from municipal facilities with approximately 7-8 mgd. The other tributaries in the Central Basin have fewer point sources.

Approximately 11 mgd of wastewater effluents are discharged into the whole Upper Passaic Basin and its tributaries from nine municipal and three private wastewater treatment plants. However, within the limits of the study area subbasin, approximately 6-7 mgd are discharged from six municipal/institutional facilities. In addition, approximately 1-2 mgd of industrial effluent is discharged from 7 industrial facilities. Two sources (Armour Pharmaceutical and Ciba-Geigy) accounted for over 90 percent of the estimated industrial effluent.

Non-Point and Intermittent Point Sources (NPS/IPS). With the increasing levels of control imposed on point sources, the uncontrolled NPS/IPS loads have become more significant and could approach the same order of magnitude as point sources.

The Lower Passaic River exhibits NPS/IPS discharges which predominate over point source discharges at most parameters. It is estimated that 99 percent of the (BOD) and suspended sediment loadings are from non-point sources. Nutrient loadings are also estimated to be predominantly from NPS/IPS discharges.

In the Central Passaic and Pompton Rivers, other than for suspended solids, water quality degradation is estimated to be from point sources. NPS/IPS suspended solids loadings in the Central Passaic River are estimated to be 20 times the point source loadings.

For the Ramapo River NPS/IPS pollutant loadings are estimated to be greater than point source loadings for almost all parameters. However, water quality problems are considered to be minor.

The Pequannock River exhibits point source discharges due to domestic sewage treatment plants which are estimated to be much greater than NPS/IPS loadings, except for suspended solids. Suspended solids loading is considered small, however, and the water is of high quality.

WATER QUALITY

The Passaic River Basin waters are utilized perhaps more than those of any other basin in New Jersey. Although in the headwater areas the river system is used for some recreational and agricultural purposes, the Passaic system is used principally as a source of water supply for both public and industrial needs and as a means for the disposal of municipal and industrial waste waters.

Two factors predominantly control water quality in a river. One factor is the soil chemistry of the aquifers feeding the rivers (along with the soil chemistry of the riverbed) and the second factor is the incidence of waste discharge into the river by industrial and municipal facilities along with non-point sources.

Heavy urbanization and significant increases in population and/or development can degrade rainfall runoff and surface water quality and, in a continued long term trend with increased groundwater pumping, degrade groundwater quality. In addition, washout of upland sediments with rainfall runoff also affects water quality.

Surface Water Quality. Much of the effect that human activity has had on surface water in the Passaic River Basin has previously been discussed in connection with the aquatic resources in the basin. These conditions vary throughout the basin, but generally follow the pattern of good water quality in the headwaters of the main stem Passaic River and its tributaries, degrading to very poor as one proceeds downstream to the mouth of the Passaic River. In overview, the water quality of the various Passaic River subbasins in the study area can be described as follows:

1. Lower Passaic River - very poor, severely degraded

2. Central Passaic River - poor

3. Whippany River below Morristown - fair to poor

4. Rockaway River below Boonton Reservoir - moderately polluted

5. Pompton River - fair to good

6. Wanaque River - high quality

7. Pequannock River - very good to excellent; among the best in the basin

8. Ramapo River below Pompton Lake Dam - good

The poor and degraded water quality of the Passaic River has resulted in failure to meet Federal goals for fishable and swimmable waters. On the tributaries, these goals are generally met, allowing various fish stocking programs in these rivers. More detailed discussion on the water quality of the Passaic River and its major tributaries may be referenced in this section under Aquatic Resources and Water Quality and in Appendix B - NATURAL RESOURCES.

Groundwater Quality. Unconsolidated glacial sediments cover large portions of the study area. Groundwater in these deposits occurs under both unconfined (water table) and confined (artesian) conditions. Heavy pumpage in the southern portions of the basin has lowered water levels, resulting in a conversion from artesian to water table conditions, and allowing the intrusion of chloride-laden seawater.

The confined and semi-confined aquifers are recharged by leakage through the overlying soil deposits, and by precipitation falling on upland regions outside of the project area. Little groundwater recharge occurs from flooding. In fact, groundwater discharge to the Passaic River accounts for a portion, and at times all, of the stream flow.

Current groundwater quality, outside of chloride intrusion, is good, although sparse long-term records show general increases in concentrations of all measured constituents (total dissolved solids, hardness, sulfate, nitrate, chlorides) over the years. These trends are indicative of low-level contamination related to increased urbanization, a pattern that is expected to continue in the future based on population and employment trends.

Sediment Transport and Riverbed Composition. Substrate of the rivers' bottoms in the Passaic River Basin generally consist of rubble, gravel and sand in the upland areas; and sand, silt and muck in the flatter, more developed areas downstream. Suspended sediments tend to settle and accumulate in the wetlands and meandering rivers of the Central Basin, and in the lower reaches of the Passaic, as evidenced by dredging required to maintain navigability.

During flood events, water velocities cause scour and erosion of the river bottoms, suspending sediment and transporting it through the system. Suspended sediments are carried out of the rivers and deposited in the floodplain. On the other hand, upland and side-slopes runoff transport and deposit new particles into the river system. In general, however, there is a net removal from the channels and a net deposition into the floodplain.

In the future, increased development in the basin will result in increased non-point source runoff, including sediment washout during and a few years after construction; and runoff from road surfaces (salts, car oils, etc.), pesticides, fertilizers, and the like. As a result, settling and accumulation of sediment in the lower reaches of the Passaic will

increase. Compounding this problem is the decrease of floodplain and natural storage areas available for removing the sediment from the channel during flood events. A large flood event would redistribute the now more contaminated sediment into the floodplain and living structures, where it is virtually impossible to cleanup.

As previously mentioned, NJDEP is committed to cleanup of dioxin-laden sediment in the Lower Valley; as such, it should not pose as a significant factor in future conditions, with or without a project in place.

HYDROPOWER

Hydropower facilities in the Passaic River Basin are presently limited to three sites. Moving upstream along the Passaic River, the first facility is encountered at Dundee Dam located between the cities of Garfield and Clifton. The maximum power capacity of this facility, operated by American Hydropower, is 2.3 MW. The next facility, the S.U.M. (Society for Establishing Useful Manufacturers) Dam, is located at the Great Falls in Paterson. The S.U.M. Dam was recently refurbished and is capable of generating 11 MW of electricity. The third facility, Beatties Dam, located at Little Falls, is under the jurisdiction of the Passaic Valley Water Commission. The facility is presently under feasibility study for hydropower refurbishment. The possible total power output of these plants, however, would only be a small fraction of the total basin power base.

It is possible that additional hydropower facilities will be developed in the future. The Monksville Dam, currently under construction on the Wanaque River, will be used for water supply; but it has been developed so that a hydropower facility could be installed at a future date. In the Rockaway River watershed, Boonton Reservoir is not capable of power production at this time. However, several proposals have been made to add hydropower to this facility. The Longwood Valley site is currently being considered for multipurpose development including pumped storage hydropower as part of a Corps interim feasibility study under the Passaic River Phase I authority. This study is scheduled for completion in 1988 and would not impact on the formulation of Passaic main stem plans.

AIR QUALITY

The U.S. Environmental Protection Agency (EPA) and the State of New Jersey Department of Environmental Protection have designated the New Jersey area as an Air Quality Maintenance Area.

In the Lower Valley, carbon monoxide levels exceed standards while sulfur dioxide and photochemical oxidants are expected to exceed standards in the near future. New pollution technology is expected to decrease emissions; however, due to development in the Central Basin, increases in traffic through the Lower Valley will add pollutants. Therefore, continued contravention of the standards is expected.

The Central Basin's air quality for sulfur dioxide and carbon monoxide is monitored by the New Jersey Department of Environmental Protection's Air Quality Monitoring Matrix in Morristown. Currently, carbon monoxide levels exceed standards fairly frequently. In the near future, particulate matter, sulfur dioxide, ozone and nitrogen oxides are also expected to exceed standards. Improved pollution technology will help lower emissions from various sources; but, increased development and traffic will raise emissions. Therefore, continued contravention of the standards in the Central Basin is expected.

NOISE

Noise levels are expected to remain fairly high in the Lower Valley area due to its urban nature. Natural areas such as parks provide zones of less noise. Where trees are present in numbers, this can be instrumental to the dampening of noise levels.

In the Central Basin, most noise is due to highway and airport related sounds, as well as, to background sounds from developed areas. Total noise is expected to increase with projected development.

AESTHETICS

The aesthetics of the Lower Valley have been adversely affected by urbanization and development along river banks, except for the areas of riverside urban parks. Future plans call for the beautification of the riverside area and increase of its recreational use.

At present Central Basin aesthetics vary from pleasing natural riparian and open areas to developed residential, commercial and industrial complexes, some of which detract from the areas' aesthetics. With the projected increase of land use in the Central Basin, more natural areas will be lost in the future. This will further disrupt vistas and generally detract from the natural setting.

FLOOD DAMAGES

Flood damages in the Passaic River Basin study area have affected a variety of land uses, ranging from open, undeveloped land to densely developed urban centers. Damages which have occurred in the past and, in the absence of flood control measures, shall continue to occur during similar events in the future include physical damage to all classes of property; loss of business equipment and merchandise; description of normal public activity; and loss of life. Floods and related damages have adversely affected the economy and general well-being of the impacted areas through disrupted operations, declines in business productivity, loss of sales, and diversion of resources to floodfight and cleanup. In addition, the release of untreated sewage from wastewater treatment plants during overflow periods, the disruption of contaminated river bottom sediments, and the dispersal of upland source pollutants pose significant impacts on environmental quality in the Passaic River Basin. Other losses and inconveniences have included the disruption of utilities and municipal services, damaged automobiles, destruction of dams and railroad and vehicular bridges, road washouts, and traffic delays with related lengthy detours.

Historical data on flood damages throughout the Passaic River Basin has been compiled from the 1903 flood to the April 1984 flood, the most damaging flood of recent record in the study area. The 1903 flood is the flood of record for most of the Passaic River Basin, while the flood of July 1945 and more recent floods are the floods of record for several tributaries. The basin experienced additional significant flooding in 1810, 1819, 1843, 1882, 1902, 1917, 1936, 1938, 1951, 1955 and 1960. More recently, flooding has occurred in 1968, 1971, 1972, 1973, July and September 1975 (for each of these six events, portions of the basin were declared Federal disaster areas), November 1977, January 1979, March and April 1983, April 1984 (also prompting a Federal disaster declaration), May 1984 and April 1987.

In each case, severe damage was sustained by residential, commercial, industrial and municipal properties, with several events causing damages in the millions of dollars. During some of these floods, entire villages were destroyed, leaving residents homeless. In other floods, residents were evacuated from their homes and businesses for extended periods of time only to return to the tasks of cleanup, discarding of destroyed property and merchandise, and property rehabilitation including purchase of replacement items. Table C-9 lists some of the major historical floods along with the estimated damages which occurred in the Passaic River Basin.

TABLE C-9

HISTORICAL FLOOD DAMAGES 1/

FLOOD EVENT	DAMAGES (in $1,000 dollars)
MAY 1968	71,700
AUGUST & SEPTEMBER 1971	27,900
AUGUST 1973	$ 2,500
NOVEMBER 1977	$179,000
APRIL 1984	$335,967

1/ October 1985 Price Levels

In the most severe recent flood in the Passaic River Basin, April 1984, overall damages totalled approximately $335,967,000 (October 1985 price levels). This flood was the worst to occur in the basin in 45 years. It resulted from a two day storm which combined about five inches of rain with one foot of snowfall already on the ground. Hydrologic analysis has shown that, in the major damage areas, this flood ranged from a 25 year event (at Little Falls) to about a 50 year flood event (at Pompton Plains).

Several communities throughout the basin along the Passaic River and tributaries sustained substantial flood damages. The worst flooding occurred in Pompton Lakes, Wayne, West Paterson, Paterson and Little Falls in Passaic County; Riverdale, Pequannock, Lincoln Park and Montville in Morris County; Oakland, Fair Lawn and Lodi in Bergen County; and Fairfield in Essex County. The impacted area was declared a National Disaster on April 12, 1984.

Evacuations totalled approximately 9,400 people. Evacuees took emergency shelter in schools, churches, fire stations, friends' and relations' homes, and hotels. About 6,400 residential, commercial, utility, and industrial establishments were significantly damaged by floodwaters. An estimated 2,500 customers of Jersey Central Power and Light Company and 1,200 customers of Public Service Electric and Gas Company lost utility services. Such disruption of up to three weeks along with damage to electric and gas meters prevented people from returning to their homes, caused damages to heating systems, and caused extensive losses in refrigerated food supplies. Water seepage into gas meters and broken seals caused explosions in several areas damaging both the exterior and interior of structures. In addition, numerous street and bridge closings were reported, creating massive traffic delays throughout the basin. Major highways were at a standstill for hours and impassible for days. Three lives were lost due to the April 1984 flood.

Flood relief for the April 1984 event involved many State of New Jersey agencies including the Departments of Health, Community Affairs, Human Services, Labor, and Transporation, as well as the State Police and the Bureau of Floodplain Management. Federal agencies such as the National Guard, U.S. Army Corps of Engineers, Environmental Protection Agency and Civil Defense also supplied aid along with national volunteer organizations, the Red Cross and the Salvation Army.

Without implementation of a solution to reduce or eliminate these flood events, it can only be expected for such flood related conditions to worsen as the basin is further developed.

Without project conditions damages for the Passaic River Basin have been assessed for the present (or existing conditions of 1985) and future (years 1990 through 2050), encompassing the period of analysis for the Passaic River main stem project. All estimates of damages are presented in October 1985 price levels. Table C-10 details the levels of damage expected to occur under present conditions during a 10 year, 100 year and 500 year flood event along the Passaic River and each major tributary. It also includes a comparison of damages for the 10 year flood versus the damages for the 1968 flood under current conditions, an approximate 10 year event. The number and type of structures in the 100 year and 500 year floodplain, for each tributary are detailed in Table C-11.

To facilitate the collection of flood damage data, as well as the economic and hydraulic analyses, the basin's study area was divided into over 200 damage reaches. A brief discussion of the river subbasins comprised of these reaches and their associated flood damages is presented below. Table C-12 summarizes existing conditions expected annual damages by damage category for each river subbasin. Damages expected to occur in years 1990, 2000 and 2050, along with equivalent annual damages, under without project conditions are presented in Table C-13. Note, however, that computation of equivalent annual damages consists of discounting expected annual damages over the period of analysis for the considered flood control solutions (years 2000 to 2050) back to the project base year (2000), and as such, does not incorporate expected annual damages for 1990.

Lower Passaic Damage Reaches. The Lower Passaic River main stem reaches, extending from the mouth of the Passaic River upstream to Beatties Dam, plus backwater areas on Molly Ann's Brook and on the Peckman River are grouped together to form the Lower Passaic damage reaches. The Lower Passaic reaches contain 6,103 residential structures and 1,881 commercial, utility and industrial establishments within the 500 year floodplain. Major damage areas extend through the industrialized municipalities of Newark, Kearny, and Harrison near the mouth; Clifton, Passaic and Wallington above Van Winkle Avenue; Paterson in the vicinity of S.U.M. Dam; and Little Falls, West Paterson and Totowa below Beatties Dam. Damages occurring in these reaches due to a 100 year flood event would be approximately $404 million while damages for a 500 year event would be approximately $1.2 billion.

Central Passaic Damage Reaches. The Central Passaic River main stem reaches, extending from Beatties Dam upstream to the U.S.G.S gage in Chatham Borough, plus backwater areas on Preakness Brook are grouped together to form the Central Passaic damage reaches. The Central Passaic reaches contain 5,683 residential structures and 1,593 nonresidential establishments in the 500 year floodplain. Major damage centers exist in the municipalities of Wayne and Little Falls near the Willowbrook

///

TABLE C-10

EXISTING CONDITIONS DAMAGES 1/

(Dollars in 1,000's, Oct. 1985 Price Level)

RIVER	MAY 1968 FLOOD CURRENT CONDITIONS 2/ 3/	10YR FLOOD EVENT 4/	100YR FLOOD EVENT	500YR FLOOD EVENT
LOWER VALLEY	29,300	28,710	403,600	1,188,090
CENTRAL BASIN	25,900	33,220	312,800	905,660
UPPER PASSAIC	2,300	1,520	6,050	15,980
POMPTON VALLEY 5/	81,500	80,180	320,980	581,940
TOTAL	139,000	143,630	1,043,430	2,691,670

1/ FIGURES HAVE BEEN ROUNDED AND, THEREFORE, MAY DIFFER FROM THOSE IN ECONOMICS SUPPORTING DOCUMENTATION.

2/ HISTORICAL FLOOD DAMAGE DATA FROM NEWSPAPER ACCOUNTS AND CORPS POST FLOOD REPORTS.

3/ FIGURES UPDATED TO REFLECT INCREASES IN DEVELOPMENT (AN APPROXIMATE 100% INCREASE IN THE NUMBER OF STRUCTURES FROM 1968-1985) AND OCT. 1985 PRICE LEVELS.

4/ EXCLUDES DAMAGES DUE TO TIDAL FLOODING FOR COMPARISON WITH MAY 1968 STORM DATA.

5/ INCLUDES POMPTON RIVER AND TRIBUTARIES - WANAQUE, PEQUANNOCK, AND RAMAPO RIVERS.

TABLE C-11
BASE CONDITION DEVELOPMENT FOR STUDY AREA

TYPE OF STRUCTURE	100 YEAR FLOODPLAIN	500 YEAR FLOODPLAIN
	LOWER PASSAIC	
RESIDENTIAL	5,267	6,103
NON-RESIDENTIAL*	1,770	1,881
TOTAL	7,037	7,984
	CENTRAL PASSAIC	
RESIDENTIAL	4,149	5,683
NON-RESIDENTIAL*	1,407	1,593
TOTAL	5,556	7,276
	UPPER PASSAIC	
RESIDENTIAL	870	1,089
NON-RESIDENTIAL*	276	297
TOTAL	1,146	1,385
	POMPTON RIVER	
RESIDENTIAL	4,587	5,283
NON-RESIDENTIAL*	513	657
TOTAL	5,200	5,940
	PEQUANNOCK RIVER	
RESIDENTIAL	317	328
NON-RESIDENTIAL*	19	22
TOTAL	336	350
	RAMAPO RIVER	
RESIDENTIAL	1,054	1,201
NON-RESIDENTIAL*	76	92
TOTAL	1,130	1,293
	WANAQUE RIVER	
RESIDENTIAL	188	233
NON-RESIDENTIAL*	27	40
TOTAL	215	273

* THE NON-RESIDENTIAL STRUCTURE TYPE INCLUDES INDUSTRIAL, COMMERCIAL, UTILITY AND APARTMENT STRUCTURES. IN MANY CASES, INDUSTRIAL COMPLEXES COUNTED AS ONE ESTABLISHMENT, CONTAINED MORE THAN ONE STRUCTURE. FOR EXAMPLE, IN THE LOWER PASSAIC REACHES, APPROXIMATELY 192 INDUSTRIAL COMPLEXES WERE FOUND TO CONTAIN 720 INDIVIDUAL STRUCTURES. SEVERAL APARTMENT BUILDINGS COMPRISING ONE COMPLEX WERE ALSO COUNTED AS ONE STRUCTURE.

TABLE C - 12

TOTAL EXISTING CONDITIONS EXPECTED ANNUAL DAMAGES[1/]
(OCTOBER 1985 PRICE LEVELS; $1,000'S)

	RES	APT	COM	IND	UTL	RESCON	APTCON	MUN	TOTAL[2/]
LOWER PASSAIC	2,770	200	4,140	16,390	790	1,090	50	4,580	30,010
CENTRAL PASSAIC	4,960	40	9,910	4,550	80	1,870	10	3,430	24,850
UPPER PASSAIC	260	0	150	30	10	90	0	90	630
POMPTON RIVER	9,010	220	6,330	1,760	180	2,930	90	3,280	23,800
PEQUANNOCK RIVER	260	0	4	0	0	100	0	50	410
LOWER RAMAPO RIVER	2,500	0	170	4	1	700	0	510	3,880
WANAQUE RIVER	270	2	70	7	0	90	1	60	500
TOTAL[1/]	20,030	460	20,770	22,740	1,060	6,870	150	12,000	84,080

1/ FIGURES HAVE BEEN ROUNDED AND, THEREFORE, MAY DIFFER FROM THOSE IN ECONOMICS SUPPORTING DOCUMENTATION.

2/ TOTALS MAY NOT MATCH DUE TO ROUNDING.

TABLE C-13

IMPACT OF FUTURE HYDROLOGY [1/]
ON BASE YEAR WITHOUT PROJECT CONDITIONS
(in $1,000 Dollars)

	EXPECTED ANNUAL DAMAGES [2/]				AVERAGE ANNUAL EQUIVALENT
	1985	1990	2000	2050	DAMAGES (AAED)
PASSAIC RIVER					
LOWER VALLEY	30,010	32,420	35,620	47,160	36,650
CENTRAL BASIN	24,850	28,880	30,900	40,300	33,280
UPPER PASSAIC	630	670	690	760	700
POMPTON RIVER	23,800	25,450	26,330	29,930	27,270
WANAQUE RIVER	500	520	530	560	540
PEQUANNOCK RIVER	410	410	420	450	430
LOWER RAMAPO RIVER	3,880	4,210	3,990	4,380	4,420
TOTAL	84,080	92,560	98,480	123,540	103,290

1/ FUTURE FLOWS INCLUDE THE EFFECTS OF PROJECTED BASIN-WIDE URBANIZATION AND PROJECTED DEVELOPMENT IN CENTRAL BASIN NATURAL STORAGE AREAS.

2/ FIGURES HAVE BEEN ROUNDED AND, THEREFORE, MAY DIFFER FROM THOSE IN ECONOMICS SUPPORTING DOCUMENTATION.

Mall Shopping complex, Fairfield and West Caldwell along Deepavaal Brook, and in Parsippany-Troy Hills, East Hanover and Lake Hiawatha along the lower Rockaway River. Damages in these reaches due to the 100 year and 500 year flood events are approximately $313 million and $906 million, respectively.

Upper Passaic Damage Reaches. The Upper Passaic River main stem reaches, extending from the U.S.G.S. gage in Chatham to the Dead River in Passaic Township, are grouped together to form the Upper Passaic damage reaches. Upper Passaic damage reaches contain 1,089 residential structures and 297 nonresidential establishments and include commercial, industrial and utility structures. Major damage areas are located in the Townships of New Providence, Berkeley Heights and Passaic. Damages in these reaches due to a 100 year flood event would be approximately $6.0 million while damages for a 500 year event would be approximately $16 million.

Pompton, Lower Ramapo, Wanaque and Pequannock Rivers Damage Reaches. Reaches along the Pompton, Lower Ramapo, Wanaque and Pequannock Rivers were analyzed with the main stem Passaic River due to the interdependence of their flows. The number of residential structures and nonresidential establishments in the 100 year floodplain and the 500 year floodplain in each of the tributary areas are listed in Table C-11. Damages for these areas due to 100 year and 500 year flood events are estimated to be $321 million and $582 million, respectively.

Total existing conditions expected annual damages for the Passaic River Basin study area are approximately $84,080,000. The existing basin conditions for which this assessment was made have been discussed previously in this section with regard to demographics, land use, biological and cultural resources, and other basin characteristics.

Future Conditions. Total expected annual damages in the study area under future without project conditions are projected to be $92,560,000 for the year 1990, $98,480,000 for 2000, and $123,540,000 for 2050. The average annual equivalent damages total $103,290,000. (See Table C-13 for a breakdown by individual river). The contributing factors in these futures have been previously discussed in this section. They include the overall impacts of land use changes expected to take place in the future, primarily urbanization and partial loss of natural storage areas, and, to lesser degrees, acquisition of structures in the floodplain, redevelopment plans for the City of Passaic, and bridge modifications. These direct causes reflect the effects from population and employment projections, local plans, and the altering status of land use regulations throughout the basin. Tables C-3 and C-7 display the projected extent of urbanization and development of natural storage areas in the study area.

NON-FEDERAL FLOOD CONTROL PROGRAMS

The State of New Jersey and, on an individual basis, some municipalities have initiated locally sponsored programs to alleviate flooding conditions in the Passaic River Basin. The State's program incorporates several actions and is broader in scope as it addresses a regional problem, while the municipal plans tend to be more focused on protecting specific structures.

State of New Jersey Flood Control Program. In conjunction with the selection of a Corps flood damage reduction alternative for the Passaic River Basin, the NJDEP has also announced, through its June 28, 1984 letter to the Corps of Enginers, that the State of New Jersey is independently proceeding with additional activities designed to provide them with a comprehensive program for the basin. Several of these initiatives are discussed in separate portions of this section including: Flood Hazard Area Regulations; Storm Water Management Regulations; preservation of natural storage areas; acquisition plans; an early flood warning system; and a snagging and clearing program. The complete list of NJDEP initiatives for the Passaic River Basin follows below:

1. New Flood Hazard Area Regulations to control construction and filling in the floodways and flood fringe areas - Effective May 21, 1984.

2. Education work sessions for municipal and county officials for the implementation and enforcement of the Flood Hazard Area Regulations.

3. Develop a formalized method for municipal and county involvement in the implementation of Flood Hazard Area Regulations.

4. Accelerate the completion of Flood Hazard Area delineations in the Passaic Basin.

5. Pursue means to make existing Storm Water Management Regulations mandatory - support Assemblyman Bennett's bill through the legislative process.

6. Preserve natural storage areas through the acquisition - regulation of wetland areas - Support legislation by Senator Lynch and Assemblywoman Ogden through the legislative process.

7. Seriously consider acquisition of frequently flooded properties on a limited scale, as an alternative to protecting those properties.

8. Continue to serve as non-Federal sponsor for a flood early warning system being developed as a Federal flood control project - support legislation by Assemblyman Loveys through the legislative process.

9. Work in conjunction with the Corps of Engineers to design a program for cleaning, desnagging and limited dredging in order to mitigate nuisance flooding.

10. Continue to serve as non-Federal sponsor for Interim Flood Control Projects in the basin.

Preservation of natural storage areas and acquisition of frequently flooded properties have been previously discussed in connection with Land Use Changes in the basin. The balance of the NJDEP initiatives are discussed below.

Flood Hazard Area Regulations. The State of New Jersey promulgated new Flood Hazard Area Regulations adopted on 21 May 1984 providing rules for the placement of fill in floodplain areas. These regulations would, in effect, limit the amount of natural storage areas which could be lost to development. The application of these regulations is further discussed in Section 5 under BUILDING BLOCK 20 - PRESERVATION OF NATURAL STORAGE AREAS. The new rules can be summarized as follows:

1. Within the flood fringe area of delineated streams or within the 100-year floodplain (but outside of encroachment lines of non-delineated streams), the volume of net fill and structures to be placed on an applicant's site is limited to 20 percent of the total volume between the natural ground surface of the applicant's property and the level of the flood hazard design elevation along delineated streams or the 100-year storm elevation along non-delineated streams.

2. Applicants must adequately show, on submitted plans and in calculations, that this limit of 20 percent is not being exceeded.

3. Fill must be placed in a manner so that for all proposed hospitals, nursing homes, schools, day care centers, residences and similar non-commercial structures, the lowest floor, including any basements, is a minimum of one foot above the 100 year flood elevation along non-delineated streams, or at or above the flood hazard design elevation along delineated streams.

4. All fill must be graded in a manner so as not to adversely affect overland drainage flows.

5. Fill must be placed so that slopes are not steeper than a ratio of two horizontal to one vertical.

6. Fill must be compacted and stabilized in accordance with the "Standards for Soil Erosion and Sediment Control in New Jersey."

Additional requirements exist for fill in the Central Passaic River Basin. They are as follows:

7. Within the Central Passaic Basin, any net fill (fill not taken from the applicant's project site) placed upon a project site must be counterbalanced by corresponding excavation within the Central Passaic Basin.

8. Both on-site borrow excavation and any corresponding excavation elsewhere in the Central Basin must be taken from between the natural ground surface and either the mean low water level of the adjacent stream, or the seasonally adjusted high groundwater level, which ever is higher.

Storm Water Management Regulations. The NJDEP's storm water management regulations for New Jersey, based on the State of New Jersey's Storm Water Management Act (PL 1981 C. 32), became effective in February 1983. This Act amends the Municipal Land Use Law to require all municipalities to develop and enforce storm water management plans and ordinances, under certain conditions. One of these conditions was the appropriation by the State of 90% of the costs for developing these plans. Between 1983 and 1985, virtually no progress was made in implementing storm water management plans, with the exception of Bergen County, since no monies had been appropriated by the State to fund the development of the plans. The Bergen County Board of Chosen Freeholders, through a resolution passed in 1980, has adopted a separate storm water management performance and design standard policy.

In 1985, however, New Jersey appropriated $2,000,000 for the local development of storm water management plans, $1,000,000 for counties and $1,000,000 for municipalities. State-wide, to date, NJDEP has approved grants to 6 counties and has received applications for grants from an additional 2 counties and 93 municipalities. Each municipality is limited to a maximum grant of $5,000. Finally, legislation is pending which would repeal the condition requiring 90% funding by the State. All communities would be required to implement storm water management plans regardless of whether they received development funds from the

State or not. Municipalities that had applied prior to this new measure would still be eligible for State funds. The introduction of this measure could have the effect of stimulating applications to the State for development funds and accelerating the spread of implemented plans.

Early Floodwarning System. An existing floodwarning system for the Passaic River Basin is maintained by the National Weather Service (NWS). As discussed in Section 5 of this appendix, the Corps of Engineers is currently implementing improvements to the preparedness system. The recommended improvements are aimed at speeding data collection, minimizing data collection inaccuracies, and enhancing the warning dissemination and response. The project, which is being implemented under the Corps' Section 205 Small Project Authority, is fully described in the portion of Section 5 entitled FLOODWARNING/PREPAREDNESS.

It is recognized that the proposed emergency preparedness plan is of a temporary nature, since it does not provide a continuous and consistent level of protection across a range of hydrologic occurrences. The overall preparedness system affects neither the stage nor the frequency of flooding; and because benefits are accrued only up to the estimated time of implementation of potential permanent projects for the basin, the without project condition would not change measurably. Nor would the potential benefit pool available to the more permanent solutions be impacted. Implementation of the emergency preparedness plan, therefore, does not preclude or alter the formulation of permanent solutions to the flooding problems along the Passaic River and its tributaries.

Snagging and Clearing. In 1986 local interests finished negotiating contracts for the cleaning of the Pompton River. The municipalities of Pequannock, Lincoln Park and Wayne signed agreements with a contractor to dredge approximately six miles of the Pompton River and almost one mile of the Ramapo River at no cost to the towns. Rather, the work is being performed in exchange for the salvage value of the fill that the contractor removes. Work is scheduled for completion in 1987. The Borough of Pompton Lakes has contracted for a cleaning and desnagging project along the Wanaque, Pequannock and Ramapo Rivers, Post and Acid Brooks. This work, which is being carried out in part with Federal funds from the Department of Housing and Urban Development, is scheduled for completion in 1988.

These two local projects are aimed at removing sediments and debris that have accumulated in the river during and subsequent to the April 1984 flood. In general, this will have the effect of returning the rivers to approximately the 1979 hydraulic conditions. Local interests hope this may partially mitigate

the effects of the nuisance floods that occur several times each year (i.e., floods with frequencies greater or equal to the annual event). However, the extent of the work is limited by requirements regarding dredging at highway bridges and conditions in permits from the NJDEP and the Corps of Engineers. It is not expected that such work would measurably modify the without project conditions, thereby maintaining the appropriate use of existing conditions analytical models for this study which reflect stream cross-sections under 1979 conditions.

Local Levee Projects. Two municipalities have considered constructing levee systems that are included in the array of Corps of Engineers alternatives, prior to Federal plan implementation. The Borough of Montville has proposed to construct a levee along the left bank of the Rockaway River north of Changebridge Road, which corresponds to the Rockaway #2 levee system in the Corps' alternatives. However, the NJDEP has not granted a stream encroachment permit to Montville for this levee because of impacts to 35 acres of natural storage along Hatfield Brook. NJDEP has indicated that it will support the construction of the Montville levee only as part of a comprehensive plan. As such, the construction of the Montville levee is not considered probable as part of the Passaic River Basin's without project conditions. Its feasibility, therefore, is considered as part of the formulation of Corps flood damage reduction alternatives.

Parsippany-Troy Hills has proposed the construction of a levee along the right bank of the Rockaway River between Vail Road and Tioga Avenue which corresponds to the Rockaway #3 levee system in the Corps' alternatives. Local interests have planned this levee with a 100 year level of protection and the NJDEP has approved the preliminary design. However, until a final decision is made regarding this levee, the without project conditions assume no action on the part of local interests, thus allowing consideration of a levee in this area, described in Section 10 of this Appendix as the Rockaway #3 levee system, without precluding Federal interest prematurely. It is noted that if local interests do win final approval of their plan and initiate construction of the levee, the without project conditions would be so modified for further design studies. Such local work in advance of Congressional authorization or financing would not be eligible for Federal reimbursement without special legislation.

SECTION 3 - PROBLEM IDENTIFICATION

GENERAL

Early study efforts were directed towards defining the physical study area and the nature of water and related land resource management problems to be addressed by the Passaic River Basin Study. This first involved establishing the range of needs (opportunities and problems) which the study could encompass. These problems and needs were derived from the following sources:

(a) Previous reports on the resources of the Passaic River Basin, including those of the Corps of Engineers, other Federal, State, County and local agencies, and public and private interests.

(b) Preferences, opinions and other inputs received from interested parties, either spontaneously, or in response to public involvement and citizen participation activities.

(c) Preliminary information developed for the Corps of Engineers by the U.S. Fish and Wildlife Service.

(d) Data developed for the Section 208 Northeast New Jersey Water Quality Management Study and the New Jersey Water Supply Master Plan Study.

PROBLEMS AND NEEDS

A list of local concerns and desires identified is presented in Table C-14. These issues were examined in order to establish their relationship with the Corps' traditional purview for water resource problems and the specific Congressional mandate for this study. Based upon this review, problem and opportunity statements for this study area were developed. The final problem and opportunity statements are presented in Table C-17 later in this Section. These statements have been modified continuously during iterations of the planning process to reflect the availability of more specific data.

The principal problem and need addressed by this study is the reduction of tidal and fluvial flood damages at areas along the Passaic River mainstream and its tributaries. It is noted that all of the problems and needs of the Passaic River Basin cannot be addressed as part of this study. Only those water resource related needs which either can be addressed within the study authority to enhance the national objective of the National Economic Development Plan (NED) or are legislative requirements were included in these statements. A brief discussion of the needs which are addressed follows below.

TABLE C-14

SUMMARY OF THE PROBLEMS AND NEEDS OF THE PASSAIC RIVER BASIN

I. Water

A. Control of flooding.
B. Hurricane protection.
C. Erosion control.
D. Storm water management
E. Water conservation/supply.
F. Maintain quality of drinking water.
G. Control point and non-point sources of pollution.
H. Improve overall quality of Basin waters.
I. Increase hydropower potential/energy conservation.
J. Maintain free flowing rivers.
K. Preserve, restore, and create wetlands.
L. Provide additional water based recreation, i.e.,lakes, white water canoeing, and fishing.
M. Protect and/or enhance aquatic habitat, particularly rare or endangered species.
N. Control areas that provide habitat for mosquitoes and other disease vectors.
O. Aquatic weed control.
P. Maintain or increase water borne commerce opportunities in the Lower Passaic River.
Q. Education of the public regarding the flood hazard and other associated problems and needs of the Basin.
R. Protection of groundwater sources.

II. LAND

A. Control development in floodplain and other environmentally sensitive areas (including flood fringe, and aquifer recharge areas).
B. Preserve open space for passive and/or recreational recreational use.
C. Preserve structures or sites of cultural significance, i.e., existing or potential national and state historic sites.
D. Preserve scenic areas, i.e., Great Falls.
E. Protection of trees and plants, particularly those of State and National significance.
F. Protect and/or enhance aquatic habitat, particularly rare or endangered species.
G. Improvement and locations of transportation networks.
H. Preserve agricultural lands.
I. Control of brush fires.
J. Create opportunity for land development.

III. POLLUTION

A. Control dumping and discharges into Basin waters.
B. Solid waste management/additional sewage treatment facilities.
C. Management of storm water runoff.
D. Improve air quality.
E. Reduce noise levels.
G. Remediate hazardous substance sites.

IV. OTHER

A. Create master plan for basin to protect its existing natural resources.
B. Develop institutional framework to address and control exploitation of natural resources.
C. Maintain status quo.
D. Creation of new jobs.

FLOODING PROBLEM

The basin's history of severe flooding stems from its geographic location in the East Coast storm belt and the fact that residential and industrial growth have led to the development of floodplain lands. Major flooding has occurred numerous times in specific areas along the Passaic River and its tributaries. Significant flooding throughout major portions of the Basin occurred as recently as April 1984.

The seriousness of the flood problem is clearly evidenced when the consequences of a recurrence of the October 1903 flood are considered. Under existing conditions of development within the Basin, a flood event comparable to the 1903 flood could inundate about 20,000 dwellings, businesses, industrial and utility plants and public institutions and result in damages totaling approximately $1.1 billion, at October 1985 price levels, along the main stem Passaic River.

As discussed in Section 2 under FLOOD DAMAGES, the Basin has experienced frequent and significant historical flooding. The estimated average annual flood damages throughout the Basin at current price levels total more than $84 million.

The flood problem within the Passaic River watershed can be considered in two parts: (1) Passaic River and Major Tributaries; and (2) Minor Tributaries. The efforts and results towards identifying, evaluating and screening flood problem areas within each of these two parts are summarized below.

Passaic River and Major Tributaries. The focus of this Feasibility Report is on this portion of the flood problem. The extent and character of the flooding problem along the mainstream Passaic River, including the Pompton and Lower Rockaway and Whippany Rivers, has been well documented in previous Corps and various other reports. Three well defined areas are subjected to the most serious flooding. One is a highly developed business, industrial and residential area in the Lower Valley from Newark to Little Falls. The second is a suburban area, composed largely of residential developments with some commercial developments in the northerly portion of the Central Basin along the Passaic River from Little Falls to Two Bridges and along the Pompton River. In the third area, the southern portion of the Central Basin, along the Passaic River from Two Bridges to Chatham and along the lower reaches of the Rockaway and Whippany Rivers, the Passaic and its tributaries are generally bounded by undeveloped swamp area. There is, however, a continuing influx of industry and residential development in the area. The main stem of the Passaic River

above Chatham, upstream through the Township of Passaic (Morris County), is also affected by flooding. It has suffered the lowest level damages for several reasons including the following: less development than the downstream areas; a long, narrow watershed; and the moderating effect exerted by the Great Swamp on stream flows downstream of Millington.

Main stem flood problems were investigated in 46 municipalities in the Lower Valley and Central Basin. These municipalities are shown in Table C-15. The problem area includes the main stem Passaic River from its mouth to Millington, N.J., the Pompton River, the lower Ramapo, Wanaque, Pequannock, Whippany and Rockaway Rivers, and numerous small tributaries affected by backwater flooding from the Passaic River. Tables C-11 and C-12 present the number of structures by class in the 100 year and 500 year floodplains and, existing conditions expected annual flood damages for the 3 regions, the Lower Valley (from Newark Bay to Little Falls), the Central Basin (from Little Falls to Chatham, including the Pompton Valley), and the Upper Passaic (upstream of Chatham).

Minor Tributaries. This category encompasses those areas for which inundation results from tributary peak flows not within the backwater influence of the mainstream and major tributaries. These flood problem areas were studied separately from the main stem in order to determine whether potential solutions to these problems would be independent from the main stem and qualify as interim projects either under this Phase I study or the Corps' small project authority. The extent and character of several tributary flood problem areas, such as the Saddle River at Lodi, N.J.; Molly Ann's Brook at Haledon, N.J.; Ramapo River at Oakland, N.J.; Mahwah River at Suffern, N.Y. and Mahwah, N.J.; the Third River at Bloomfield and Belleville, N.J.; and the Rockaway River at Denville, N.J., like the mainstream study area, have been well documented in previous Corps and various other reports. Nakoma Brook at Sloatsburg, N.Y. was also among the areas requiring further study. However, hydrologic studies have estimated the 10 year discharge for Nakoma Brook significantly below the 800 cfs minimum required for Federal interest. Therefore, the Nakoma Brook study was suspended. However, the Water Resources Development Act of 1986 authorized planning, engineering and design activities for Nakoma Brook. Therefore, pending receipt of policy guidance, Nakoma Brook may be restudied.

In order to ensure a thorough review of the Basin's remaining tributary flood problems, information was solicited via telephone from the municipalities within the watershed regarding their historical flood experiences. These initial contacts were followed up by letters and, in many cases, field investigation by representatives of the Passaic River Study Group. These visits, along with information provided by the municipal engineers, other unpublished data, and applicable Federal and

TABLE C-15 MUNICIPALITES INVESTIGATED AS PART OF MAIN STEM STUDY EFFORT

LOWER VALLEY

Newark (Essex)
Kearny (Hudson)
Harrison (Hudson)
East Newark (Hudson)
Belleville (Essex)
Nutley (Essex)
North Arlington (Bergen)
Lyndhurst (Bergen)
Rutherford (Bergen)
East Rutherford (Bergen)
Wallington (Bergen)
Garfield (Bergen)
Elmwood Park (Bergen)
Fair Lawn (Bergen)
Clifton (Passaic)
Passaic (Passaic)
Paterson (Passaic)
Hawthorne (Passaic)
Prospect Park (Passaic)
West Paterson (Passaic)
Little Falls (Passaic)

CENTRAL BASIN

Totowa (Passaic)
Wayne (Passaic)

CENTRAL BASIN (cont)

Lincoln Park (Morris)
Montville (Morris)
North Caldwell (Essex)
Fairfield (Essex)
West Caldwell (Essex)
Roseland (Essex)
Livingston (Essex)
Millburn (Essex)
East Hanover Township (Morris)
Madison (Morris)
Florham Park (Morris)
Chatham (Morris)
Chatham Township (Morris)
Passaic (Morris)
Summit (Union)
New Providence (Union)
Berkeley Heights (Union)
Warren (Somerset)
Caldwell (Essex)
Hanover Township (Morris)
Parsippany-Troy Hills (Morris)
Pequannock Township (Morris)
Pompton Lakes (Passaic)

Corps' guidelines for determining eligibility for Federal participation in a project, were the basis for evaluating and screening the tributary flood problem areas. This resulted in a determination as to which areas warrant inclusion in the Phase I Study. The location of the problem areas studied are shown on Figure C-15. Table C-16 lists the minor tributary areas which were studied along with the findings and/or status of the study. As can be seen from this table, except for the Third River and the Upper Rockaway River area, reports with recommendations for interim projects as part of the Phase I study or under the small project authority have been completed.

WATER SUPPLY PROBLEM

Although the Passaic River Basin's average annual rainfall is about 47 inches, water supply is another major problem. Readily available water supply sources have been almost fully developed. The severity of the water supply problem was evidenced by the shortages experienced and emergency actions implemented during the 1961-1965 drought, the 1980-1981 drought, and the 1985 drought.

During the 1961-1965 drought, the worst on record in many portions of the Basin, the Governor of New Jersey declared a state of emergency and extensive conservation measures were instituted. Water was pumped into the Passaic Basin from Lakes Hopatcong and Wawayanda to augment in-Basin sources. The cities of Paterson and Newark were within days of running out of water. If a similar drought were to occur today, the consequences would be much more severe, as current water demand is well beyond 1965 levels.

During the 1980-1981 drought, the Governor of New Jersey instituted a mandatory water rationing program and authorized water purveyors to issue surcharges to consumers for failure to achieve the mandated reductions. The peak of the crisis occurred when the water supply fell to a 20 day reserve.

The most recent drought occurred during 1985. A state of water supply emergency was again declared by the Governor of New Jersey. The restrictions on water use and the rationing program that were implemented in previous droughts again were used in the municipalities in the Passaic River Basin.

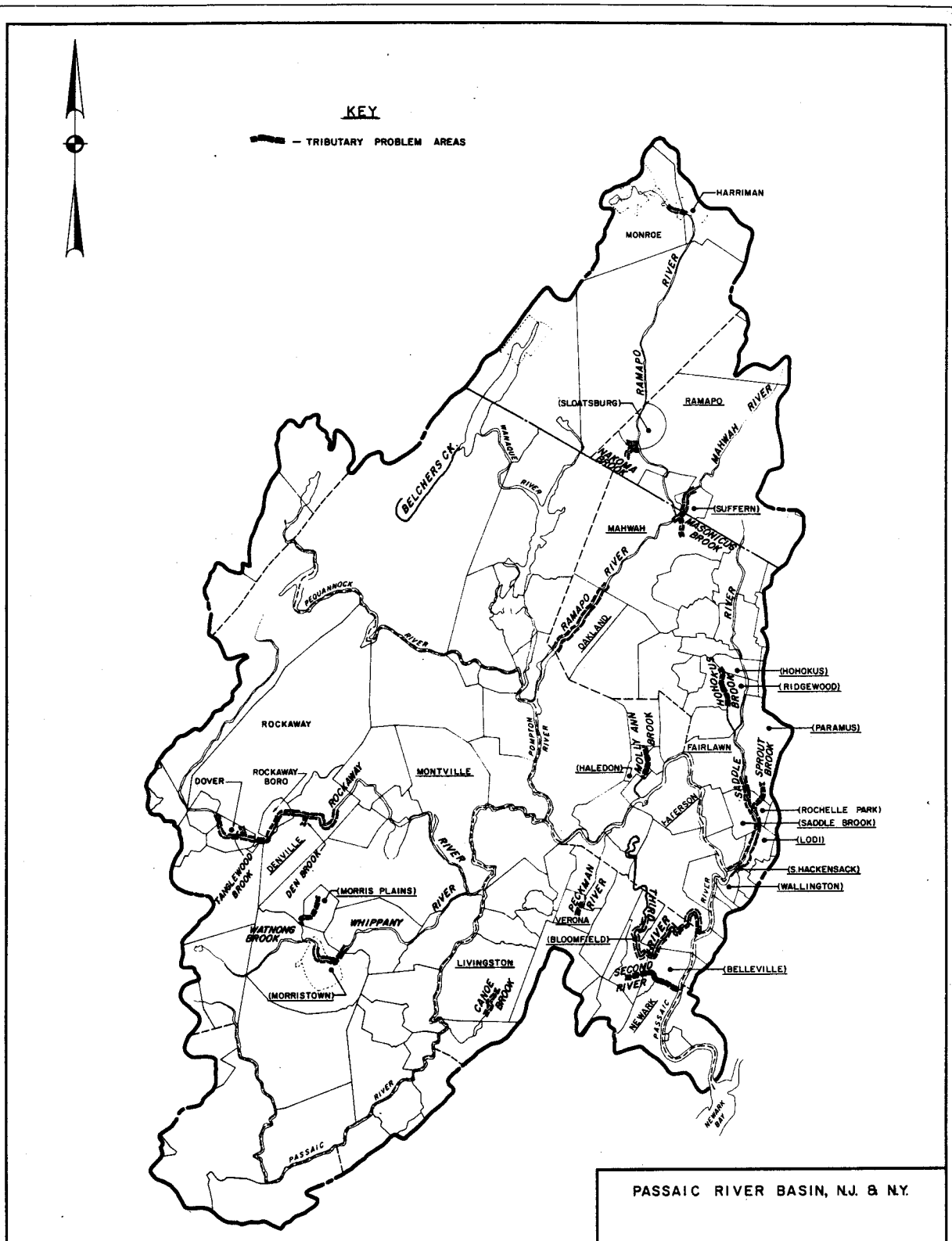

KEY
— TRIBUTARY PROBLEM AREAS
HARRIMAN
MONROE
RAMAPO RIVER
(SLOATSBURG)
RAMAPO
MAHWAH RIVER
WARORA BROOK
BELCHERS CK.
RAMAPO RIVER
(SUFFERN)
MAHWAH
RAMAPO RIVER
RAMAPO RIVER
OAKLAND
PEQUANNOCK RIVER
(HOHOKUS)
(RIDGEWOOD)
(PARAMUS)
FAIRLAWN
ROCKAWAY
TOMPTOR RIVER
MOLLY ANN BROOK
(HALEDON)
SPROUT BROOK
SADDLE RIVER
(ROCHELLE PARK)
(SADDLE BROOK)
(LODI)
(S.HACKENSACK)
(WALLINGTON)
ROCKAWAY BORO
DOVER
MONTVILLE
ROCKAWAY RIVER
DENVILLE
DEN BROOK
HANLEWOOD BROOK
(MORRIS PLAINS)
WHIPPANY RIVER
WATNONG BROOK
WHIPPANY
(MORRISTOWN)
LIVINGSTON
CANOE BROOK
PASSAIC RIVER
PASSAIC
PECKMAN RIVER
VERONA
(BLOOMFIELD)
THIRD RIVER
SECOND RIVER
(BELLEVILLE)
NEWARK
PASSAIC
NEWARK BAY
SCALE IN MILES
3 0 3
PASSAIC RIVER BASIN, N.J. & N.Y.
TRIBUTARY FLOOD PROBLEMS

FIGURE C-15

TABLE C-16 RESULTS OF MINOR TRIBUTARY STUDIES

Tributaries	Communities	Findings	Status
Second River	Belleville, N.J. Bloomfield	Reconnaissance level investigation completed. No Federal Interest in providing flood damage reduction.	No further study.
Third River	Clifton, N.J. Nutley Belleville Bloomfield	Intermediate Planning Stage completed. Recommendation for additional study under the Small Project Authority.	Feasibility Studies underway.
Saddle River & Sprout Brook	Wallington, N.J. So. Hackensack, Lodi, Paramus, Saddle Brook, Rochelle Park, Fair Lawn	Feasibility Studies completed. Approved by Chief of Engineers.	Authorized by Congress for construction. Preconstruction Engineering and Design (PED) to commence in FY88.
Ho-Ho-Kus Brook	Waldwick, N.J.	Favorable expanded Reconnaissance Report for Emergency Streambank Protection completed under Small Project Authority.	Plans & Specs, construction completed in 1981.
Ho-Ho-Kus Brook	Ridgewood, N.J. Ho-Ho-Kus	Reconnaissance level investigation completed. No Federal Interest in providing flood damage reduction.	No further study.

TABLE C-16 RESULTS OF MINOR TRIBUTARY STUDIES (CONT)

Tributaries	Communities	Findings	Status
Ramapo River	Oakland, N.J. Pompton Lakes Wayne	Feasibility studies completed. Approved by Chief of Engineers.	Authorized by Congress for construction. PED to commence in FY88.
Ramapo River	Monroe, N.Y.	Favorable Detailed Project Report under Small Project Authority completed.	Completion of Plans & Specs and submission to the Office of Chief of Engineers by the end of 1987.
Belchers Creek	West Milford, N.J.	Unfavorable Reconnaissance Report completed under Small Project Authority. No Federal Interest in providing flood damage reduction.	No further Study.
Rockaway River	Denville, N.J. Rockaway Boro Rockaway Township Dover	Plan formulation link established between local protection and Longwood Valley Pumped Storage Reservoir Project.	Detailed Planning Studies ongoing. Congressional approval of authority expansion for Longwood Valley received.
Whippany River	Morristown, N.J.	Reconnaissance level investigation completed. No Federal Interest in providing flood damage reduction.	No further study.
Watnong Brook	Morris Plains, N.J.	Hydrologic studies complete. 10yr discharge does not meet minimum requirement for Corps Study.	No further study.
Canoe Brook	Livingston, N.J.	Unfavorable Reconnaissance Report completed under Small Project Authority. No Federal Interest in providing flood damage reduction.	No further study.

/3/

TABLE C-16 RESULTS OF MINOR TRIBUTARY STUDIES (CONT)

Tributaries	Communities	Findings	Status
Molly Ann's Brook	Haledon, N.J. Paterson	Feasibility studies completed. Approved by Chief of Engineers.	Authorized by Congress for construction. PED to commence in FY88.
Peckman River	Verona, N.J. Cedar Grove	Unfavorable DPR under Small Project Authority completed. No Federal Interest in providing flood damage reduction.	No further study.
Ramapo and Mahwah Rivers	Mahwah, N.J. Suffern, N.Y.	Feasibility studies completed. Approved by Chief of Engineers.	Authorized by Congress for construction. As part of ongoing PED, Plans and Specifications to commence in FY88.
Masonicus Brook	Mahwah, N.J.	Hydrologic studies complete. 10yr discharge does not meet minimum requirement for Corps Study.	No further study.
Nakoma Brook	Sloatsburg, N.Y.	Hydrologic studies complete. 10yr discharge does not meet minimum requirement for Corps Study.	Study suspended due to discharge criteria. Re-study authorized in WRDA of 1986. Awaiting policy guidance on discharge criteria.

The Wanaque South/Monksville Reservoir project, recently completed by the North Jersey Water Supply Commission and the Hackensack Water Company, is expected to ease the water supply problem for the foreseeable future. Nevertheless, concerns over water supply were expressed at public meetings held both by the Corps of Engineers and the State of New Jersey. These concerns include protecting existing sources from degradation, and extending existing supplies through water conservation or the development of additional sources. Furthermore, Congressional guidance directed that consideration be given to fulfilling water supply objectives together with flood control.

During the course of this study, therefore, investigations were undertaken to determine the feasibility of providing additional sources of water supply in conjunction with flood control. The results of these investigations, which are documented in Section 5 of this appendix, indicate that with the possible exception of the Longwood Valley site, located in the Upper Rockaway River Basin, there are no feasible opportunities for developing water supply sources in conjunction with flood control. The feasibility of developing the Longwood Valley site as a multi-purpose reservoir is being investigated as part of the ongoing studies of the Upper Rockaway River Basin, which are independent of the main stem study.

ENVIRONMENTAL CONCERNS

Economic growth in the Central Basin and Highland Area, and the associated impacts of such development and growth on the quality of natural land areas, streams, and lakes, has resulted in substantial pressure on the environmental resources of the Basin. Interest has been expressed at the Federal, State and local levels to preserve and, to the extent practical, restore the environmental quality of the Basin. In particular, those areas which can be used for natural storage of flood waters have been repeatedly nominated for preservation.

Water Quality. The Basin contains a diversity of environmental conditions ranging in degree from the urban Lower Valley to the natural wetlands of the Central Basin to the relatively undisturbed headwater forests of the mountainous Highland Area. Degraded water quality caused by point and non-point sources has reduced the diversity of aquatic resources throughout the basin. Generally, the water quality in the Passaic River is poorest in the reaches between the mouth and Dundee Dam (tidal) and between Dundee Dam and the confluence with the Rockaway River. Upstream of this point, water quality steadily improves. The lower Rockaway and Whippany Rivers add to poor water quality, while the Pompton River and its tributaries help to temporarily improve water quality between

Two Bridges and Beatties Dam. Point source pollution has been reduced through better sewage treatment, but non-point source pollution remains unabated and has increased with continued development. Further details regarding the environmental setting, concerns and needs within the Basin are presented in the Main Report and Appendix B - Natural Resources.

Anadromous Fish. The lower Passaic River and its tributaries, to the extent of its free flowing reaches, contain five anadromous fish species. Anadromous fish are recognized to be of a national concern, due to the steady decline in their numbers. Two temperate bass (striped bass and white perch) and three herrings (American shad, blueback, and alewife) are found in small numbers. The striped bass found in sampling were juveniles and spawning is not known to occur here. The other four species breed in limited numbers in those reaches mentioned above. Reasons for the low numbers of individuals of these species include poor water quality, particularly low dissolved oxygen (DO) levels (both seasonal and short term) and the lack of suitable habitat, in part caused by flow restrictions in the river (e.g. Dundee Dam). Since water quality and extent of habitat is not expected to change, the population of these fish is expected to remain about the same. Maintaining these species, including the State threatened American Shad is of concern and coordination with appropriate Federal and State agencies is ongoing.

State Stocking Program. The New Jersey Department of Environmental Protection (NJDEP) maintains a stocking program for trout in the proposed project area in the Wanaque, Ramapo, and Pompton Rivers. This stocking program is a significant concern of the NJDEP. It represents an important recreational opportunity for fishermen in an area of the state where a deficit exists and is expected to increase by about 50% by the year 2000. It also provides license revenue to the NJDEP for continued stocking and improvement in fishing recreation opportunities. Further, with the closing of the outdated Butler-Bloomingdale Sewage Treatment Plant, the reintroduction of trout stocking is likely to occur in the potential project area of the Pequannock River. Additionally, these reaches, especially the Wanaque and Ramapo Rivers, have balanced warmwater fisheries. Coordination with the Fish and Wildlife Service (FWS) and NJDEP is continuing in order to plan for the stocking program.

Wetlands. The protection of the Basin's wetland areas and associated habitats is especially important. The Basin's major contiguous freshwater marshes include Black Meadows, Bog and Vly Meadows, Great Piece Meadows, Great Swamp, Hatfield Swamp, Hatfield Swamp South, Canoe Brook, and Troy Meadows. These

wetlands have been impacted upon by mosquito ditching, airports, garbage dumps, highways and suburban developments. Despite these disturbances, the wetlands support diverse flora and fauna including rare and unique plant species, and are important habitats for State and Federal endangered and threatened species. These wetlands are ecologically significant because they serve as breeding, feeding and nursery areas for amphibians, turtles and other reptiles, centrachid, cyprinid, and esocid fish, small mammals, and a number of shore birds, marsh birds, waterfowl and songbirds.

There are about 24,100 acres of major freshwater marshes intermixed with various quantities of hardwood swamp within the Passaic Basin. In addition, marshy expansions of streams and the shallow littoral zones of lakes are widespread in the Passaic Basin.

Endangered and Threatened Species. Two Federally--endangered animal species -- the bald eagle and the peregrine falcon -- have been determined to occur only incidentally in the Passaic River Basin, since their presence is related to their migratory movements. It should be noted, however, that the bald eagle has increased substantially in recent years, including more sightings in the last several winters. Thus, occasional use of the Passaic wetlands and reservoirs in the future by individuals of these species is possible. Additionally, a substantial number of State endangered and threatened species are found in wetlands in the proposed project area (see Appendix B - Natural Resources for species).

Herbaria, literature and field searches failed to find any Federal or State endangered or threatened plant species in the project area. Two State species considered rare may still exist, one each in Troy and Great Piece Meadows.

Cultural Resources. Both prehistoric and historic archaeological sites, are important features of the Passaic Basin. More than 1,700 historic sites have been recorded basin-wide, and numerous prehistoric archaeological sites exist, most of which were discovered before the recent accelerated pace of development.

Continued coordination and planning for the identification of previously unknown sites, preservation of existing sites, and the potential for enhancing cultural resources will continue into the engineering phase. After precise locations are mapped, the potential project area will be surveyed by archaeologists. If significant sites are discovered, they will be either avoided, preserved, enhanced, or, if necessary, mitigated.

Toxic and Hazardous Wastes. A major concern throughout the Basin is toxic and hazardous waste sites. Probably the best known of these is in the Ironbound section of Newark. Plans are being developed at this time by the owners of the site, in conjunction with the State of New Jersey and the U.S. Environmental Protection Agency to contain toxic and hazardous materials on the site and clean up the sections of the Passaic River contaminated by that site. Coordination is ongoing with the State to insure that flood damage reduction plans reflect up-to-date information on any newly discovered sites.

Aesthetics. The basin contains many unique and scenic areas. These areas are endangered by development and abuse. Three reaches of the Passaic River (from Two Bridges upstream to I-80; from Cook's Bridge to the Morris Turnpike; and from Interstate Route 78 to Osborn Mills, including Great Brook from the Passaic River to Silver Lake) are included in the Nationwide Rivers Inventory and have potential for future addition to the National Wild and Scenic Rivers System as recreational rivers.

EROSION PROBLEM

An attendant problem to flooding is the erosive action the river flows exert on the streambed and banks. Erosion within the Passaic River Basin is primarily along tributaries where it has resulted in the physical loss of land, degradation of water quality, depletion of reservoir storage, silting of wetlands and estuaries, and disruption of ecological and economic activities. While erosion and the accompanying sedimentation are less significant along the Pompton River and the main stem Passaic River in the Central Basin and the Lower Valley, the public is aware of this problem and interest has been expressed in some sort of erosion control.

OTHER NEEDS

There are several other needs in the Basin including:

(a) There are very large peak-day demand deficits for water-related recreational facilities within the Passaic Basin. Although there are numerous public parks, forest areas and historic sites in and adjacent to the Passaic River Basin, with

about 25% of New Jersey's population located in the Basin, much of this recreation demand must be satisfied outside of the Basin. A major problem of recreation in this area is the disparity of the distribution of population and of available recreational open space and facilities. Degraded water quality further limits recreational opportunities in the Basin, particularly in the densely populated Lower Valley.

(b) The Passaic River is navigable from its mouth to the Eighth Street Bridge in the City of Passaic. The existing channel is part of the authorized Federal Project for the Passaic River. However, while there are frequent delays and occasional groundings at low tide, the limited commercial traffic on the river is not sufficient to justify navigational enhancements. Instead, commercial and recreational navigation opportunities should be preserved.

(c) The Passaic River was once heavily utilized for water generated power in the late 19th Century. Most of these plants were retired but renewed interest in hydropower has led to the renovation of several of these plants. Currently, power plants are operating at S.U.M. Dam and Dundee Dam on the Passaic River. Local interests are currently studying the feasibility of restoring the hydro-electric power plant at the Beatties Dam on the Passaic River.

(d) Strong developmental pressure exists in the basin, particularly in the flat floodplain areas of the Central Basin. The demand for land for development often results in conflicts of use. Development in the floodplain, or in natural flood detention areas, is in direct conflict with flood damage mitigation. Sanitary landfills in lowland areas not only eliminate natural flood detention areas, but can degrade groundwater systems that are recharged by these areas. Management that recognizes these and other sensitive areas is needed to provide a balance between development and conservation purposes.

PLANNING CONSTRAINTS

The problem and opportunity statements listed in Table C-17 reflect certain concerns which are not necessarily directly related to the NED objective, but are so important that they impose constraints on the planning process. In the case of the Passaic River Basin Phase I study, a constraint of a public policy nature is the mandate from Congress, as expressed in U.S. House of Representatives Report No. 94-1702, establishing the range of measures to be considered as possible plans for implementation. That range of measures reflected the local opposition to any plan which relies upon extensive use of dikes, dams, and levees. In any event, alternatives involving reservoirs, such as the plan which served as the basis for the authorization of this Phase I study, were found to be prohibitively expensive and economically infeasible.

Certain other statements, such as those relating to the protection of Federally declared endangered and threatened species and the preservation of cultural resources, also express concerns in the form of constraints. These items are components of existing legislation and administrative policy which cannot be violated and act as planning constraints.

TABLE C-17
STATEMENT OF PROBLEMS AND OPPORTUNITIES

The following problem and opportunity statements have been developed for the Passaic River Basin Study.

1. Reduce tidal and fluvial flood damages at areas along the Passaic River mainstream and tributaries including those areas within the development region of the Passaic River Coastal Zone Management Act jurisdiction.

2. Preserve the water supply potential of the Passaic River Basin in conjunction with the new regional water supply sources which have been identified for the State of New Jersey by the New Jersey Department of Environmental Protection, Division of Water Resources.

3. Preserve and/or enhance fish and wildlife habitat in the study area, including anadromous fish species, which are a national concern.

4. Preserve and/or enhance low head hydropower generation potential at possible sites in the study area, such as S.U.M. Dam, Beatties Dam and Dundee Dam along the mainstream.

5. Preserve and enhance the Basin's remaining wetlands, such as the Great Swamp, Black Meadows, Troy Meadows, Great Piece Meadows, Bog and Vly Meadows, Hatfield Swamp, Hatfield Swamp South, Canoe Brook and others, which lie within potential project boundaries.

6. Protect and improve surface and groundwater quality, including the E.P.A. designated sole source aquifer in Morris County, within the Passaic River study area in conjunction with water quality standards and policies of the New Jersey Department of Environmental Protection.

7. Preserve outdoor recreational opportunities and open space in the Passaic River study area, such as fishing, boating, picnicking, bicycling, hiking and nature study, consistent with local and regional recreation needs.

8. Preserve commercial and recreational navigation opportunities along the lower Passaic River from its mouth upstream to the Eighth Street Bridge in Passaic, N.J. consistent with the needs of the study area.

9. Preserve and protect all Federal and State endangered and threatened species and their habitats which are found within potential project boundaries.

10. Reduce streambank erosion along the Passaic River and its tributaries within potential project boundaries.

11. Preserve all significant archaeological, cultural or historic resources discovered within potential project boundaries.

12. Prevent the disturbance of known toxic waste sites and protect them from flooding that could cause the further disbursement of contaminants.

13. Improve aesthetics and preserve scenic or unique sites within potential project boundaries.

14. Protect and enhance the three free-flowing Passaic River reaches identified in the U.S. Department of the Interior's Nationwide Rivers Inventory. They have potential for future addition to the National Wild and Scenic Rivers System as recreational rivers (Passaic River from: 1) Two Bridges to Interstate 80; 2) Route 24 to Route 10; 3) Route 78 to Osborn Mills, including Great Brook from its confluence with the Passaic River to Silver Lake).

MODIFICATION OF PROBLEM AND OPPORTUNITY STATEMENTS

The basis of our plan formulation was primarily the flood damage reduction problem. As a result of the public involvement effort, there has been continuous modification to the original problem and opportunity statements during the conduct of the study.

All references to future development were removed from the problem and opportunity statements since such development would run counter to the Federal interest in preserving natural storage areas, water quality, and fish and wildlife habitats.

The words "preserve" and "generation potential" were added to the statement on hydropower to reflect renewed interest in generation of low-head hydropower particularly at sites where power was generated in the past and has since been discontinued.

In the period since these statements were first written, several interests are renovating retired sites or have begun the generation of hydropower at existing dams in the Passaic River Basin.

The statement on water quality has been updated to reflect completion of the Federal Section 208 Study by the State of New Jersey which is now implementing its findings.

The statement regarding the Wild and Scenic Rivers System has been revised to include the two Passaic River reaches nominated for botanical and recreational reasons.

The disease vector problem and opportunity statement was eliminated in view of the success of the county mosquito control commissions and since mosquito control measures are not compatible to the final array of flood damage reduction alternatives. In fact, these measures run counter to the Federal interest in preserving natural storage areas and fish and wildlife habitats.

A statement on toxic and hazardous waste sites was added in view of the discovery, during the course of the study of contaminants, such as dioxin, at a site adjacent to the river in Newark.

The statement on water supply was changed from enhance to preserve when it became clear that, with the exception of Longwood Valley, no opportunities to develop water supply in conjunction with flood control existed.

UTILIZING PROBLEM AND OPPORTUNITY STATEMENTS IN PLAN FORMULATION

Plans have been formulated in accordance with House Report 94-1702 and as outlined in the Passaic River Plan of Study, Appendix C. Although much study effort was expended to develop background and technical information as a basis for the evaluation of the remaining problems and opportunities, the initial plan formulation focused on the flood damage reduction problem statement since this was the primary objective of the study. Once the basis for feasible flood damage reduction alternatives was established, measures that address the remaining problem and opportunity statements influenced formulation, primarily where the plan would significantly affect or would be counterproductive to satisfying their intent. As an example, channel modification plans that were proposed in earlier reports to facilitate flows from the Pompton and Passaic Rivers to a Beatties Dam tunnel diversion inlet did not consider the effect of lower flowlines on the vast Central Basin wetlands. In plans developed for this study, maintenance of

these wetlands was considered as were project features, such as moving the inlet upstream of Beatties Dam, to maintain existing river stages at upstream areas under normal conditions. Recent drought conditions in the northern New Jersey region have again highlighted the need to develop additional water supply sources. Water supply development was considered in any situation as an adjunct to flood control development in a trade-off context. Two types of trade-offs have been analyzed: (1) trading-off water supply for flood control by re-regulation of existing reservoirs; and (2) developing new water supply sources which would permit existing reservoir storage to be changed from water supply to flood control usage. The seriousness of the water supply situation, however, dictates that the re-regulation of existing reservoirs for flood damage reductions does not reduce the yields of the existing systems. Thus reservoir re-regulation involves an equivalent water supply/flood control trade-off. Where it has been determined that an existing water supply reservoir would be effective in reducing flood flows in a downstream damage area, it would be necessary to develop a new water supply site that would be, at a minimum, hydrologically equivalent to the storage given up in the existing reservoir to flood flow reduction.

No plans have been developed which do not have flood control as the primary plan purpose. Measures that address some of the other problem statements were incorporated in later iterations of these plans. As part of the continuing planning process, these expressions of problems and opportunities were modified as preferences and desires became more clearly defined and as the characteristics of plans became more specific.

SECTION 4 - PLAN FORMULATION APPROACH

MANAGEMENT MEASURES

Management measures are the technical and institutional means for managing resources, and may represent part of a plan or the entire plan itself. The formulation of comprehensive water resource management plans for the Passaic River Basin was accomplished by assembling various management measures in different scales, extents and combinations. The management measures used to develop plans were those which the House of Representatives, in HR 94-1702, directed to be used. The measures were evaluated considering the current state of the art utilized by the Corps and other Federal agencies, recognized professionals in the applicable field, and state and local governments.

These measures, which include both nonstructural and structural techniques, are listed in Table C-18. Included, in addition to those flood damage reduction measures which Congress has directed the Corps to investigate are selected measures directed at the other remaining problem and opportunity statements.

Structural flood control measures are physical measures which act directly on riverine or tidal waters to change their direction, area of inundation, volume, stage or frequency, to reduce flood damages or to enhance the value of the floodplain. Structural flood protection measures considered include channel modifications, dams and reservoirs, diversions, levees, floodwalls, and diversion tunnels.

Nonstructural measures encompass those techniques which are alternatives to the physical control of riverine or tidal waters. As such they are primarily directed at the occupants of the floodplain and the resultant use of and impacts on water resources. Nonstructural flood damage reduction measures considered include the floodproofing/raising of structures, permanent evacuation, floodwarning, preparedness, floodplain zoning, and preservation of natural storage areas.

The step by step formulation and decision process that was followed in the Passaic River Study is presented in Figure C-16. Decisions regarding alternatives in the Local Land Management Plan category were documented in the Plan of Action report dated January 1980. The development of a full range "Building Block," and Intermediate Stage Plan, Detailed Stage Plans and Plan Selection are documented in this report.

TABLE C-18 MANAGEMENT MEASURES

MEASURES	DESCRIPTION
Flood Diversions	Rerouting flood flows around or under flood problem areas through either tunnels orchannels.
Channel Modifications	Straightening, widening, deepening or protecting a stream to reduce flooding or prevent erosion.
Levees and Floodwalls	Earthen or concrete wall-type structures used for holding back water.
Tidal Gates	Barrier to keep hurricane tides from flooding estuaries during storms.
Water Conservation Practices	Use of present water supplies more efficiently, thus reducing the need for new water sources.
Drought Contingency	Emergency planning measures implemented during severe droughts.
Interconnection of Water Supplies	Allows surplus water supplies in one area to be transferred to areas of need by connecting the water supply systems.
Stream Diversions for Water Supply	Taking water directly from streams for water supply, or diverting stream water to reservoirs to maintain water supply storage.
Land Treatment of Wastewater	Return of water to system after natural biological, chemical and filtration processes.
Streambank Stabilization	Measures to prevent streambank erosion, including vegetation, walls, and rip-rap.
Sedimentation Basins	Wide and deep areas of streams which reduce flow velocities and allow settling out of sediment.
Energy Dissipators	Structures or devices used to dissipate the energy of flowing waters causing reductions in velocity, which reduce erosive effects.
Create Turning Areas Navigation	Allows vessels to turn around or pass each other increasing the efficiency of transportation and reducing accident potential.
Water Quality Projects	Measures which upgrade water quality allowing for more use, including recreation and water supply.
Energy Conservation Practices.	Use of energy conservation measures, including car pooling, use of more efficient appliances, apartment living.

MEASURES	DESCRIPTION
Flood Warning and Preparedness Plans	System of warning notices which would allow the public to be notified of an oncoming flood and procedures which could reduce flood damages and threats to health and safety.
Preserve Natural Storage Areas	Preserve those natural storage areas which are presently effective in reducing flood flows so that they will not be developed in the future.
Flood Plain Land Use Controls	Regulations restricting the types, and numbers of structures, and where they may be located in a flood plain.
Floodproofing and Raising Structures	Preventing water from entering a building by making all openings water tight by various methods. This can also be achieved by raising structures.
Permanent Evacuation of the Flood Plain	Removal of structures from flood plain permanently by either purchase or physical relocation.
Stormwater Management	Local stormwater detention areas or other facilities to reduce peak flood flows downstream.
Public Education	Making public aware of needs, problems and the self-help measures available to them.
Bridge and Dam Modification	Modification of bridges and dams to eliminate hindrances to flow.
Debris removal	Removal of debris from stream channel.
Clearing Snagging	Debris removal, and minor channel modifications, realignment and/or restriction removals.
Reregulate or Modify Existing Reservoirs	Changing operating rules or modifying existing reservoirs so that they can also be utilized for flood control.
Dry Detention Reservoir	A dam and detention area which only impounds water during flood periods.
Wet Detention Reservoir	A dam with a capacity for storing additional water during flood periods.
Aquifer Recharge	Method of allowing floodwaters to percolate through the soil to be stored in existing underground storage areas.

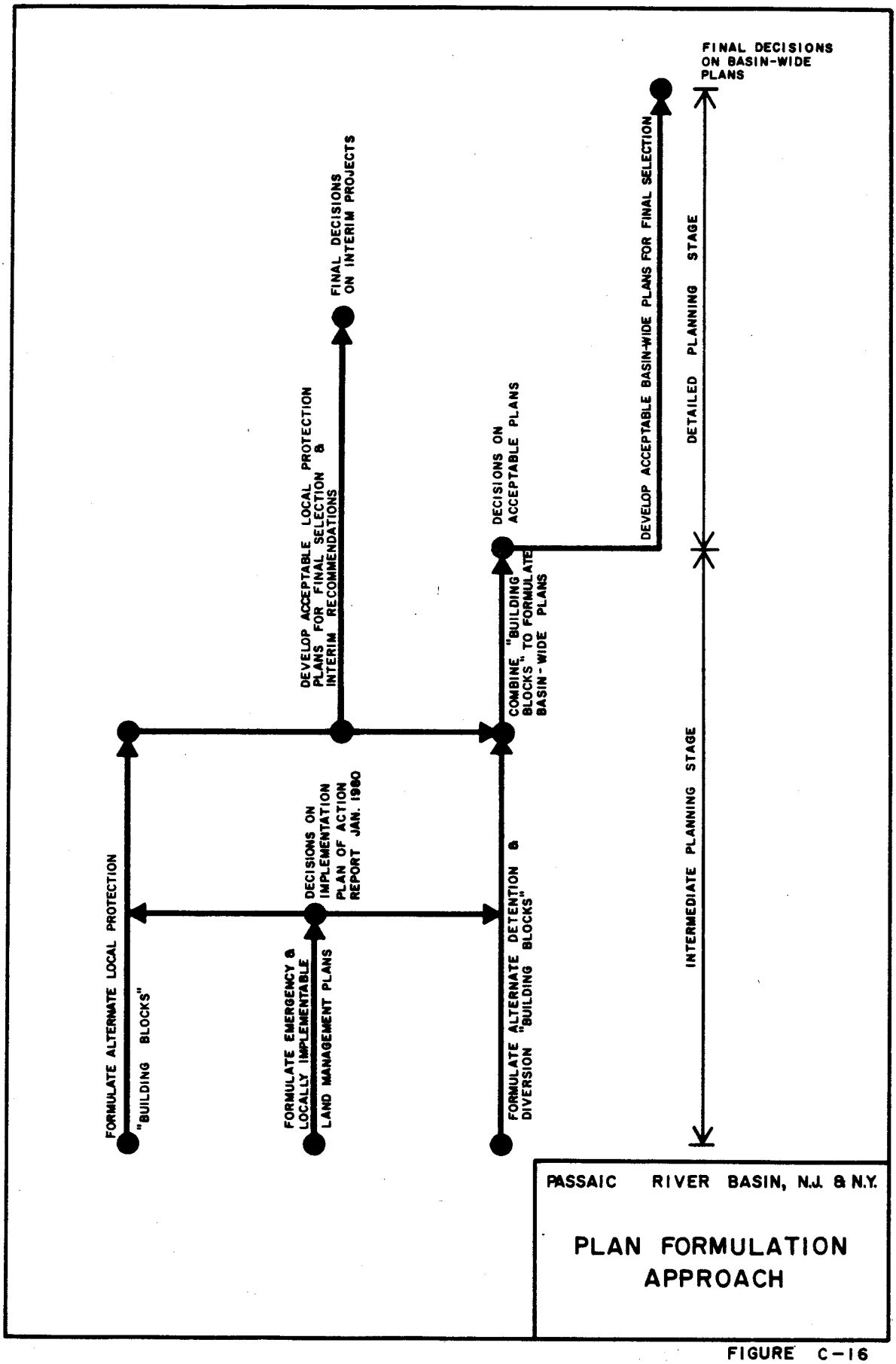

FINAL DECISIONS ON BASIN-WIDE PLANS
DEVELOP ACCEPTABLE BASIN-WIDE PLANS FOR FINAL SELECTION
DETAILED PLANNING STAGE
DECISIONS ON ACCEPTABLE PLANS
COMBINE "BUILDING BLOCKS" TO FORMULATE BASIN-WIDE PLANS
FINAL DECISIONS ON INTERIM PROJECTS
DEVELOP ACCEPTABLE LOCAL PROTECTION PLANS FOR FINAL SELECTION & INTERIM RECOMMENDATIONS
DECISIONS ON IMPLEMENTATION PLAN OF ACTION REPORT JAN. 1980
FORMULATE ALTERNATE LOCAL PROTECTION "BUILDING BLOCKS"
FORMULATE EMERGENCY & LOCALLY IMPLEMENTABLE LAND MANAGEMENT PLANS
FORMULATE ALTERNATE DETENTION & DIVERSION "BUILDING BLOCKS"
INTERMEDIATE PLANNING STAGE
PASSAIC RIVER BASIN, N.J. & N.Y.
PLAN FORMULATION APPROACH

FIGURE C-16

PLAN CATEGORIES

The various systems to manage the water and related land resources in the Basin were investigated under three categories as planned in the Passaic River Plan of Study. These categories, which were established to facilitate the planning and decision making process, are: (1) Basin-Wide Emergency and Local Land Management; (2) Basic "Building Blocks" plan components; and (3) Complete, basin-wide multi-measure combination plans based on the results of the "Building Blocks." Figure C-16 displays the role that local land management plans have in the plan formulation approach, while Figure C-17 presents the relationship between "Building Blocks" and comprehensive, basin-wide alternatives. Each of the categories are briefly described below.

Basin-Wide Emergency and Local Land Management Category. This category consists of compatible basin-wide, early action nonstructural management plans (interim measures) that are essentially institutional and educational in nature. Many of these measures can be implemented by non-Federal interests in cooperation with appropriate Federal agencies. It is noted that such plans do not, by themselves, result in any significant reduction in existing flood damages. But such measures minimize increases in future flood damage potential and reduce the threat to public health, safety, and property during flood events.

The management measures which were investigated in the Passaic River Study as part of the basin-wide emergency and land management plan category are as follows:

(a) Floodwarning and preparedness measures.

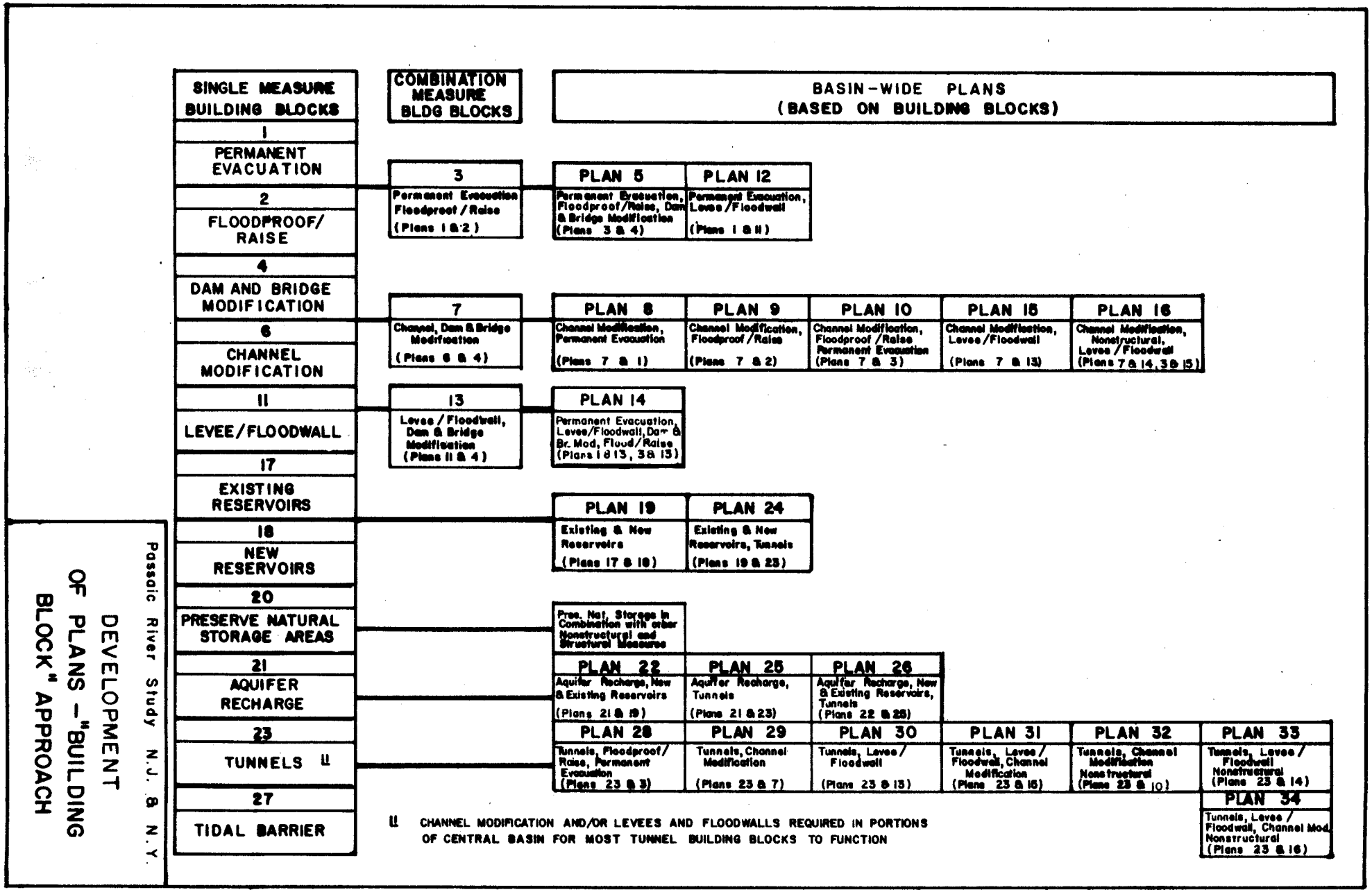
(b) Floodplain mapping.

(c) Public education on methods to reduce damages by floodproofing damageable contents.

(d) Preservation of natural storage areas (this measure is also a potential "Building Block" alternative (see Building Block 20 of Figure C-17 and discussion in Section 5).

(e) Control of increased runoff from future basin development.

(f) Floodplain land use control measures, such as zoning and flood insurance.



DEVELOPMENT OF PLANS - "BUILDING BLOCK" APPROACH

Passaic River Study N.J. & N.Y.

FIGURE C-17

"Building Block" Category. This category initially consisted of single measure nonstructural and structural alternatives for which there is Corps or other Federal study and implementation responsibility as long term solutions to the basin-wide flood problem. However, as discussed in Section 5, during the Intermediate Planning Stage the concept of "Building Blocks" was expanded to include multi-measure alternatives to substitute for single measure plans which were found not to be practical or efficient. The single measure and combination of measures "Building Blocks" are shown in the first and second columns, respectively, of Figure C-17.

Basin-Wide Plan Category. This category consists of alternatives which were developed through the evaluation, screening and combination of measures considered as "Building Block" Plans. The formulation process was then reiterated using these alternatives to develop the final array of basin-wide plans from which the recommended plan was selected. The process by which such plans were developed is discussed below and depicted on Figures C-16 and C-17.

"BUILDING BLOCK" APPROACH

Plan formulation studies follow the procedures presented in the Passaic River Basin Plan of Study dated July 1979, and are in accordance with the six step planning process (Specific Problems and Opportunities, Inventory and Forecast, Formulate Alternative Plans, Evaluate Plans, Compare Plans, and Select Plan) as presented in ER 1105-2-30, General Planning Principles of the Planning Guidance Notebook. Specifically, flood damage reduction plans were developed through successive iterations of the planning process. This process involved initially identifying basic "Building Block" plan elements and/or plans, as well as the technical basis upon which plans were to be evaluated. Subsequent to plan evaluation and comparison activities, after the screening of alternatives, plans consisting of combinations of these alternatives were developed. These "Building Blocks" include all fundamental flood damage reduction measures which can act as major elements of plans that are responsive to the Congressional Guidance for this study.

The "Building Block" approach was first utilized for developing and evaluating flood damage reduction alternatives. Subsequent to this, measures that address other problem and opportunity statements, such as recreation, were also evaluated based on the "Building Block" approach in combination with other measures. The "Building Blocks" that were considered for flood damage reduction, and their relationship in formulating other alternative plans, are presented in Figure C-17. Studies in

the Intermediate Planning Stage were conducted to analyze the effectiveness, economic feasibility, environmental impacts and acceptability of the alternatives within the plan categories displayed on this Figure. During the Detailed Planning Stage, studies were undertaken to develop the final array of plans to a level of detail sufficient to make a project recommendation.

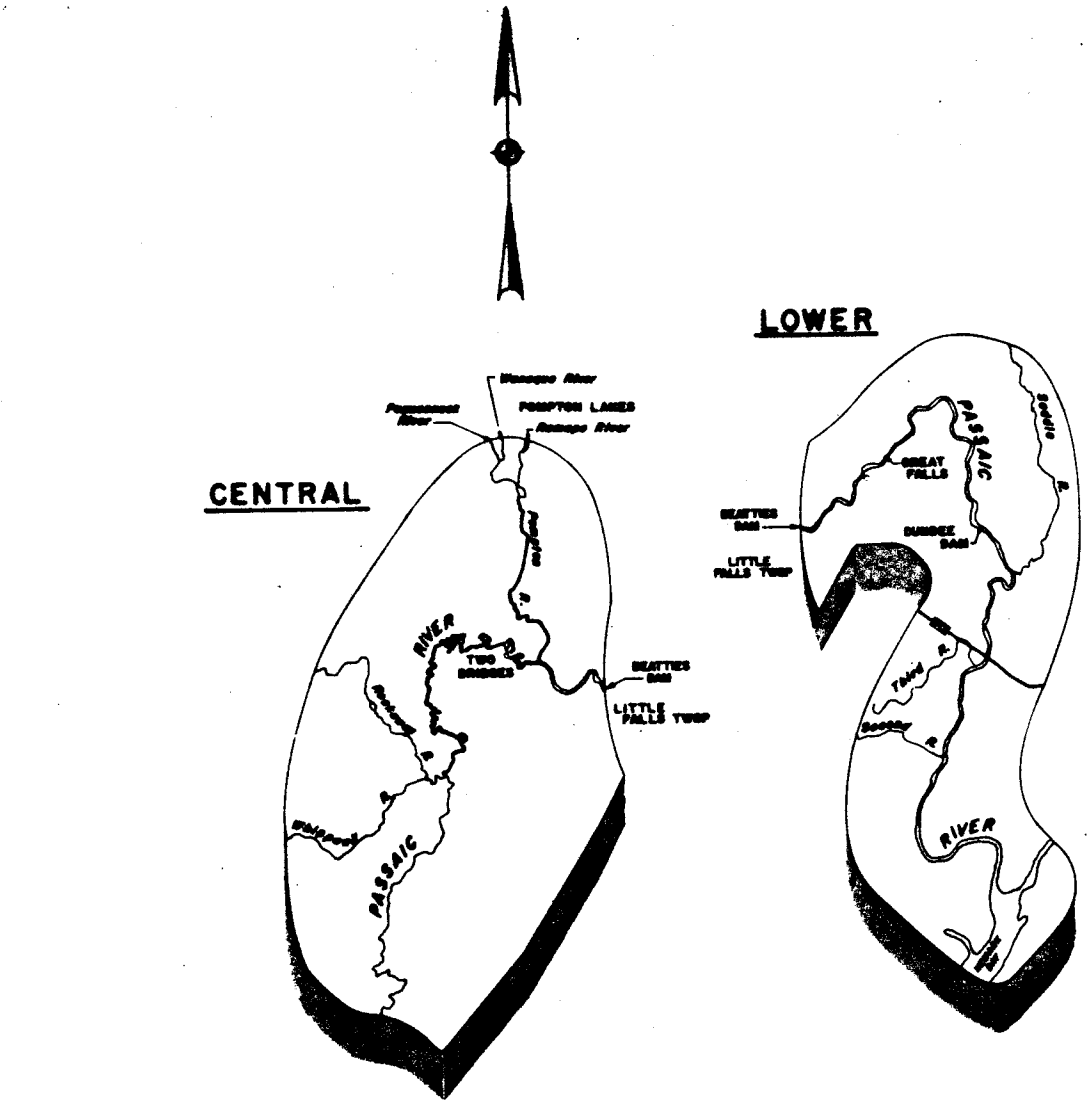
The presentation of alternatives in Section 5 - PLAN FORMULATION RESULTS utilizes the numerical hierarchy of Figure C-17 in designating the plans. For example, Permanent Evacuation "Building Blocks" have been designated as 1A, 1B, 1C, etc., while Tunnel Diversion "Building Blocks" have been labeled as 23A, 23B,...etc.

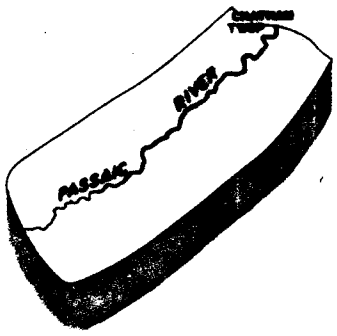
TECHNICAL BASIS FOR PLAN FORMULATION

To facilitate plan development, evaluation analysis, and the comparison of alternatives, flood damage reduction measures were first investigated for the three reaches of the Passaic River Basin: Lower Passaic River, Central Passaic River and Upper Passaic River. The characteristics of flooding, the location of damage areas, and the significant environmental attributes of the Passaic River Basin reaches were considered when solutions to the flood problem were developed. Descriptions of the damage areas and environmental features of each reach are provided in Section 2, while the characteristics of flooding are discussed in the following paragraphs.

Generally, flooding in the densely urbanized Lower Passaic River reach downstream of Dundee Dam is caused by upstream fluvial flows, or by hurricane related tidal surges from Newark Bay. For the urban areas upstream of Dundee Dam to Beatties Dam, flooding is fluvial in nature and is caused by insufficient channel capacity. Flooding in the suburban Central Passaic reach upstream of Beatties Dam is characterized by a reversal of flow from the Pompton River to main stem reaches of the Passaic River upstream of Two Bridges, and along the lower Rockaway and Whippany Rivers. Flooding at the more sparsely populated areas along the Upper Passaic River reach upstream of Chatham is moderated by the natural storage effects of the Great Swamp.

Lower Passaic River. This formulation area extends from the mouth of the Passaic River upstream about 30 miles to Beatties Dam in Little Falls and Wayne. As shown in Figure C-18, it lies between the Central Passaic area, which has its outlet at Little Falls, and Newark Bay. The major streams within this area, besides the main stem Passaic River itself, include Molly Ann's Brook, the Second, Third, Peckman and Saddle Rivers. The water surface elevations in the lower reaches of these tributaries and others such as Weasel and Goffle Brooks, are influenced by backwater from the Passaic River.





Passaic River Study N.J. & N.Y.

PLAN FORMULATION REACHES

FIGURE C—[illegible]

'48

The characteristics of flooding in the Lower Passaic River area were important to consider when the types of solutions to the flood problem were determined. Along the Passaic main stem, flooding may be caused by generalized rainfall over parts of the entire Basin; by localized storms over the Lower Passaic area itself; or by hurricane related tidal surges from Newark Bay. For this reason, flood control alternatives which were of interest in treating the Lower Passaic River flood problem considered both measures lying entirely within the boundaries of the Lower Passaic itself, and also comprehensive, basin-wide measures which were primarily located upstream in the Central Passaic River area.

Solutions such as flood detention and tunnel diversion plans would have the effect of moderating or considerably reducing peak flows through portions of the Lower Passaic River. On the other extreme, channel modification or riverbank levee and floodwall plans in the Central Passaic area tend to increase peak flows entering the Lower Passaic River. The feasibility of potential levee plans and relocation plans was affected by the lack of available land in this heavily urbanized reach.

In the Lower Passaic, there are three run-of-the-river dams that divide it into three hydraulically separate areas. The first reach is the tidal estuary which lies between the river mouth at Kearny and Dundee Dam in Garfield and Clifton. The second and third reaches extend upstream from Dundee Dam to Great Falls (S.U.M. Dam) in Paterson, and then from Great Falls to Beatties Dam at Little Falls and Wayne.

The feature which is unique to the Lower Passaic River is its estuarine character from Dundee Dam to Newark Bay. Within this reach, the channel of the Passaic River has been enlarged for navigation purposes upstream to the Eighth Street Bridge and, therefore, it has a large hydraulic capacity for flood flows. This enlarged channel can contain, for example, the 10 year fluvial flow, although flood damages occur in this area for tidal surges more frequent than the 10 year event. Further upstream towards Dundee Dam, the channel size decreases with a resulting reduction in hydraulic capacity. In this reach, the susceptibility to fluvial flooding gradually increases upstream towards Dundee Dam.

Within this tidal reach, the 100 year frequency tide is 9.3 feet National Geodetic Vertical Datum (NGVD) under existing conditions and would cause flooding upstream to the lower limits of the City of Garfield, just downstream of Dundee Dam. Historically, peak tidal events have not occurred coincidently with fluvial flood peaks. Tidal surges are caused either by hurricane storms which are intense in rainfall and of short duration, or by northeaster storms which can have a longer

duration but more moderate rainfall. In the case of hurricanes, storm surges recede before flood peaks enter the Lower Passaic River; and for northeasters, storms producing extreme tides have not recorded significant fluvial flood flows. For this reason, tidal and fluvial events may be considered independent.

Therefore, the approach to plan formulation in this reach, for example, was to compare the stages of 100 year fluvial flows occurring on a one year tide of 4.9 feet NGVD, versus 9.3 feet NGVD 100 year tidal elevation and protect against the higher of the two stages. This comparison indicated that tidal elevations dominated along the Lower Passaic River from Newark Bay upstream to the Route 3 Bridge. Upstream of this point fluvial stages dominated and governed formulation and design decisions. Protection for areas upstream of the Route 3 Bridge, where the fluvial stage exceeds the tidal stage at a corresponding frequency, may be provided by levees, channel modifications, nonstructural measures or a combination of these. At the area downstream of the Route 3 Bridge where the tidal stage controls, levees and floodwalls or a tidal barrier with appropriate closures would be the only structural measures which could provide adequate protection.

The upper two segments of the Lower Passiac River have channels of moderate gradients and are essentially of similar hydraulic characteristics. The nature of local protection works would therefore be similar in terms of potential levees/ floodwalls, channel modifications and dam modifications. Nonstructural plans were considered for all three segments both as "Building Blocks" and in combination with other alternatives.

Existing conditions hydrology indicated that there are two Passaic River flood flow peaks downstream of Beatties Dam in the Lower Valley, as shown in Figure C-19. The first peak is caused by Lower Valley tributary flows, in combination with coincidental Central Passaic flows entering at Little Falls, and usually occurs within 24 hours after the beginning of a storm event. The second peak in the Lower Valley occurs two to three days after the beginning of the storm event. This larger peak is the result of the arrival of flows from the Pompton River. Flows arriving from the Upper Passaic River are delayed by the moderating effect of the existing natural storage of the Central Basin. These flows do not produce a separate third peak in the Lower Valley, however, they do increase the duration of the receding limb of the hydrograph for the second Lower Valley peak. This double peak phenomenon was important in designing diversions to protect the Lower Valley. The difference between these two peaks for a specified design event was the approximate scale for which a diversion tunnel was sized, since even if the

47 0707

K&E 10 X 10 TO THE INCH • 10 X 15 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.



FIGURE C-19

scale of the diversion was increased further and the second peak further reduced, local protection works in the Lower Valley had to be sized to handle the first peak. This consideration is further described in Section 5, Building Block 23 Tunnels and Section 8 - OPTIMIZATION.

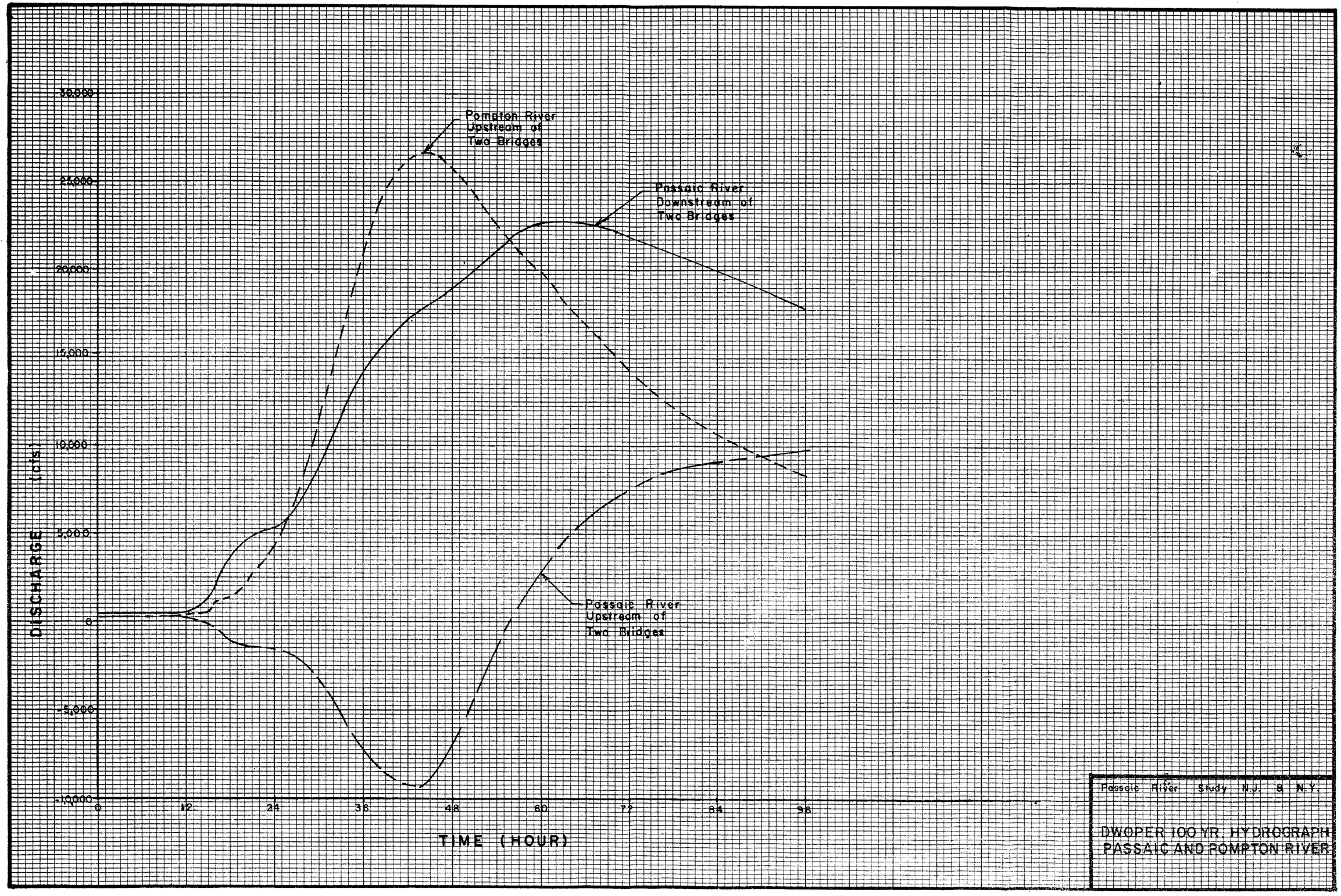
Central Passaic River. The Central Passaic River plan formulation study reach is a flat, low lying area which includes the Passaic River main stem from Little Falls to just downstream of Chatham, the Pompton River, and the lower reaches of the Rockaway, Whippany, Wanaque, Pequannock and Ramapo Rivers. Approximately 38 square miles of environmentally sensitive wetland areas border the Passaic River in this reach. Much of the marshy land is tree-covered. The Passaic River enters the Central Passaic Reach from the south and meanders generally to the north and east until it passes out of the Central Basin over Beatties Dam at Little Falls as shown in Figure C-18.

The drainage areas of the main tributary streams entering the study area are 29 square miles for the Whippany River near Morristown, 116 square miles for the Rockaway River and 355 square miles for the Pompton River at Pompton Plains. The drainage area of the Passaic River is 100 square miles at the upper boundary of the Central Basin at Chatham while it is 762 square miles at Beatties Dam. Pompton River inflows to the Basin, therefore, constitute runoff from approximately 50% of the total area at Beatties Dam.

Without an understanding of the dynamics of flood wave routing in the Central Basin, it would be expected that under existing conditions, peak discharges occurring at Beatties Dam would be comparable to or larger than the peak discharges produced by the Pompton River at Two Bridges. However, in the Central Passaic River this is not the case. This is illustrated by an analysis of streamflow gage data for the area which is given in Table C-19. For the 100 year event, peak flows along the Pompton River at the Pompton Plains U.S.G.S. gage (a drainage area of 355 square miles) are in excess of 32,000 cfs under existing conditions. Passaic River peak flows at Beatties Dam for the 100 year event are in excess of only 27,000 cfs. Essentially, the 762 square mile Passaic river drainage area produces a peak significantly lower than the 355 square mile Pompton River watershed. Peak discharges on the Pompton River at its confluence with the Passaic River occur 40-50 hours prior to the arrival of the flood peak on the Passaic River. Figure C-20 depicts the Passaic and Pompton Rivers flow contribution to the 100 year event hydrograph downstream of Two Bridges.

TABLE C-19 CENTRAL BASIN FLOW ANALYSIS
FOR EXISTING CONDITIONS 100 YEAR FLOOD

LOCATION	Peak Discharge (cfs)	Time of Peak Discharge (hour)
Pompton River at U.S.G.S.	32,515	34
Pompton River at Mouth	29,144	49
Passaic River, Upstream of Pompton River	12,040	98
Passaic River, Downstream of Pompton River	26,843	56
Passaic River at Beatties Dam	27,533	59



K·E 12 x 20 TO THE INCH • 10 x 15 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

FIGURE C-20

This phenomenon occurs because the Passaic River channel is narrowly constricted downstream of Two Bridges. This constraint, in addition to the control of Beatties Dam, tends to limit the flow out of the Central Basin into the Lower Valley. This limit produces a Passaic River backwater effect upstream on the Pompton River which causes the Pompton River to reverse and flow upstream along the Passaic River into the Central Basin floodplain, as well as downstream towards Beatties Dam. The resulting combined flow from the total watershed above Two Bridges begins to fill up the natural storage areas of the Central Basin including the Great Piece Meadows. Flooding in the Passaic River reach upstream of Two Bridges is thus caused by both the Pompton and Passaic River floodwaters. This flow reversal continues until the water level in the Meadows becomes equal to or greater than that at Little Falls. In addition to the initial flow reversal, there is a second phase to this phenomenon. This second phase results when the peak stage along the Passaic River upstream of Two Bridges occurs several hours after the Pompton River peak discharge at Two Bridges. This peak stage results from the combination of Passaic River flow and the reversed flow of the Pompton River. This combination produces a higher stage along the Passaic River and portions of the Pompton River than would the peak of the Passaic River alone due to the decreasing availability of natural storage area in the Great Piece Meadows and the high Pompton River coincidental flows. Once again, the constrictive channel downstream of Two Bridges aggravates this flooding problem.

Knowledge of these flow reversal phenomena is important in order to understand the nature of flooding (in terms of peak discharges and stages) in the Central Basin and to allow for a complete evaluation of flood management measures. To aid in the understanding of flood wave routing in the Central Basin, the Dynamic Wave Operational (DWOPER) Model was used to evaluate flow reversals in the Central Basin. Use of the DWOPER model, which analyzes unsteady flow, provided a basis for improving the representation of flood wave movement in the Central Basin as modelled by the HEC-1 Flood Hydrograph Package. Outputs of the DWOPER model included stage and discharge hydrographs. Figure C-21, which contains a DWOPER discharge hydrograph for the May 1968 flood, illustrates the negative streamflow (flow reversal) that occurs along the Passaic River upstream of Two Bridges at a time when the Pompton River is peaking.

Thus, the nature of the physical characteristics of the Central Passaic area significantly impacts on the formulation of structural alternatives in this reach. Any alternative which modifies or reduces the flow reversal phenomena and makes less use of the natural storage areas upstream of Two Bridges would have the effect of increasing flows at downstream areas in the Lower Valley. Channel modification and riverbank

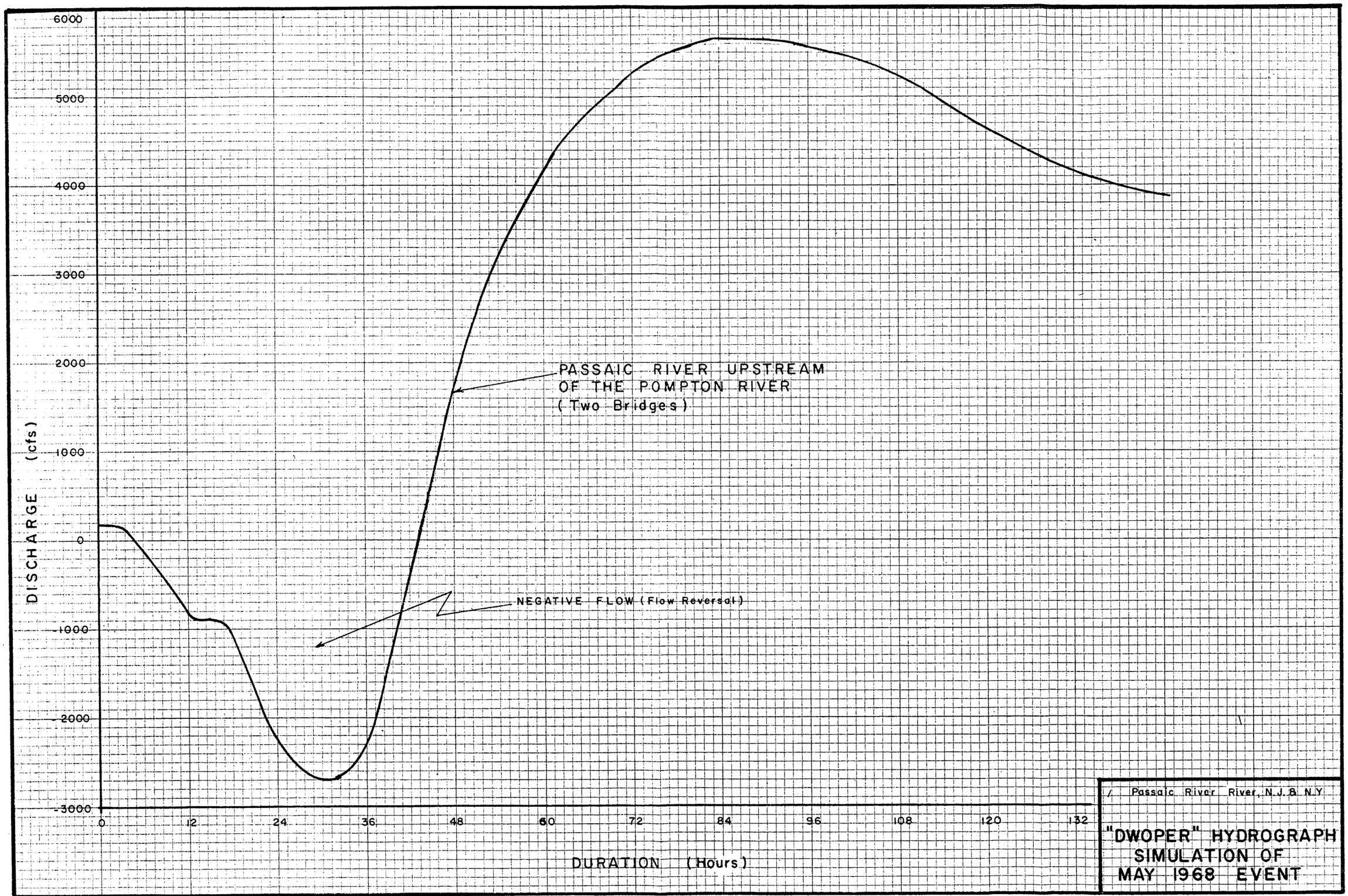

6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
DISCHARGE (cfs)
0
12
24
36
48
60
72
84
96
108
120
132
DURATION (Hours)
PASSAIC RIVER UPSTREAM
OF THE POMPTON RIVER
(Two Bridges)
NEGATIVE FLOW (Flow Reversal)
Passaic River River, N.J. & N.Y.
"DWOPER" HYDROGRAPH
SIMULATION OF
MAY 1968 EVENT

FIGURE C-21

levee/floodwall alternatives in the Central Basin certainly have such effects; while setback levee alternatives have an insignificant impact. Tunnel diversion plans were developed with inlets strategically located to maximize flood stage reduction based on the flow behavior in the Central Basin. However, the downstream effects of tunnel plans were carefully evaluated to determine the resulting impact on flow reversal and downstream flooding.

Upper Passaic River. In the Upper Passaic reach, the Passaic River flows a distance of 12 miles through a narrow corridor between two flanking ridges limiting the watershed to an average 3 miles in width. Figure C-18 depicts the Upper Passaic reach.

Although the Passaic River has been subject to a long and significant history of relatively intense rainfalls and related flooding, flooding along the Passaic River upstream of Chatham and Summit has occurred to a lesser degree when compared to the problems in downstream areas. This is due to the characteristically long, narrow watershed and the moderating effects of the extensive wetland areas on streamflows below Millington. In particular, the Great Swamp National Wildlife refuge, which is a 6,700 acre wetland above Millington, acts as a collecting basin for headwater tributaries and is one of the basin's largest natural flood water storage areas.

The formulation of localized measures required that consideration be given to the various physical characteristics of the Upper Passaic which in turn imposed economic limitations on each alternative. These characteristics include severe backwater caused by mild slopes, a comparatively broader floodplain upstream of the Chatham Township/Passaic Township border, suburban development patterns featuring clusters of structures which are interspersed with wetland acreage, bridges with narrow openings, and some inundated structures which border the Passaic River or its tributaries. The economics of altering these elements through measures developed to alleviate the flooding problems were evaluated during the formulation process.

SECTION 5 - PLAN FORMULATION RESULTS - INTERMEDIATE STAGE

I - EMERGENCY AND LOCALLY IMPLEMENTABLE LAND MANAGEMENT PLANS

INTRODUCTION

The measures considered in this category are presented in Table C-20 in three subcategories, depending on the appropriate study and implementaiton responsibilities, and the timing for possible implementation. Category I includes those measures for which the Corps has both study responsibility and implementation responsibility as Interim output or recommendation from the Passaic River Phase I study. Category II includes those immediate measures which the Corps will either evaluate or provide some technical assistance. The immediate implementation of the interim measures in this category can only be accomplished by non-Federal interest. Category III encompasses measures for which both the study and implementation authorities are not within the purview of the Corps of Engineers. All of these measures were considered in the context of this study; however, the degree to which each measure was examined ranged from providing technical advice or assistance to State/local interests, to the more comprehensive technical treatment of potential enhancement to the existing preparedness system.

Study products and technical assistance have been provided to local interests regarding floodplain delineations and mapping; the hydraulic effects of bridges; stream cross-sections; the hydrologic and hydraulic evaluation of the potential increase in flood flows associated with future urbanization and the loss of natural storage areas. It can then be used in making decisions regarding stormwater management, land use planning, and fill regulations. Information regarding other local flood damage reduction actions has been communicated via the Public Involvement and Citizen Participation Program. Further discussion of the status of study products follows below.

FLOODWARNING/PREPAREDNESS

In accordance with congressional guidelines set forth under the U.S. House of Representatives Report No. 94-1702, the Passaic River Basin Study was directed to consider the feasibility of a floodwarning/preparedness alternative. The principal objectives of the investigation of this measure were: 1) to evaluate the adequacy of the existing floodwarning/-

TABLE C-20

EMERGENCY AND LOCALLY IMPLEMENTABLE LAND MANAGEMENT MEASURES

CATEGORY I - INTERIM CORPS OUTPUT OF PHASE I STUDY

Regionalized Floodwarning/Preparedness
Flood Plain Mapping
Public Education
Preservation of Natural Storage Areas
Clearing & Snagging

CATEGORY II - IMMEDIATE LOCAL INTERIM MEASURES (CORPS TECHNICAL ASSISTANCE AVAILABLE)

Stormwater Management (On-site Detention)
Technical Assistance (Debris Removal/Modification or Removal of Bridges/Modification or Removal of Dams)

CATEGORY III - IMMEDIATE LOCAL INTERIM MEASURES

Flood Plain Landuse Controls - Local Flood Plain Zoning/Flood Insurance/Removal of Structures from Flood Plain(also Inland Wetland Legislation/Transfer Development Rights/Building Moritorium/Building Codes/Subdivision Regs/Community Master Plans/Flood Potential Disclosure/Property Tax Deductions)
Stream Maintenance/Debris Clearance/Sediment Control

preparedness system of the Passaic River Basin; and 2) to consider the feasibility of increasing the effectiveness of "enhancing" both the warning and response elements of this system to reduce risk to life and property damage, and to minimize social loss and disruption.

A floodwarning/preparedness plan is a group of related emergency actions designed to mitigate flood losses. The plan actions which are implemented on a response basis prior to and during floods. The principal components of floodwarning/-preparedness plans include early recognition of a flood threat, dissemination of floodwarnings, emergency response actions, recovery and reoccupation of flood areas, and continuous management of the flood preparedness plan.

Existing Floodwarning/Preparedness System. An existing floodwarning program for the Passaic River Basin was established and is maintained by the National Weather Service (NWS). This program consists of three components: 1) river stage warnings; 2) flash floodwarnings; and 3) a self-help program. River stage warnings are provided for specific points on major streams for which the time from the start of rainfall to peak flooding is generally longer than six hours. Area-wide flash floodwarnings are provided for areas where damaging floods can occur in less than six hours and frequently within just a few hours after the beginning of rainfall. Self-help programs are locally operated community warning systems that receive NWS technical support, primarily in providing staff gages and other equipment, and the training of local volunteers to act as observers.

In the Passaic River basin, the river stage flood forecast program produces flood predictions for 11 specific points in the Basin as shown in Figure C-22. The forecasts provide quantified estimates of the stream stages and times of start of overflow, peak, and return to bank full capacity.

Data from rainfall and river gage readings are assembled by the National Weather Service River District Office at Philadelphia, Pennsylvania and sent to the Middle Atlantic River Forecast Center at Harrisburg, Pennsylvania. Using gage readings and meteorological data, the Middle Atlantic River Forecast Center hydrologists prepare river flood forecasts and transmit them to the Philadelphia River District office. The River District office issues the forecasts and warnings to Federal and state emergency management agencies, and to the news media for public dissemination. The river stage warning system network is diagrammed on Figure C-23.

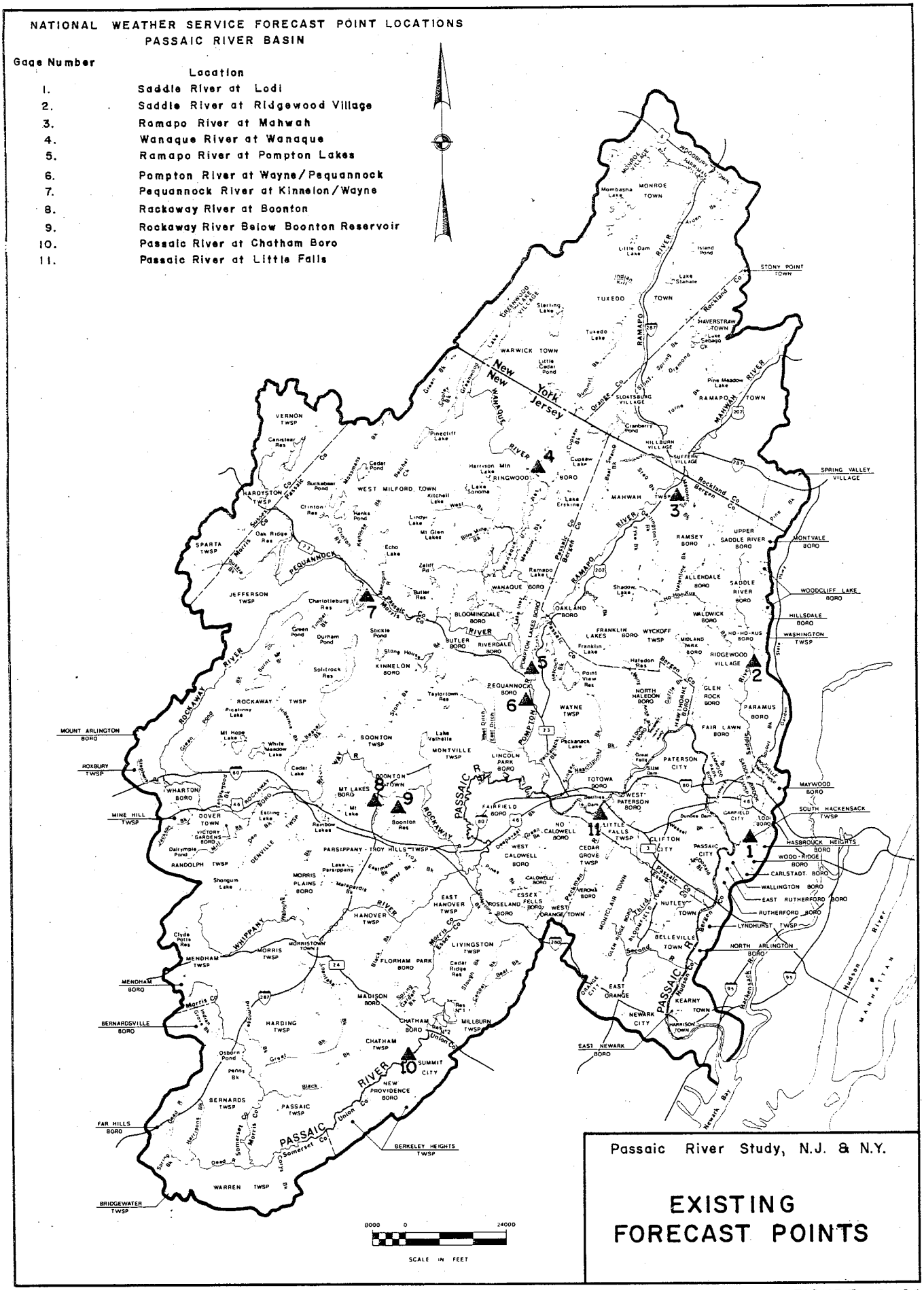
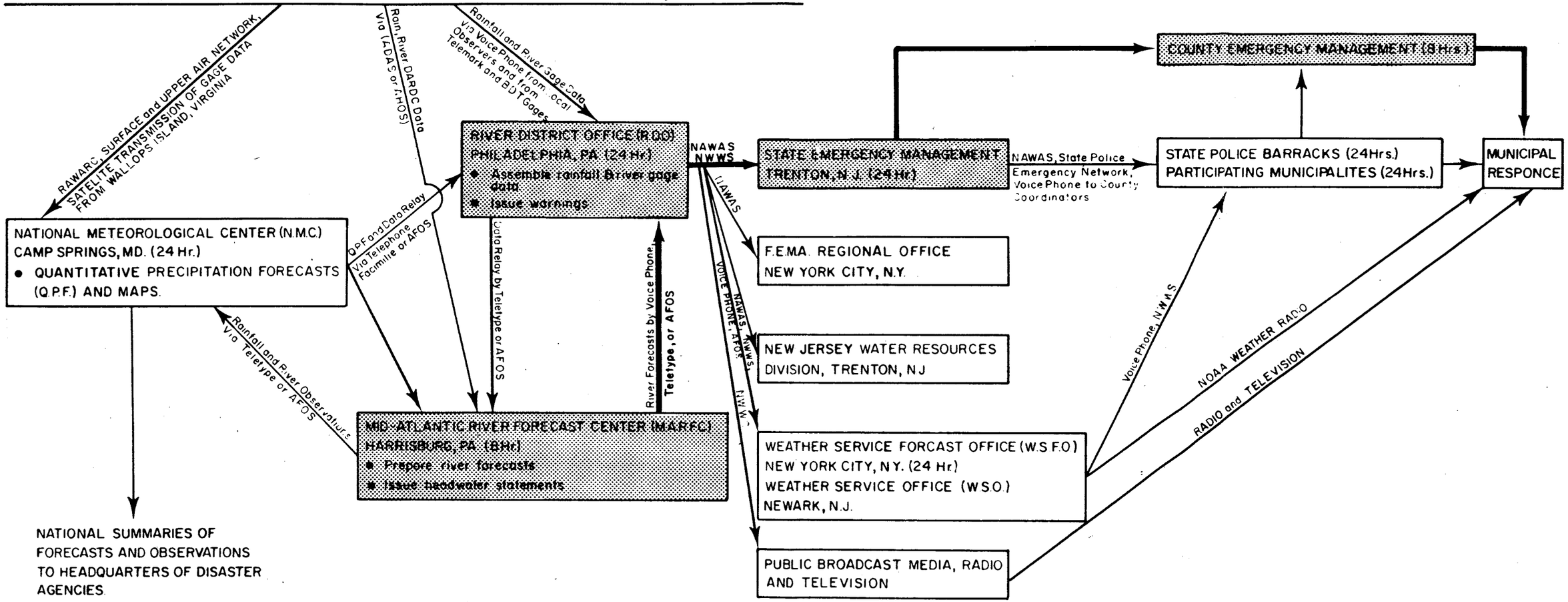

NATIONAL WEATHER SERVICE FORECAST POINT LOCATIONS
PASSAIC RIVER BASIN
Gage Number
Location
1. Saddle River at Lodi
2. Saddle River at Ridgewood Village
3. Ramapo River at Mahwah
4. Wanaque River at Wanaque
5. Ramapo River at Pompton Lakes
6. Pompton River at Wayne/Pequannock
7. Pequannock River at Kinnelon/Wayne
8. Rockaway River at Boonton
9. Rockaway River Below Boonton Reservoir
10. Passaic River at Chatham Boro
11. Passaic River at Little Falls
New York
New Jersey
SCALE IN FEET
8000 0 24000
Passaic River Study, N.J. & N.Y.
EXISTING FORECAST POINTS

FIGURE C-22

RIVER FLOOD FORECAST SERVICE

(Passaic River, Saddle River, Pompton River, Ramopo River, Pequannock River, Wanaque River, and Rockaway River)

OBSERVATIONAL DATA Rainfall Gages, River Stage and Discharge Gages.
Surface and Upper Air Data, Radar (New York City and Atlantic City)



Passaic River Study N.J. & N.Y.

RIVER FLOOD FORECAST SERVICE

FIGURE C-23

Meteorological and radar observations, combined with rainfall predictions provide NWS staff advance information about the potential for flash flooding in local areas. In the Passaic River Basin, the New York City Weather Service Forecast Office issues the flash flood watches, which are transmitted to the Newark Weather Office for further dissemination. Flash flood watches are usually valid for periods of 12 hours or less. If rainfall commences and flooding occurs or is imminent, a flash flood warning is issued by the NWS office in Newark, N.J. Flash flood warnings are usually issued for periods of less than 4 hours. If the Newark office cannot issue the warning, the Harrisburg Forecast Office will do so. The flash flood warning system network is diagrammed on Figure C-24.

The main component of self-help programs in the Passaic River Basin is a local flash flood warning system. The design of these locally operated systems depends upon site specific problems (e.g. geography, population in the floodplain, flood control structures, and warning time) and the resources available for program implementation and maintenance. The NWS assists communities in establishing their flash flood warning program by surveying the area, recommending the appropriate equipment and network design, and providing some of the necessary equipment and techniques. They work with communities so that the forecasting and warning can be done directly by the County or Municipal Emergency Management Coordinator.

Review of the existing floodwarning preparedness systems indicate that some or all of the potential warning time is lost due to slow data collection, data collection inaccuracies, less than efficient warning release systems, and potentially slow warning dissemination techniques.

Recommended Improvements to Preparedness System. The following enhancements to the existing system were recommended:

a. The addition of 23 radio reporting rain gages, with solar panels and batteries, and 2 new radio towers within the basin to ensure continuous reporting.

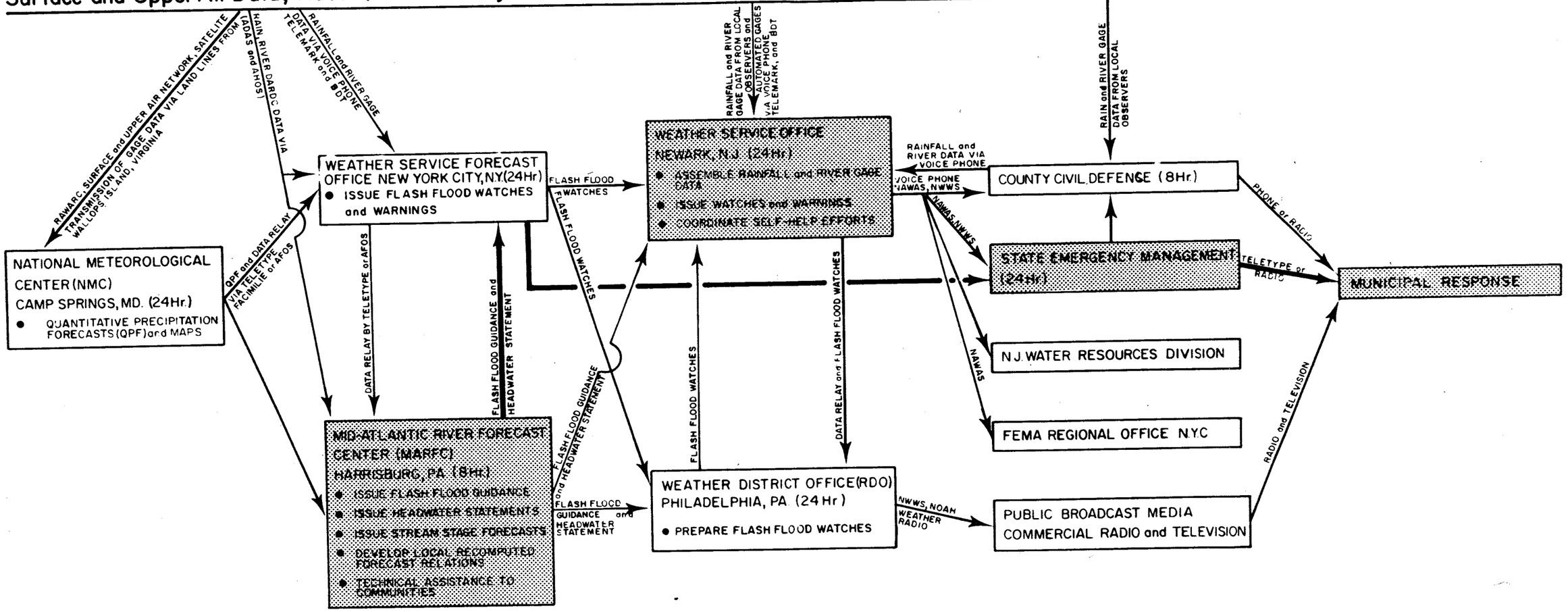
b. The installation of 16 new river gages for forecasting purposes.

c. The installation of 9 micro computers at key locations within the State.

d. The installation of 15 remote terminals in high risk municipalities.

FLASH FLOOD WARNING SERVICE

OBSERVATIONAL DATA Rainfall Gages, River Stage and Discharge Gages.
Surface and Upper Air Data, Radar (New York City and Atlantic City)



Passaic River Study N.J. & N.Y.

FLASH FLOOD WARNING SERVICE

FIGURE C-24

e. The distribution of 150 tone alert weather radios to critical areas and to individuals for flash flood situations.

f. Flash floodwarning systems for five tributary flood problems, whose warning lead times are too short for enhancement from basin-wide elements.

These enhancements to the warning phase were then the catalyst for requiring improvements to the non-Federal portion of the system, the response phase. In addition to the "standard" items of cooperation associated with the project, the State of New Jersey, as non-Federal sponsor, agreed to:

a. Develop stage inundation maps for 39 communities.

b. Coordinate the county and municipal response plans into an overall consistent response.

c. Disseminate information and hold periodic flood exercises to evaluate plans.

d. Update and revise plans periodically to reflect changed conditions.

e. Provide operations and maintenance assistance for all enhancements.

f. Assist in the development of self-help networks for flash flood problem areas.

g. Provide periodic public education efforts to inform floodplain residents on "what to do."

As discussed in Section 1 under RECENT SMALL PROJECT REPORTS, enhancement of the Passaic River Basin's Flood Emergency Preparedness System was recommended for implementation under the Corps' Section 205 Small Project Authority. Construction is currently ongoing.

It is recognized that the proposed emergency preparedness plan is of a temporary nature, in that it does not provide a continuous and consistent level of protection across a range of hydrologic occurrences. The overall preparedness system affects neither the stage nor the frequency of flooding and because

benefits are accrued only up to the estimated time of implementation of potential permanent projects for the basin, the without project condition would not change measurably. Nor would the potential benefit pool available to the more permanent solutions be impacted. Implementation of the emergency preparedness plan, therefore, does not preclude or alter the formulation of permanent solutions to the flooding problems along the Passaic River and tributaries.

If, at the end of the 20 year project life of the preparedness elements, it is apparent that more permanent solutions will not be implemented, then the replacement of warning equipment would be required to extend the life of the system and provide some measure of relief to flood prone areas. Replacement of parts of the system may also be necessary to assure the effective operation of several structural measures proposed as part of the Passaic River Phase I study. For example, if levee/floodwall systems containing stoplog or gated closures or if diversion tunnels utilizing gates to control flows are included in the overall Passaic River Plan, they would require warning elements provided by the preparedness system since these structures are dependent on human operation. In addition, the preparedness system would provide advance warning if flooding is expected to exceed the design level of a comprehensive flood control project. An enhanced preparedness system is, therefore, compatible to both the with and the without project conditions in the Passaic River Basin.

FLOODPLAIN MAPPING

As part of this Phase I Study topographic mapping was prepared by photogrammetric methods for approximately 105 square miles of floodplain along the Passaic River main stem and its tributaries. The mapped area includes the entire SPF floodplain. The maps are scaled 1"=200' with a 2' contour interval; they display all rivers, drainage lines, buildings and other structures, highways, railroads, etc., along with State, County and municipal subdivision boundaries. In addition to using the mapping in hydraulic, economic, environmental and plan formulation studies, the data was provided to the basin states for their use in ongoing flood insurance and floodplain studies. Official NJDEP floodplain delineations have been added where available to the mapping before the final maps were distributed to floodplain communities. Where NJDEP delineations have not been finalized, preliminary maps, without these delineations , have been furnished to all floodplain communities for their use in identifying flood hazard areas.

PUBLIC EDUCATION

Numerous public information distributions have been made to inform the public of the Corps' Passaic River Basin Study and of both the general and specific nature of the flood hazard in the watershed. Information has also been disseminated regarding the types of measures and their application in flood damage reduction. This public education has been the result of efforts by both the Passaic River Study Group directly (through its Subbasin Coordination Program, general mailings through a basin-wide mailing list, radio and news releases) and in cooperation with the environmental departments of both basin States. Examples of information distributed include: 1) a summary brochure of the Passaic River Basin Plan of Study distributed through general mailing; 2) Passaic River Basin Study leaflet entitled "A Major East Coast Flood Problem" distributed through a general mailing; 3) participation in the development of an engineering glossary by NJDEP's Citizen's Task Force; 4) distribution of EP 1105-2-4 entitled "Floodplain Handle With Care" along with other nonstructural information and guidance through NJDEP's Passaic River Basin field office; 5) flood hazard and plan formulation information distributed through the eight Subbasin Coordination Groups; and 6) distribution of the results of various interim studies within the basin.

PRESERVATION OF NATURAL STORAGE

Although this measure is treated in detail as "Building Block" #20 in accordance with Figure C-17, it is also included in the Local Land Management Category because of the existing non-Federal implementation responsibility for such actions. Portions of the watersheds' storage are already in a protective status through the flood insurance program (which requires local zoning to establish a floodway where no development is permitted), the State of New Jersey's Stream Encroachment Permit and Green Acres programs, and other municipal zoning authorities. Corps interest in participating in the preservation of the Passaic River's natural storage areas (through acquisition, flowage easements, local cooperation agreements, etc.) would, therefore, be limited to those areas not protected through other Federal, state, or local programs. It should be noted, however, that floodways have not been adopted in some portions of the Passaic River's Central Basin wetlands because of legal and technical problems encountered in completing flood insurance studies for the key communities along the Rockaway and Whippany Rivers. Table C-21 provides a listing of the status of floodway adoption in the Central Passaic River Basin.

TABLE C-21

Status of Adoption of FIA Floodway - Central Basin Communities

County	Town	Final Flood Insurance Study	
		Adopted	Not Adopted
Essex	Fairfield Borough	X	
	Livingston Township	X	
	Millburn Township	X	
	North Caldwell Borough	X	
	Roseland Borough	X	
	West Caldwell Borough	X	
Morris	Chatham Borough	X	
	Chatham Township	X	
	East Hanover Township		X 1/
	Florham Park Borough	X	
	Hanover Township		X 1/
	Lincoln Park Borough	X	
	Madison Borough	X	
	Montville Township	X	
	Parsippany-Troy Hills		X 1/
	Passaic Township	X	
	Pequannock Township	X	
	Riverdale Borough	X	
Passaic	Pompton Lakes Borough	X	
	Totowa Borough	X	
	Wayne Township	X	
Somerset	Warren Township (U.P.)	X	
Union	Berkeley Heights Township (U.P.)	X	
	New Providence Borough (U.P.)	X	
	Summit City (U.P.)	X	

1/ Adoption of FIA Floodway is expected shortly.

(U.P.) - Upper Passaic River

STORM WATER MANAGEMENT

The HEC-1 hydrologic model for the Passaic River Basin was utilized in conjunction with the future land use projections for the years 1990 and 2040 stored in the grid cell data bank, and HEC's HYDPAR program to develop the potential impact on flood flows from urbanization impacts without local mitigation of potential development via storm water management or other local land use controls. The results of this technical analysis are presented in Table C-22. As can be seen from this table, the number of acres developed in the Basin is expected to increase in the future, with accompanying increases in stream discharge. Compared to historical growth in the Passaic River Basin, the future acreage projected to develop is relatively small. Although comparatively more acres were developed in the past than are projected for the 1990 to 2040 period, the incremental effect on frequent flooding would be more significant, as reflected by the 6.6% increase in discharge expected for the 1 year flood at Little Falls for 2040 conditions. The less frequent events selected as design storms in this study would not significantly increase along the mainstream, as seen by the 2.3% increase in the 100 year flood discharge resulting from development changes through the year 2040. Also, as shown in Table C-22, residentially developed acres are expected to have the largest incremental increase from 1999 to 2040, with most of this change in the Highland Area.

The NJDEP's storm water management regulations for the State, based on the State Storm Water Management Act (PL 1981 C. 32), became effective in February 1983. This Act amends the Municipal Land Use Law to require all municipalities in the State to develop and enforce storm water management plans and ordinances, under certain conditions. One of these conditions was the appropriation by the State of 90% of the costs for developing these plans. Between 1983 and 1985, virtually no progress was made in implementing storm water management plans, with the exception of Bergen County, since no monies had been appropriated by the State to fund the development of the plans. In 1985, however, $2,000,000 was appropriated, $1,000,000 for counties and $1,000,000 for municipalities. State-wide to date, NJDEP has approved grants to 6 counties and has received applications for grants from an additional 2 counties and 93 municipalities. Each municipality is limited to a maximum grant of $5,000. Finally, legislation is pending which would repeal the condition requiring 90% funding by the State. All communities would be required to implement storm water management plans regardless of whether they received development funds from the State or not. Municipalities that had applied prior to this new measure would still be eligible for State funds. The introduction of this measure could have the effect of stimulating applications to the State for development funds and accelerating the spread of implemented plans.

TABLE C-22 PASSAIC RIVER BASIN FUTURE DEVELOPMENT
PROJECTIONS AND HYDROLOGIC IMPACTS
DUE TO URBANIZATION

FUTURE DEVELOPMENT

LAND USE CATEGORY	1990 Development (Acres)	2040 Development (Acres)	% Increase
Residential	213,042	237,126	11.3%
Commercial	28,312	31,472	11.2%
Industrial	13,867	15,042	8.5%
Other 1/	50,070	57,004	13.8%
Developed Basin Acreage 2/	305,291	340,644	12%
Total Basin Acreage	600,147	600,147	-

HYDROLOGIC IMPACT - Passaic River Main stem at Little Falls

Event (Recurrence Freq)	1990 Conditions Discharge (cfs)	2040 Conditions Discharge (cfs)	% Increase
1yr	5,773	6,153	6.6%
100yr	27,527	28,156	2.3%

1/ Other acres include agriculture, mining, construction, transportation, government and miscellaneous public and institutional usages.

2/ The developed acreage in the basin does not include woodland, wetland and other undeveloped land. Therefore, the developed acreage is less than the total drainage basin acreage.

The effects of such storm water management plans were considered in the formulation of Corps flood control plans. The only such plan implemented to date is in Bergen County. Under Bergen County's program, all "applications for development that propose one acre or more of additional impervious surfaces are required to detail, on the plans submitted, storm water management facilities to retain/detain the additional storm water runoff being generated by the developed properties if downstream drainage has been determined to be inadequate to meet design standards." The design storm for all retention or detention facilities is the 25 year storm. Also, according to Bergen County, such storm water management facilities should not allow any incremental increases in runoff for the more frequent events (i.e. the 1-, 5-, and 10-year events).

With these storm water management requirements and information from the county regarding the effectiveness of the program to date, the Corps' hydrologic model for the Saddle River Basin was modified to simulate the effect of the county program. Review of information received from the county indicated that only 40% of the total acres developed since the adoption of these rules required the incorporation of storm water management measures into their plans. Based on this, projected 1990 and 2040 stream discharges were modified to reflect the estimated 40% effectiveness of the program on storms up to the 25-year event.

The results showed that on the Saddle River in Lodi, stream discharges between now and 2040 exhibited increases only slightly less with the storm water management program in place as opposed to having no program. For instance, the one year discharge under the program would be only 2.4% less than it would without the program, while the 25 year discharge would be only 1% less. Applying these results basin-wide, it was determined that Storm water Management Programs would not change the design level of the overall plan and would have no significant effect on expected annual damages.

FLOODPLAIN ZONING

As part of the State of New Jersey's conduct of flood insurance studies in conjunction with FEMA, NJDEP is developing official flood hazard delineations for the Passaic River Basin. In support of this work, the Corps has furnished the State with basic engineering data such as topographic mapping, stream cross sections and the results of hydrologic and hydraulic studies, as they have become available.

Flood Insurance. Flood insurance is available to all persons in communities designated by the Federal Insurance Administration as participating communities. Residents within communities not in the program are not eligible for insurance. As of December 1982, all communities within the Basin are participating in the program, except for East Rutherford, N.J. However, a number of participating communities have not as yet had flood hazard maps and floodway delineations adopted. These communities include the key Central Basin areas of East Hanover, Hanover, and Parsippany-Troy Hills. These communities are expected to adopt these measures shortly.

Floodplain Evacuation. Several options exist for non-Federal interests to evacuate flood prone structures from hazard areas. Several municipalities have used their own resources and zoning authorities to remove small numbers of structures and replace them with land uses compatible with the flood hazard. Areas where this has happened or is underway include Fairfield, Morristown, and Lodi, N.J.

The Borough of Lodi has also evacuated several structures in coordination with FEMA under the authority of Section 1362 of the National Flood Insurance Act. As provided by this section of the Flood Disaster Protection Act of 1973 (PL 93-234), the National Flood Insurance Program provides a "relocation by attrition" approach to managing floodplains. This Act provides that no Federal Agency or Federally backed financial institution shall approve any financial assistance for acquisition or construction purposes in flood hazard areas unless the community in which the area is located is participating in the National Flood Insurance Program. Floodplain occupants cannot qualify for any Federal financial assistance including most home mortgages unless they have flood insurance and their community participates in the program. In effect, the program subsidizes existing floodplain development and prevents any future development subject to significant flooding. When existing floodplain structures deteriorate, they will not be replaced, and flood damages will, theoretically, decline over time. To a certain extent, the Eagleton Rider to the Housing and Community Development Act of 1977 takes some of the impact out of the flood insurance program as provided by PL 93-234 by now allowing Federal funds to be used for development in the floodplains of communities not enrolled in the program.

FEMA is also involved in floodplain evacuation in the Central Passaic Basin. IN Pequannock, a FEMA buyout program approved the acquisition of 40 homes. The owners of 28 of these homes agreed to the sale. To date, 8 structures have been acquired and demolished. Currently, six structures in Riverdale and nine in Montville are under consideration for inclusion in an acquisition program. In Fairfield, 103 structures were considered for acquisition. A total of $736,000 was approved to acquire 24 of these structures. In Wayne, $1,814,000 was approved for buying 49 of the 117 structures investigated. In Lincoln Park, 58 structures have been declared eligible and $2,219,000 was approved for the acquisitions. Only 16 of the structures' owners, however, have applied for the Lincoln Park program. This again points up the escalating real estate prices in the Central Passaic Basin, which places additional development pressures on natural storage areas as described above.

The State of New Jersey, through NJDEP, is also pursuing the acquisition of frequently flooded properties on a limited scale. The N.J. State Legislature has appropriated $5,000,000 for the acquisition of such properties and NJDEP has identified areas in Wayne, Pequannock, Oakland, Lincoln Park, and Fairfield for possible evacuations. As of August 1987, 13 structures have been acquired and five of these have already been demolished. The acquisition of an additional 12 structures is expected to be completed in the near future and value appraisals are underway for several more structures. While coordination between the State, municipal government and local residents is ongoing, the same problem encountered by FEMA in Lincoln Park could arise, that is, purchase prices approved under the program cannot keep pace with the market prices of even structures highly susceptible to flood damage.

The Water Resources Development Act of 1986 (PL 99-662) also contains a provision for a buyout plan for the Passaic River Basin. Section 1148 of the Act authorized the Secretary of the Army to acquire floodprone residential structures in the Passaic River Basin, based on a willing seller approach. The authorized cost of the buyout plan is $50,000,000, with a 25 percent non-Federal share. Such a project would affect only several hundred homes in the Basin and would not provide a long-term, basin-wide solution to the flood problem. The authorized buy-out plan is, therefore, independent of the recommendations of this study.

TECHNICAL ASSISTANCE

In connection with local needs as described above, study products and technical assistance have been provided to the Basin States, counties, municipalities and other watershed

interests. Products furnished include: floodplain mapping and delineations; the hydraulic effects of bridges; stream cross-sections and hydraulic flow lines for use in local stream maintenance projects; wetland inventories and wetland faunal surveys; hydrologic data; hydrologic evaluations of potential increases in flood flows associated with both future urbanization and the loss of natural storage areas for consideration by local interests in making decisions regarding storm water management, fill regulations and land use planning; and information regarding interim flood damage reduction actions. A copy of the HEC-1 hydrologic model for the Basin is scheduled to be made available to the State of New Jersey for their use. The State is already making extensive use of this study's flood plain mapping and hydrologic and hydraulic data in their flood hazard and flood insurance studies.

ulation was conducted in iterative sequences of the
ess, with the level of detail increased as approp-
h decisions regarding the feasibility and
alternative actions. Additional iterations were
quired when the evaluation of alternative plans
tfalls in reducing the Basin's flood damages, or in
NED objective.

, a number of alternatives, each consisting of a
e, were developed as plans to address the Basin's
. These alternatives have been designated as
re Building Blocks" and are depicted in the first
ure C-17. "Building Blocks" were defined in the
Basin Plan of Study as single management measures
as major elements of plans addressing the planning
d which are responsive to the Congressional
this study. The evaluation of the initially
uilding Blocks" indicated the following.

All of the "Building Blocks" are limited in the
ch they can uniformly reduce flood damages from a
basin-wide basis because of their single measure
measures such as Dam and Bridge Modifications
ck 4), Reservoirs (Building Blocks 17 & 18), Tunnel
uilding Block 23) and the Tidal Barrier (Building
e maximum beneficial effects occur at specific
uence centered at the immediate vicinity of the
ures of the project and progressively diminish
stream or downstream from these locations. It is
nce "Building Blocks" do not address the Passaic
em flood problem from a consistent, uniform and
perspective, they cannot be considered as complete
of themselves. It was confirmed that "Building
applicable only as major elements of comprehensive
n their ability to efficiently provide the desired
ection to the study area in combination with other
cks."

The extent to which the Channel Modification
ck 6) and Levee/Floodwall (Building Block 11)
efficiently reduce flooding without combination
nd Dam Modifications (Building Block 4) is limited
that these measures by themselves are not
'Building Blocks." Likewise, the Floodproof/Raise
cannot be applied without the utilization of
uation (Building Block 1) to at least a few

structures for which floodproofing or raising is not feasible from an engineering perspective. Therefore, as shown in the middle column of Figure C-17, a number of "Combination Measure" alternatives were also formulated and subsequently utilized as "Building Blocks" (i.e., Building Blocks 3, 7 and 13).

c) No "Building Blocks" were found to be economically feasible for the Upper Passaic River study reach (i.e., main stem upstream of Chatham, N.J.). The findings regarding specific measures at this area are found in the discussion of individual "Building Blocks" contained in the paragraphs below.

d) The following measures were found to be impractical and/or economically unjustified: Existing Reservoirs (Building Block 17), New Reservoirs (Building Block 18), Aquifer Recharge (Building Block 21) and Tidal Barrier (Building Block 27). In addition, it was found that Permanent Evacuation (Building Block 1) was not economically feasible for the study area as a whole or for large portions thereof; however, it is economically feasible at a few individual locations within the 10 year floodplain. The negative findings regarding these "Building Blocks" are contained in the paragraphs below.

A complete list of the "Building Blocks" developed, both those consisting of single measures and combinations of measures, are summarized in Table C-23. This table also presents a summary of the findings for each "Building Block." Discussions of the formulation rationale and results for each "Building Block" are contained in the paragraphs below. Although the current hydrology and hydraulics were not utilized in the "Building Block" analyses the base relationships and resulting decisions are still valid.

BUILDING BLOCK 1 - PERMANENT EVACUATION

The feasibility of permanently evacuating all structures in the 10, 50, and 100 year floodplains as a separate plan was examined for each of the nonstructural study areas to eliminate the potential damage problem. The evacuated areas could then be available for uses consistent with the flood hazard such as parks or other facilities. For this screening, the cost associated with the evacuation of a structure was considered to be the cost of buying out the structure and land, in addition to the cost of removing the structure from the floodplain. The 10 year evacuation plan is presented as Building Block 1A, the 50 year 1B, and the 100 year 1C.

The number of structures considered for evacuation and the costs associated with Building Blocks 1A, 1B, and 1C are summarized in Table C-24. The number of structures in the 100 year floodplain differs from that presented in Table C-11, since those structures that are affected only slightly by overland flooding were not included in the nonstructural plans. Due to the low economic efficiency of 1A, 1B, and 1C, the next

Table C-23 Summary of Passaic River Basin Building Blocks

"Building Block"	Single Measure Alternative	Combination of Measures Alternative	Not Effective as Single Measure "Building Block"	Economically Feasible as "Building Block"	Not Economically Feasible Overall/But is Feasible at Selected Reaches	Not Economically Feasible
1A 10yr Permanent Evacuation	X				X	
1B 50yr Permanent Evacuation	X					X
1C 100yr Permanent Evacuation	X					X
1D 10yr Main Floor Flooding Permanent Evacuation	X				X	
1E Incremental analysis, Permanent Evacuation	X			X		
2 Floodproofing Raising	X		X			
3A 10yr Floodproof/ Raise/Perm. Evac.		X			X	
3B 50yr Floodproof/ Raise/Perm. Evac.		X			X	
3C 100yr Floodproof/ Raise/Perm. Evac.		X			X	
4 Dam and Bridge Modification	X		X			
6 Channel Modification	X		X			
7A 100yr Lower Valley Channel/Bridge + Dam Modification		X		X		
7B 50yr Lower Valley Channel/Bridge + Dam Modification		X		X		

Table C-23 Summary of Passaic River Basin Building Blocks (Cont)

"Building Block"		Single Measures Alternative	Combination of Single Measure Alternative	Not Effective as Single Measure "Building Block"	Economically Feasible as "Building Block"	Not Economically Feasible Overall/But is Feasible at Selected Reaches	Not Economically Feasible
11	Levees/Floodwalls	X		X			
13A	100yr Levee/ Floodwall/Bridge		X		X		
13B	SPF Levee/Flood-wall/Bridge		X				X
17	Existing Reservoirs	X		X			
18	New Reservoirs	X		X			X
20	Preservation of Natural Storage Areas	X			X		
21	Aquifer Recharge	X		X			
23A	Beatties Dam Inlet/35'Dia. Tunnel	X			X		
23B	Beatties Dam Inlet/40'DIA. Tunnel	X			x		
23C	Pompton River Inlet/40'Dia. Tunnel	X			x		
23D	Pompton River Inlet/35'Dia. Tunnel	X			x		
23E	Double Inlet/40'/ Dia. Tunnel	X			x		
23F	Double Inlet/35'/ 40'Dia. Tunnel	X			x		
23G	Two Bridges Inlet 40' Dia. Tunnel	X			x		
Plan 27 Tidal Barrier		X					X

TABLE C-24 BUILDING BLOCKS 1A, 1B, AND 1C
PERMANENT EVACUATION

(Oct. 85 Price Level, 8-5/8% Interest Rate, 100 Year Project Life)

STUDY AREA	FLOOD PLAIN	NUMBER OF STRUCTURES RES.	NON-RES.	TOTAL FIRST COST ($1,000)	TOTAL ANNUAL COSTS ($1,000)	TOTAL ANNUAL BENEFITS ($1,000)	B/C
	10 YR	3966	598	1,323,600	114,189	25,462	.2
LOWER VALLEY	50 YR	5224	1021	1,879,200	162,122		.2
	100 YR	5577	1212	2,043,600	176,305		.1
CENTRAL BASIN							
	10 YR	1828	172	377,500	32,567	21,413	.7
Passaic, Rockaway, Whippany	50 YR	2850	389	735,000	63,409		.3
	100 YR	3290	521	939,125	81,020		.3
	10 YR	2616	208	387,500	33,430	20,512	.6
Pompton	50 YR	3423	322	486,250	41,949		.5
	100 YR	4070	422	601,250	51,871		.4
	10 YR	103	9	12,875	1,110	435	.4
Wanaque	50 YR	141	13	19,000	1,639		.3
	100 YR	217	31	32,000	2,760		.2
	10 YR	211	2	21,500	1,854	363	.2
Pequannock	50 YR	268	5	27,875	2,404		.2
	100 YR	284	5	29,875	2,577		.1
	10 YR	600	4	56,125	4,842	3,370	.7
Ramapo	50 YR	858	26	87,125	7,516		.4
	100 YR	899	27	91,125	7,861		.4
	10 YR	470	34	60, 875	5,251	559	.1
UPPER PASSAIC	50 YR	660	49	84,875	7,322		.1
	100 YR	754	69	102,500	8,842		.1

1/ Benefits (net of municipal damages) were taken to the higher of the 500 year or SPF level to obtain the highest possible B/C ratio.

iteration focused on only the most frequently flooded structures in the Basin. This was accomplished by eliminating the structures on the outer portions of the floodplains from further consideration. Thus, only the structures with the highest damage potential were included. For this latter analysis, structures for which the main floor would be inundated by the 10 year event were selected for consideration. This alternative was designated as Building Block 1D. However, as a basin-wide measure, this also proved to be economically infeasible. The results of this analysis are shown on Table C-25.

Although the two analyses presented above indicated that a basin-wide approach to permanent evacuation was not an economically feasible alternative, incremental analyses showed that several reaches were economically justified. The alternative which considered permanent evacuation at only these reaches was designated Building Block 1E. Table C-26 is a summary of the number of structures and cost associated with the permanent evacuation of these reaches.

BUILDING BLOCK 2 - FLOODPROOF/RAISE

The second nonstructural "Building Block" utilized floodproofing and raising only. An analysis of the 10, 50, and 100 year floodplains throughout the Basin indicated that even within the 10 year floodplain, it would be necessary to permanently evacuate certain structures because of their structural characteristics, and would be economically more efficient to evacuate others. Consequently, plans which utilized only floodproofing and raising would not provide a consistent level of protection to all the structures within a given floodplain. This measure was, therefore, combined with permanent evacuation, where appropriate, to generate a "Building Block" combination of these nonstructural alternatives (Building Block 3).

BUILDING BLOCK 3 - PERMANENT EVACUATION, FLOODPROOF/RAISE

This combination plan consisted of the application of the appropriate nonstructural measure for each structure within the 10 year, 50 year, and 100 year floodplains to provide a consistent level of protection within each area.

Design Criteria. The application of a selected measure to a specific structure utilized the design criteria which is described below and summarized in Table C-27. The design flood is alternately defined as the 10, 50, or 100 year flood. The following is a description of each measure considered. It is noted that a floodwarning system would be included as part of each plan.

TABLE C-25 BUILDING BLOCK 1D

PERMANENT EVACUATION, MAIN FLOOR FLOODING BY 10 YEAR EVENT
(Oct.85 Price Level, 8-5/8% Interest Rate, 100 Year Project Life)

Reach	Number of Structures Residential	Non-Residential	Annual Benefits ($)	First Cost ($)	Annual Cost ($)	B/C
LOWER VALLEY	98	201	6,440,000	257,000,000	22,170,000	0.3
CENTRAL BASIN Passaic, Rockaway and Whippany	138	90	4,286,000	102,600,000	8,852,000	0.5
Pompton	582	154	7,781,000	116,400,000	10,040,000	0.8
Wanaque, Pequannock and Ramapo	77	10	669,700	9,580,000	826,000	0.8
UPPER PASSAIC 1/	6	3				

1/ Since only 9 widespread structures are affected, Federal interest is not warranted.

181

TABLE C-26 BUILDING BLOCK 1E PERMANENT EVACUATION, INCREMENTAL ANALYSIS
(Oct. 85 Price Level, 8-5/8% Interest Rate, 100 Year Project Life)

Study Area	Damage Reach	Township	Location	Res. Evacuations	Non Res. Evacuations	Total Annual Benefits ($)	Total First Cost ($)	Total Annual Cost ($)	B/C
Lower Passaic	010072	Passaic	Route 3	4	31	79,000	389,000	34,000	2.3
Central Passaic	020015	Wayne	Hobson Ave.	21	0	159,000	1,619,000	150,000	1.1
	020161	Livingston	Dorsa Ave.	0	4	192,000	1,629,000	141,000	1.4
	020221	Chatham	Commerce Rd.	4	11	724,000	3,143,000	271,000	2.7
Pompton	600016 600018	Wayne	Islands upstream of Two Bridges	14	0	111,000	788,400	68,000	1.6

TABLE C-27

APPLICABILITY OF NONSTRUCTURAL MEASURES

	STRUCTURE/BASEMENT TYPE					
	Residential			Non-residential		
FLOOD DEPTH	Full or Partial	Crawl	None	Full or Partial	Crawl	None
Below Basement Floor	No Action	N/A	N/A	No Action	N/A	N/A
Basement Floor to Ground Elevation	Floodproof; (Sump Pump, Check Valve & Watertight Chamber)	N/A	N/A	Same as Residential (Full or Partial)	N/A	N/A
Ground to Main Floor Elevation	Floodproof as above - add Flood shielding	Floodproof Utilities	No Action	Same as Residential	Floodproof Utilities	No Action
Main Floor to 4 ft. above ground	Raise	Raise	Construct Wall Around Structure	Raise if Main floor area $\leq$ 4,000 Sq.Ft. If not, build wall around structure, and compare to evacuation cost. If flood exceeds 9 Ft., and main floor area $\leq$ 4,000, raise and build wall.		Construct Wall Around Structure
4 ft. Above Ground to 9 ft. Above Main Floor	Raise	Raise	Raise			Raise if main floor area $\leq$ 4,000 Sq. Ft. If not, build wall, check for evacuation.
Above 9 ft.	Permanent Evacuation	Permanent Evacuation	Permanent Evacuation			If main floor area $\leq$ 4,000 sq. ft. raise 9 ft. and build wall. If $\geq$ 4,000 ft., build wall. Check for evacuation.

a) Floodproofing. This measure would be applied to all structures where the design flood is below the main floor. Floodproofing the damageable components of structures of all types was examined for flooding up to the design flood elevation. For structures that are susceptible to basement seepage, floodproofing would consist of the installation of a sump pump, a utility check value, and a concrete "utility chamber" (waterproofed concrete wall around the utility). This measure was not developed to create a watertight basement; however, damage from seepage would be minimized in a cost effective manner by preventing any damage to utilities. Floodshielding would protect the structure against overland flooding not higher than the main floor. (Floodshielding consists of closing all openings such as doors and windows.) In cases where the main floor would be inundated by the design flood, the floodproofing measures described would not suffice in eliminating flood damages, due to the extensive hydrostatic forces associated with such flooding. Raising was one option which was considered in such a case.

b) Raising. This measure was considered for all structures where the design flood stage is above the main floor. Raising a structure would consist of extending the height of the foundation walls (or constructing new walls for structures without basements) to an elevation such that the main floor would be higher than the design level. Fill would be placed on the existing basement floor slab and a new slab constructed. The original height from the basement floor to the main floor would, therefore, be maintained. The wall and slab would then be waterproofed. This condition would result in a watertight basement which would be structurally stable under flooding conditions, with the main floor at a higher elevation than the design level. A sump pump would be installed in the basement, and the land around the structure would be filled and regraded. Raising was considered for both residential and non-residential frame structures, with main floor areas up to 4,000 square feet.

c) Nonstructural Wall. This measure, which can be considered a form of floodproofing, was utilized for all structures whose main floor area is greater than 4,000 square feet, and whose main floor would be inundated by the design flood. In this case, a waterproofed concrete wall would be constructed around the building and joined to the existing walls of the structure. An impervious bentonite slurry wall would extend into the ground to a depth sufficient to prevent any seepage from entering the structure from under the wall. The wall would be architecturally treated at minimal cost for aesthetic purposes. This improvement would yield a watertight structure for floods up to the design level.

d) Permanent Evacuation. Permanent evacuation was considered for all structures. The cost to evacuate a structure was compared to the cost of implementing either a, b, or c, above, and the least costly alternative chosen. Permanent evacuation was also the alternative selected in cases where the depth of flooding exceeded practical engineering constraints to floodproof or raise a particular structure.

Methodology. In order to decide the measure to be applied to a particular structure for each design flood, information pertaining to the structures involved, the costs associated with the various measures, and water surface elevations was needed. First, an inventory was developed for the structures within the floodplain which included such information as the main floor area and elevation, structure type, usage, construction type, market value, and basement and foundation data. This structure inventory was keyed to the structure's location on 1" = 200' scale topographic mapping with a 2' contour interval.

Next, construction cost curves were generated for each alternative under consideration for different flood depths, and for each type of structure. To obtain such data, structural analyses were performed.

The third set of data developed were hydraulic water surface profiles. Hydraulic data were necessary for establishing levels of protection ("design levels") for each damage reach. For consistency the study reaches for the determination of nonstructural alternatives corresponded to the reaches selected for the hydraulic and economic evaluation model.

The 10, 50, and 100 year flood elevations were used for the nonstructural analysis, in accordance with the approach indicated in the Plan of Study. The objective in selecting these floods was to maximize the potential for net economic benefits for nonstructural protection, by including frequently inundated floodplains (such as the 10 yr.) in the study, and maximizing the number of structures to be included in the analysis.

The actual process of formulating the nonstructural alternatives consisted of calculating the depth of flooding for a specific level of protection at each structure; comparing this flood depth with the main floor elevation; and then, based on the structure type and the engineering criteria discussed above, the appropriate nonstructural measure was selected. After the overall alternative was formulated, the cost of the plan was determined by using the cost curves for the types of structures in question. Due to the large number of structures which were included in the analysis, the procedure was computerized.

A FORTRAN computer program, entitled Nonstructural Program (NSP), was developed and applied to a structure file specially created for nonstructural formulation. This file combined the additional structure data needed to determine the appropriate measure with the "structure file" used in the economic analysis. NSP sorts the structures by type and reach, calculates the differences between a structure's main floor elevation and the design flood elevation based on flood depths, indicates the appropriate nonstructural measure for each structure based on the criteria for selection, and applies the corresponding cost curve to individual structures.

Results. The results of nonstructural formulation for permanent evacuation, floodproofing/raising alternatives are summarized in Table C-28 on an aggregate basis for each of the Lower, Central, and Upper Passaic formulation reaches. An economic summary is shown in Tables C-29 to C-31. The alternatives for the 10 year, 50 year and 100 year floodplains have been designated as Building Blocks 3A, 3B and 3C, respectively, in accordance with Figure C-17.

BUILDING BLOCK 4 - DAM AND BRIDGE MODIFICATION

The purpose of this plan was to reduce flooding due to backwater caused by the many bridges and dams throughout the Basin.

Bridges. The modification of bridges for flood control purposes was investigated to determine whether significant reductions in flood stages could be achieved by modifying or replacing specific bridges within the Basin. Preliminary hydraulic investigations revealed, however, that replacement or modification of existing bridges would not produce significant stage reductions over a large enough distance to economically justify the cost involved. Bridge replacement and modification was, therefore, only proposed where required as part of channel modification or levee plans. The technical results regarding specific bridges and the hydraulic effect of their removal were made available to local interests.

Dams. The modification of dams for flood control purposes was analyzed for three dams: Dundee and the S.U.M. Dams in the Lower Valley, and Beatties Dam between the Central Basin and the Lower Valley.

TABLE C-28 SUMMARY OF BUILDING BLOCKS 3A, 3B AND 3C
PERMANENT EVACUATION, FLOODPROOF/RAISE

Number of Structures

Building Block	Protection Level	Subbasin	Floodproof		Raise		Wall Around Structure		Permanent Evacuation		Total First Cost	Total Annual Cost *
			R	NR	R	NR	R	NR	R	NR		
3A	10 Yr.	Lower Passaic	3,868	397	82	42	14	143	2	16	95,700,000	
		Central Passaic	1,690	82	74	5	45	76	19	9	32,900,000	
		Upper Passaic	464	31	1	0	1	2	4	1	4,400,000	
		Pompton	2,034	54	469	12	105	128	8	14	49,400,000	
		Wanaque	102	3	1	0	0	6	0	0	1,300,000	
		Pequannock	209	0	2	0	0	2	0	0	1,800,000	
		Ramapo	526	2	44	0	28	1	2	1	7,000,000	
		Total	8,893	569	673	59	193	358	35	41	192,500,000	19,100,000
3B	50 Yr.	Lower Passaic	4,419	372	754	175	40	428	11	46	213,900,000	
		Central Passaic	2,339	110	338	27	141	232	32	20	81,600,000	
		Upper Passaic	651	40	3	0	2	8	4	1	12,200,000	
		Pompton	1,860	44	1287	105	133	142	143	31	109,400,000	
		Wanaque	107	4	27	2	7	6	0	1	2,600,000	
		Pequannock	247	2	19	0	2	3	0	0	3,000,000	
		Ramapo	564	15	258	1	34	8	2	2	16,100,000	
		Total	10,187	587	2428	310	359	827	192	101	438,800,000	46,700,000
3C	100 Yr.	Lower Passaic	3,971	337	1550	255	38	555	18	65	292,300,000	
		Central Passaic	2,530	108	550	44	156	344	54	25	120,700,000	
		Upper Passaic	740	50	4	3	6	14	4	2	14,400,000	
		Pompton	1,940	40	1728	145	174	193	228	44	163,500,000	
		Wanaque	106	18	107	6	4	5	0	2	7,100,000	
		Pequannock	256	2	26	2	2	1	0	0	3,500,000	
		Ramapo	516	11	337	5	44	9	2	2	18,700,000	
		Total	10,059	566	4302	460	424	1121	306	140	620,200,000	68,330,000

R = Residential
NR = Non-Residential (Commercial, Industrial, Apartments)
* Does not include Upper Passaic (not economically feasible - see Table C-29 to C-31). Expenditures included for floodwarning, operation and maintenance, and limited access.

TABLE C-29 BUILDING BLOCK 3A (10 YEAR LEVEL OF PROTECTION)
ECONOMIC SUMMARY
(Oct. 85 Price Level, 8-5/8% Interest Rate, 50 Year Project Life)

	Annual Benefits	Annual Cost ($)	B/C ($)	B/C	($)
Lower Valley		4,612,000	8,388,000	0.5	-3,776,000
Central Basin		9,760,000	8,099,000	1.2	1,661,000
Upper Passaic		139,000	389,000	0.4	-247,000
Total/Lower Valley Central Basin		14,372,000	19,100,000 1/	0.8	-4,728,000

1/ Includes expenditures for floodwarning, operation, maintenance and limited access.

TABLE C-30 BUILDING BLOCK 3B (50 YEAR LEVEL OF PROTECTION)
ECONOMIC SUMMARY
(Oct. 85 Price Level, 8-5/8% Interest Rate, 50 Year Project Life)

	Annual Benefits ($)	Annual Cost ($)	B/C	B/C ($)
Lower Valley	9,610,000	18,748,000	0.5	-9,138,000
Central Basin	16,618,000	18,138,000	0.9	-1,520,000
Upper Passaic	225,000	1,069,000	0.2	-844,000
Total/Lower Valley Central Basin	26,228,000	46,700,000 1/	0.6	-20,472,000

1/ Includes expenditures for floodwarning, operation, maintenance and limited access.

06/90

TABLE C-31 BUILDING BLOCK 3C (100 YEAR LEVEL OF PROTECTION)
ECONOMIC SUMMARY
(Oct. 85 Price Level, 8-5/8% Interest Rate, 50 Year Project Life)

	Annual Benefits ($)	Annual Cost ($)	B/C	B/C ($)
Lower Valley	11,271,000	25,620,000	0.4	-14,349,000
Central Basin	19,085,000	27,478,000	0.7	-8,393,000
Upper Passaic	250,000	1,262,000	0.2	-1,012,000
Total/Lower Valley Central Basin	30,356,000	68,330,000 1/	0.4	-37,974,000

1/ Includes expenditures for floodwarning, operation, maintenance and limited access.

The first scenario evaluated consisted of total removal of the dam. As shown in Table C-32, significant reductions in water surface elevations would only extend a short distance upstream. Next, the effect of minor channel regrading upstream of the dam was analyzed. This measure by itself resulted in minimal reductions in water surface elevations. However, analyses were then made of the effects of combining the channel regrading with lowering the dam's crest by 3, 6 and 9 feet and with total removal of the dam. In each case, it was determined that the combination of measures was more effective in reducing water surface elevations than either the channel regrading or dam modification independently.

All the modifications investigated would reduce upstream water surface elevations, with total removal of Beatties Dam in conjunction with minor channel regrading resulting in the most significant reductions. However, even this combination of measures would not be effective as a solution to the flood problem since about a 50 year level of protection would be provided only within the first quarter mile upstream of Beatties Dam in Little Falls and Wayne. Beyond the railroad bridge, about a mile upstream of Beatties Dam, the protection would be less than the 10 year frequency event. Therefore, while 400 structures may receive some benefit, only a small portion of them would benefit significantly.

The results of this analysis clearly showed that flooding at Two Bridges and along the Pompton River results from a natural flow constriction in the Passaic River channel above Beatties Dam which prohibits flood flows from rushing downstream. Any significant reduction in the water surface elevation at Two Bridges would require removal of the constriction which is formed by the narrow rock-lined channel in this area, and enlargement of the Passaic River channel in conjunction with modifications to Beatties Dam. However, removal of the natural constriction would not only eliminate flood storage in the Little Falls area, but would also reduce flood storage further upstream. The elimination of this flood storage capability could have significant adverse impacts on downstream communities. This is further discussed in Building Block 7.

The uncertainty of balancing adverse effects to downstream communities and upstream wetland areas with the beneficial flood damage reduction impacts results in the feasibility and extent of such Beatties Dam modifications being in doubt without detailed hydrologic and hydraulic study of these impacts. What is clear, however, is that the relatively limited flood protection afforded by this dam modification is not responsive to the objective of the main stem study of providing comprehensive basin-wide protection. Therefore, specific modifications in the vicinity of Beatties Dam are best considered further as a potential interim action in accordance with Section 607 of 99-662.

TABLE C-32 EFFECTS OF MODIFYING BEATTIES DAM
ELEVATION REDUCTION (FT.) UPSTREAM OF BEATTIES DAM

FLOOD EVENT	Sta 1568+65 Beatties Dam	Sta 1573+10	Sta 1579+00	Sta 1614+70	Sta 1627+24 Erie-Lackawanna RR Bridge	Sta 1638+00	Sta 1720+00 Route 80 Bridge
Distance Above Beatties Dam (ft)	445	1,035		4,605	5,859	6,935	15,135
Remove Beatties Dam - Existing Channel							
1 year	7.2	2.8	2.7	1.1	1.1	1.0	0.6
10 "	6.7	2.4	2.3	1.0	0.9	0.8	0.4
50 "	6.2	2.4	2.2	0.9	0.9	0.8	0.2
100 "	6.0	2.4	2.2	0.9	0.9	0.8	0.3
500 "	5.4	2.6	2.5	1.0	1.0	0.7	0.3
Existing Beatties Dam - Modify Channel							
1 year	0.0	0.2	0.0	0.7	0.6	0.5	0.1
10 "	0.0	0.1	0.0	0.9	0.8	0.7	0.1
50 "	0.0	0.0	0.0	0.9	0.8	0.8	0.1
100 "	0.0	0.0	0.0	0.9	0.8	0.7	0.1
500 "	0.0	0.0	0.0	0.6	0.6	0.3	0.1
Lower Beatties Dam Crest by 3 feet - Modify Channel							
1 year	2.8	2.8	2.7	3.0	2.7	2.4	0.8
10 "	2.9	2.8	2.6	3.0	2.6	2.2	0.6
50 "	2.8	2.4	2.4	2.8	2.4	2.1	1.0
100 "	2.8	2.6	2.3	2.6	2.4	2.1	0.4
500 "	2.6	2.1	2.1	2.1	2.0	1.3	0.5
Lower Beatties Dam Crest by 6 feet - Modify Channel							
1 year	5.9	5.6	5.1	4.6	3.8	3.2	0.8
10 "	5.8	5.3	4.7	4.2	3.4	2.8	0.8
50 "	5.4	4.8	4.2	3.9	3.3	2.7	1.1
100 "	5.3	4.7	4.1	3.7	3.2	2.7	0.5
500 "	4.7	3.9	3.6	3.0	2.7	1.8	0.7
Lower Beatties Dam Crest by 9 feet - Modify Channel							
1 year	7.2	6.4	5.7	4.8	3.9	3.3	0.9
10 "	6.7	5.8	5.1	4.3	3.5	2.9	0.8
50 "	6.3	5.4	4.6	4.1	3.4	2.8	1.1
100 "	6.1	5.2	4.5	3.9	3.4	2.8	0.5
500 "	5.4	4.5	4.0	3.2	3.0	2.0	0.8
Remove Beatties Dam - Modify Channel							
1 year	7.2	6.4	5.7	4.8	3.9	3.3	0.8
10 "	6.7	5.8	5.1	4.3	3.5	2.9	0.8
50 "	6.2	5.4	4.6	4.1	3.4	2.8	1.1
100 "	6.1	5.2	4.5	3.9	3.3	2.8	0.5
500 "	5.4	4.5	4.0	3.2	3.0	2.0	0.8

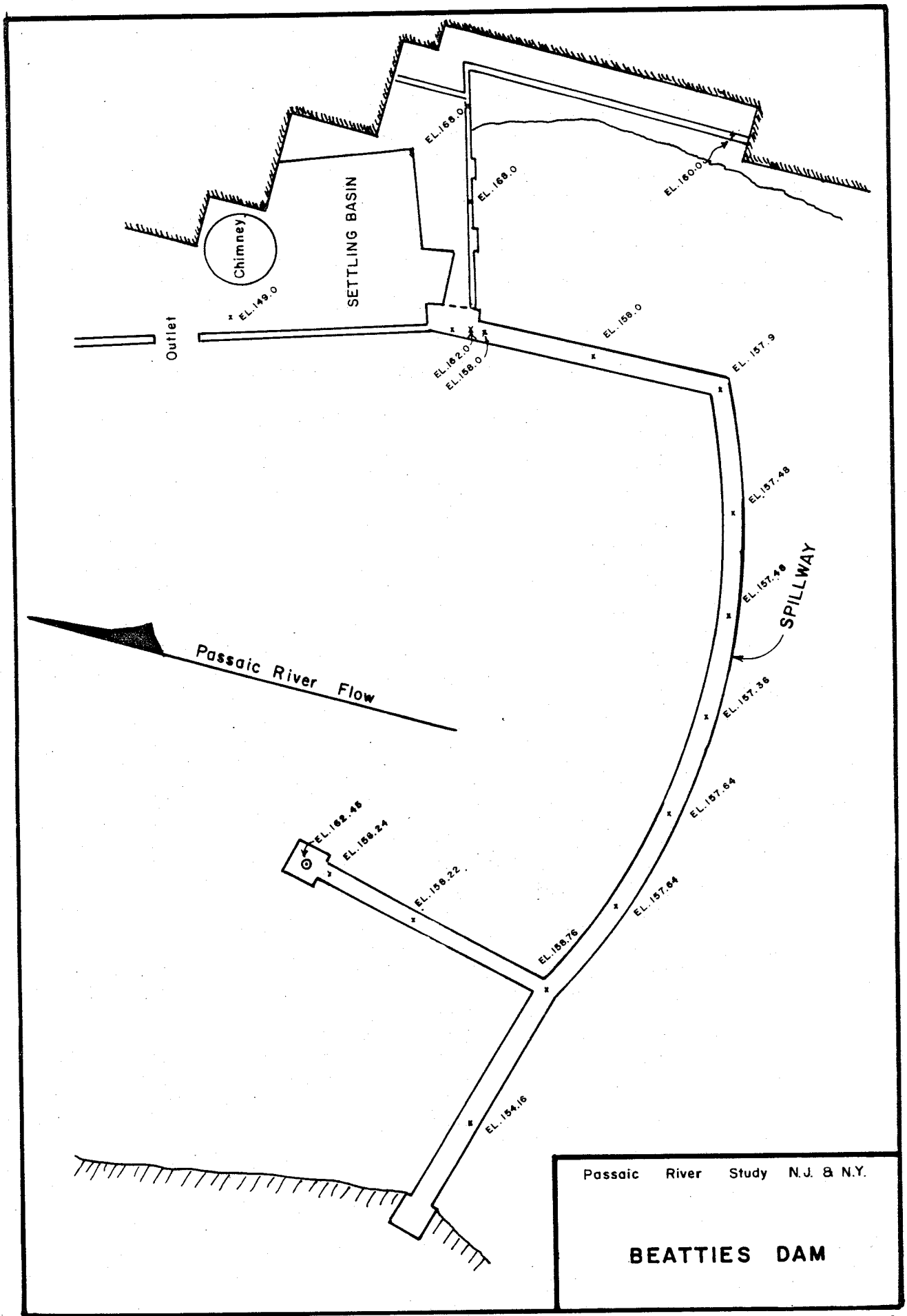
Dundee Dam is located on the Passaic River in the cities of Clifton and Garfield, as shown in Figure C-2. A series of modifications, including completely removing the dam, were investigated. The steep slope immediately downstream of the dam would produce a critical depth flow if the dam was removed. This critical depth starting condition combined with the relative flatness of the channel upstream of the dam would cause stage reductions obtained by removing the dam to diminish quickly as one moves upstream. Therefore, the cost of removing or modifying the dam would not be justified economically. Channel modifications in combination with the dam removal were also investigated and found to be unjustified economically.

The S.U.M. Dam is located on the Passaic River in the City of Paterson, as shown in Figure C-2. A series of modifications, similar to those investigated for Dundee Dam, were analyzed. The river upstream of the dam is relatively flat, while located just downstream of the dam are the Great Falls which bring about a critical depth starting condition. Thus, as with Dundee Dam, the effects of removing or modifying the dam would diminish quickly, only slightly affecting the amount of channel modification required.

Additionally, since the S.U.M. Dam is utilized for hydropower, lowering the dam's crest would require the installation of gates on the dam in order to maintain the existing water surface elevations during non-flood conditions. The cost of modifying the dam and installing gates would not be economically justified.

Beatties Dam, located on the Passaic River in the Townships of Little Falls and Wayne, is a 220-foot long masonry dam with a 60-foot straight section and a 160-foot arched section (Figure C-25). Beatties Dam is considered by some municipalities to be the cause of upstream flooding along the Passaic and Pompton rivers. Therefore, an investigation was undertaken to determine the hydraulic effects that physical modifications to Beatties Dam might have on upstream flooding.

Based on the sensitivity analysis of Beatties Dam, which is described in the following paragraphs, it was determined that modification of the dam does not meet the criteria established for recommendation as an independent measure under the Passaic River Phase 1 study authority since such modifications would impact on the formulation of an overall basin plan. Other interim critieria require that a measure must be effective as a solution to the water resources and needs in the basin and not cause any significant adverse impacts to other areas in the basin. Furthermore, the measure must be economically feasible and environmentally sound.



194

C-171

FIGURE C-25

Based on these analyses, potential modifications to Dundee, S.U.M. and Beatties Dams were eliminated from further consideration as independent measures. They were only considered further in conjunction with channel modification and/or tunnel diversion alternatives.

BUILDING BLOCK 6 - CHANNEL MODIFICATION

Analysis of the channel modifications that have been developed is found in the description of Building Block 7- Channel, Dam and Bridge Modifications. It was found that all channel modifications require bridge and dam modification as well. Building Block 6 has been combined with Building Block 4 and analyzed as Building Block 7.

BUILDING BLOCK 7 - CHANNEL, DAM AND BRIDGE MODIFICATION

The purpose of a channel, dam and bridge modification alternative was to increase the capacity of the stream channel to contain flood flows. The potential channel modifications consisted of either earthen/trapezoidal and/or concrete/rectangular configurations. The effectiveness of these modifications to solve main stem Passaic River flooding depends upon their engineering and economic efficiency, their cost and their environmental effects. Initially (Plan of Study July 1979), the intention was to utilize the 10 year and 50 year flows as design flows for the development of these plans. However, early in the development of alternatives, more detailed information regarding the capacity of existing channel configurations to contain flood flows, the location and extent of the major damage areas, and the number of structures located in the various floodplains, made it clear that the cost of a 10 year channel, dam and bridge modification plan for the Passaic main stem was in excess of the benefits it would provide. Consequently, the design levels were redefined. Subsequent investigations utilized the 100 year flood flow as the design level and then a lower design flow based upon the degree to which the existing channel alignment could be modified without requiring levees and/or floodwalls or removal of structures. These plans were developed and their economic efficiency analyzed. As a result of that analysis several conclusions were reached:

1. The 50 year channel, dam and bridge modifications were not economically justified for the damage areas located along the main stem Passaic River above the Chatham gage. This area was, therefore, eliminated from further consideration in all subsequent channel, dam and bridge modification plans.

2. Channel, dam and bridge modifications to protect the Central Basin from the Chatham gage to Beatties Dam from main stem Passaic River flooding were not feasible because of the flat stream slopes in this area. Consequently, all subsequent channel, dam and bridge modification plans in the Central Basin were limited to the Pompton Valley and the Passaic River from Two Bridges to Beatties Dam in order to permit the Pompton River flows to be contained.

3. A comprehensive 100 year channel, dam and bridge modification plan to protect the Pompton Valley, the Central Basin and the Lower Valley would be economically and engineeringly infeasible. The large increase in flows entering the Lower Valley as a result of modifying the channel on the Pompton River and on the Central Passaic River would require such extensive modifications to the existing Lower Valley channel, in both depth and width, that all bridges would have to be replaced, the three existing dams removed, and concrete retaining walls would be required along virtually the entire length of the channel, causing the plan to be economically infeasible.

4. As a consequence of (3) above, Lower Valley channel, dam and bridge modification plans were combined with levee/ floodwall plans to develop combination plans which could be utilized to protect the Lower Valley in conjunction with Pompton River to Beatties Dam channel modifications. These plans are presented in the Plan 15 discussion. Channel, dam and bridge modifications in the Lower Valley were not utilized in the tidal portion of this reach, downstream of Route 3, because they would be engineeringly ineffective.

5. With the one exception discussed in 4 above (Plan 15), channel, dam and bridge modifications to the remaining areas - the Pompton River and the Passaic River between Two Bridges and the Route 3 Bridge in the City of Passaic - were utilized in combination with other measures to develop comprehensive basin-wide plans. In addition, the Lower Valley channel, dam and bridge modifications can be thought of as independent solutions, if, no plan elements are implemented upstream of Beatties Dam. Two such alternatives, designated Building Blocks 7A and 7B, which consist of Lower Valley channel, bridge and dam modifications between Beatties Dam and Route 3, designed against the 100 and 50 year events, respectively, are described below and illustrated on Figure C-26.

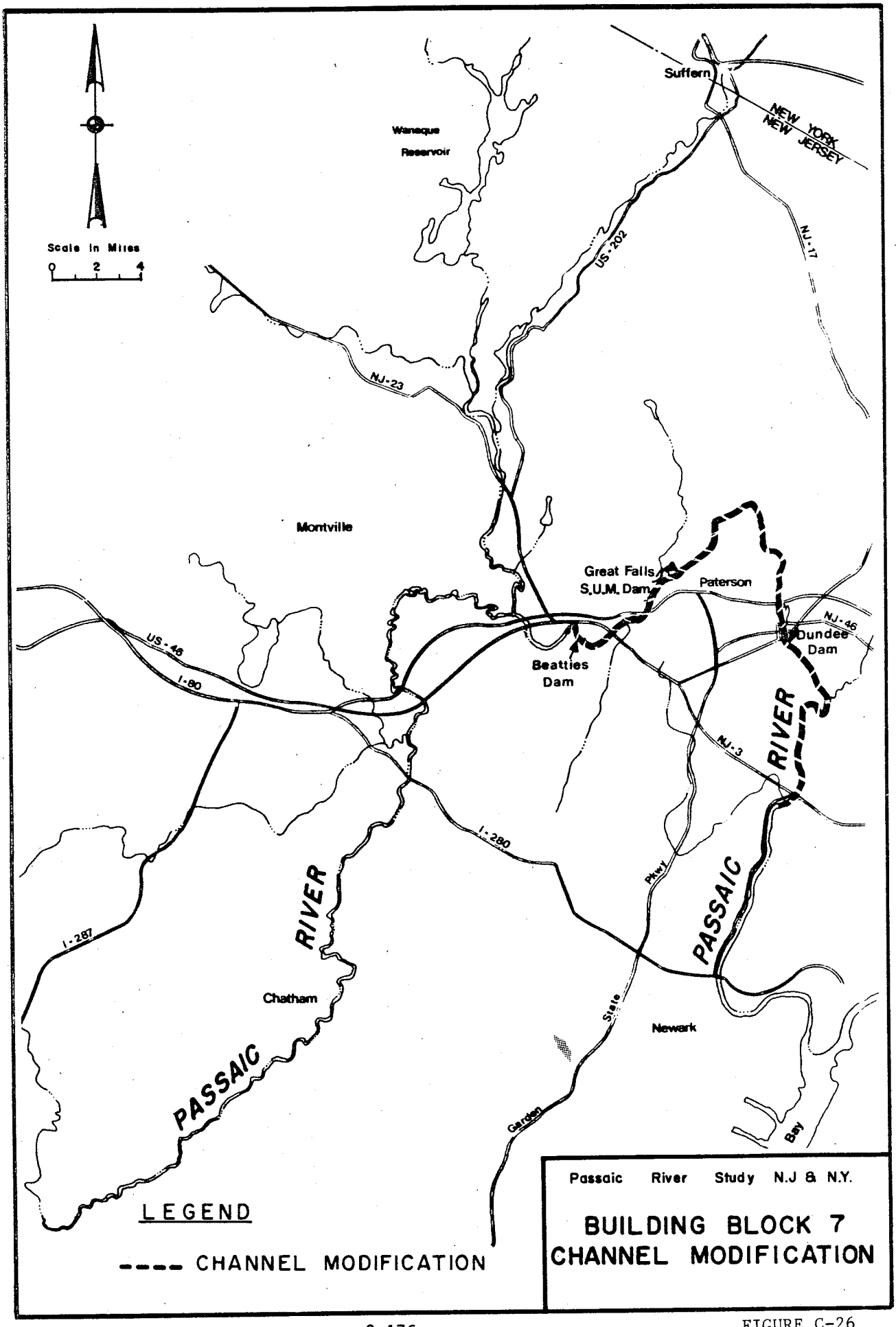

Scale in Miles
0 2 4
Suffern
NEW YORK
NEW JERSEY
Wanaque
Reservoir
US-202
NJ-17
NJ-23
Montville
Great Falls
S.U.M. Dam
Paterson
NJ-46
Dundee
Dam
Beatties
Dam
US-46
I-80
NJ-3
RIVER
PASSAIC
I-280
Pkwy
I-287
RIVER
PASSAIC
Chatham
State
Newark
Garden
Bay
LEGEND
---- CHANNEL MODIFICATION
Passaic River Study N.J & N.Y.
BUILDING BLOCK 7
CHANNEL MODIFICATION

FIGURE C-26

Building Block 7A. This channel modification alternative was designed to provide protection against the 100 year storm along the Passaic River's Lower Valley from the N.J. Route 3 Bridge upstream to Beatties Dam in Little Falls. This 100 year level of protection assumed that no improvements were implemented in the Central Basin. The benefits and costs of this measure are summarized in Table C-33. The Lower Valley consists of three hydraulically independent reaches: 1) from the mouth upstream to Dundee Dam; 2) from Dundee Dam upstream to Great Falls; and 3) from Great Falls upstream to Beatties Dam.

Investigation of the Passaic River downstream of Dundee Dam revealed that in the area downstream of the N.J. Route 3 Bridge, water surface elevations of the Passaic River are controlled by tidal influence. Therefore, channel modifications would not be effective in this reach. Upstream of the N.J. Route 3 Bridge, the water surface elevations are fluvially controlled, although some tidal influence remains as far upstream as Dundee Dam. Channel modification upstream of N.J. Route 3 would be effective in reducing flood stages. However, channel modifications would have to be extended downstream of N.J. Route 3, into the tidal portion of the river, in order to obtain an acceptable channel slope, an adequate transition section, and desired water surface elevations further upstream.

Through the entire Lower Valley, the stream banks are lined with industrial and commercial structures, residences, and roads. In many cases, buildings and roads are constructed adjacent to the river's edge. Proposed configurations, therefore, were restricted in most areas to the existing channel top width. Various combinations of bottom widths, slopes, and lengths were analyzed in order to obtain a plan providing significant protection with minimal modification to the channel. The physical features of this alternative are detailed in Table C-34.

The proposed channel modification scheme for the Lower Passaic River would start just downstream of the N.J. Route 3 Bridge, and extend upstream to a point near Fleishers Brook in Garfield, a distance of approximately 5.4 miles. The bottom width of the modified channel would be 135 feet for a distance of 4.8 miles. The alignment and top width of the modified channel would be confined to those of the existing channel for almost its entire length. The proposed channel would include two sections of semi-trapezoidal channel and two sections of trapezoidal channel. The channel would be deepened an average of 8 feet. There would be 0.3 miles of transition channel at both the upstream and downstream limits of the modified channel.

TABLE C-33 ECONOMIC ANALYSIS OF INTERMEDIATE STAGE ALTERNATIVES
(Oct. 85 Price Level, 8-5/8%, $1,000's)

PLAN NUMBER	ANNUAL BENEFITS	ANNUAL COSTS	B/C RATIO	NET BENEFITS	PLAN NUMBER	ANNUAL BENEFITS	ANNUAL COSTS	B/C RATIO	NET BENEFITS
1E	1,300	700	1.9	600	28C1	86,700	80,900	1.08	5,800
3A	14,400	19,100	.8	-4,700	28C2	84,800	80,000	1.06	4,800
3B	26,200	46,700	.6	-20,500	28C3	89,100	84,300	1.06	4,800
3C	30,400	68,300	.4	-37,900	28D	85,200	79,200	1.08	6,000
7A	25,800	17,600	1.5	8,200	28E1	88,700	81,600	1.09	7,100
7B	16,300	10,900	1.5	5,400	28E2	86,400	80,700	1.07	5,700
8	27,100	18,300	1.5	8,800	28E3	90,800	85,000	1.07	5,800
10A	61,800	64,100	.96	-2,300	28F	85,200	79,400	1.07	5,800
10B	52,700	69,500	.8	-16,800	28G	86,200	85,200	1.01	1,000
13A	36,400	33,600	1.08	2,800	30A	98,100	85,700	1.1	12,400
13B	42,700	67,300	.6	-24,600	30B	99,000	87,300	1.1	11,700
14A	39,700	37,300	1.06	2,400	30C	98,700	89,900	1.1	8,800
14B	37,400	34,100	1.1	3,300	30D	98,000	88,800	1.1	9,200
15A	87,600	84,100	1.04	3,500	30E	100,700	90,500	1.1	10,200
15B	31,700	26,400	1.2	5,300	30F	98,000	89,100	1.1	8,900
16A	46,000	41,800	1.1	4,200	30G	99,000	95,000	1.04	4,000
16B	82,800	81,600	1.01	1,200	33A	99,300	87,100	1.1	12,200
16C	59,400	62,900	.94	-3,500	33B	100,300	88,700	1.1	11,600
20	3,700	1,400	2.6	2,300	33C1	100,000	91,800	1.09	8,200
23A	76,000	67,300	1.1	8,700	33C2	99,100	91,200	1.09	7,900
23B	77,600	69,000	1.1	8,600	33C3	99,300	96,900	1.02	2,400
23C	77,300	71,500	1.09	5,800	33D	99,200	91,100	1.09	8,100
23D	76,400	70,500	1.08	5,900	33E1	101,900	92,400	1.1	9,500
23E	79,200	72,200	1.1	7,000	33E2	100,600	91,800	1.1	8,800
23F	76,400	70,700	1.08	5,700	33E3	100,800	97,500	1.03	3,300
23G	77,600	76,600	1.01	1,000	33F	99,200	91,300	1.09	7,900
28A	85,400	75,900	1.1	9,500	33G	97,100	96,400	1.01	700
28B	86,200	77,600	1.1	8,600					

TABLE C-34 BUILDING BLOCKS 7A AND 7B

BUILDING BLOCK	LOCATION	STATION	CHANNEL LENGTH (Ft)	CHANNEL MODIFICATION	REMARKS
7A	Route 3 to Dundee Dam	599+00 to 619+00	2,000	Channel Dredged	
		619+00 to 645+00	2,600	Vertical Wall, 30', 135'	
		645+00 to 773+50	12,850	30', 135'	
		773+50 to 790+84	1,734	Vertical Wall, 30', 135'	Raise W. 8th Street Bridge
		790+84 to 870+00	7,916	30', 135'	Raise Wall Street, Erie Railroad and Monroe Street Bridges.
		870+00 to 890+00	2,000	Channel Dredged	
	Dundee Dam to Great Falls	917+85 to 963+00	4,515	25', 540'	Improve Weir Efficiency to of Dundee Dam

TABLE C-34 BUILDING BLOCKS 7A AND 7B (CONT'D)

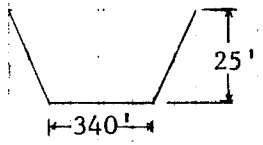
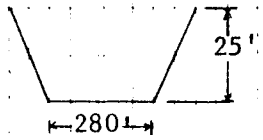
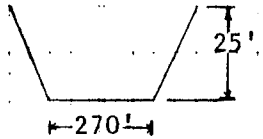
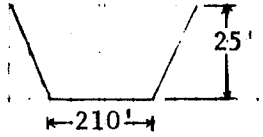
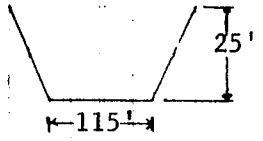
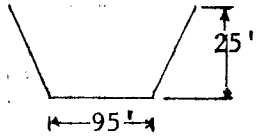
BUILDING BLOCKS	LOCATION	STATION	CHANNEL LENGTH(Ft)	CHANNEL MODIFICATION	REMARKS
		963+00 to 987+50	2,450		
		987+50 to 1011+00	2,350		
		1011+00 to 1093+00	8,200		
		1093+00 to 1225+00	13,200		
		1225+00 to 1260+00	3,500		
		1260+00 to 1304+00	4,400		

TABLE C-34 BUILDING BLOCKS 7A AND 7B (CONT'D)

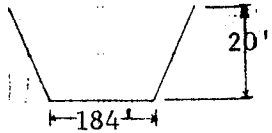
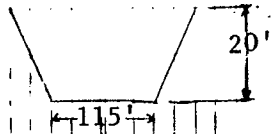
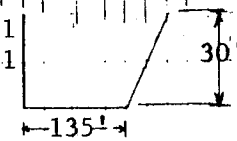
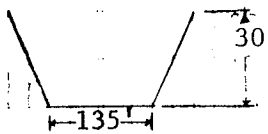
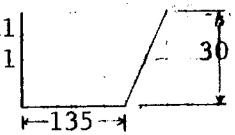
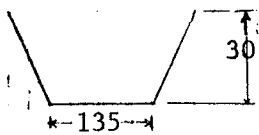
BUILDING BLOCKS	LOCATION	STATION	CHANNEL LENGTH(Ft)	CHANNEL MODIFICATION	REMARKS
	Great Falls to Beatties Dam	1338+60 to 1443+20	10,460		. SUM Dam - Improve Weir Efficiency & Lower Crest to Elev. 113.0 Ft. Raise Hillery Street Bridge.
		1443+20 to 1536+00	9,280		
7B	Route 3 to Dundee Dam	599+00 to 619+00	2,000	Channel Dredged	
		619+00 to 645+00	2,600	Vertical Wall 	
		645+00 to 773+50	12,850		
		773+50 to 790+84	1,734	Vertical Wall 	
		790+84 to 870+00	7,916		. Raise Wall Street, Erie Railroad and Monroe Street Bridges.

TABLE C-34 BUILDING BLOCKS 7A AND 7B (CONT'D)

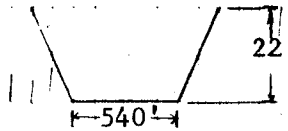
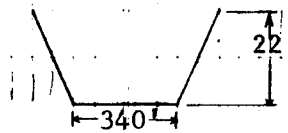
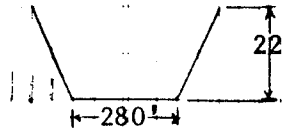
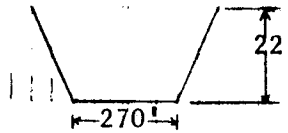
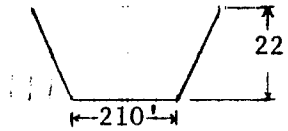
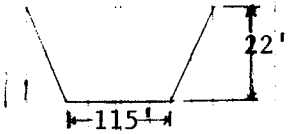
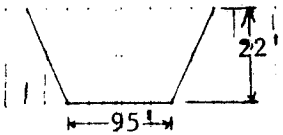
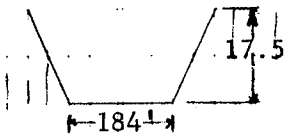
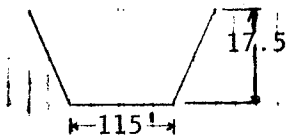
BUILDING BLOCK	LOCATION	STATION	CHANNEL LENGTH(Ft)	CHANNEL MODIFICATION	REMARKS
		870+00 to 890+00	2,000	Channel Dredged	
	Dundee Dam to Great Falls	917+85 to 963+00	4,515		• Improve Weir Efficiency of Dundee Dam
		963+00 to 987+50	2,450		
		987+50 to 1011+00	2,350		
		1011+00 to 1093+00	8,200		
		1093+00 to 1225+00	13,200		

TABLE C-34 BUILDING BLOCKS 7A AND 7B (CONT'D)

BUILDING BLOCK	LOCATION	STATION	CHANNEL	CHANNEL LENGTH(Ft)	MODIFICATION	REMARKS
		1225+00 to 1260+00	3,500			
		1260+00 to 1304+00	4,400			
	Great Falls to Beatties Dam	1338+60 to 1443+20	10,460			
		1443+20 to 1536+00	9,280			

The upper two reaches, from Dundee Dam to Great Falls and from Great Falls to Beatties Dam, are similar in several ways. Both begin and end at a dam or waterfall. Both have similar invert profiles which are mild over the downstream two-thirds of each reach and then steepen considerably at the upstream end. The banks of both reaches are lined with industrial complexes, high density residential areas, and access roads. In many cases, this development extends to the edges of the river bank.

The extent of possible channel modification in the two upper reaches is constrained by the physical settings, as described above. The dams limit both the depth to which the thalweg can be lowered and the degree to which its slope can be altered. Where the thalweg would be lowered, it would be necessary to protect some bridge foundations which become exposed. At the same time, the top width of the modified channel would be restricted to the existing top width due to the heavy development along the banks. Lowering dam crests would, therefore, be necessary to obtain desired stage reductions.

Between Dundee Dam and Great Falls, the proposed channel would be a trapezoidal channel with a bottom width ranging from 540 feet at Dundee Dam to 95 feet at the upstream limit of the reach. The length of the modified channel would be approximately 7.3 miles. The proposed thalweg would be lowered an average of 10 feet.

Between Great Falls and Beatties Dam, there would be 3.7 miles of trapezoidal channel with bottom widths ranging from 184 feet at the S.U.M. Dam to 115 feet at Beatties Dam. The channel would be deepened an average of 6 feet. This alternative also called for lowering the crest of the S.U.M. Dam by 1.6 feet, to an elevation of 113.0 feet MSL.

Downstream impacts of the Lower Valley channel modification were analyzed with existing conditions retained in the Central Basin. The results indicated that there would be a negligible difference in peak flows with a channel in place. The 10 year flood flow increased by 0.43% at the mouth of the Passaic River; the 100 year flood flow increased by 1.28% at the mouth and the SPF flow increased by 5.56% at the mouth.

Building Block 7B. A channel modification with a lower (50 year) level of protection than the 100 year channel modification alternative was developed for the Lower Valley. This channel modification could be combined with other structural or nonstructural works to provide a higher level of protection. Since the constraints imposed upon the 100 year channel by streambank development still applied, the proposed channel had a very similar configuration and layout to that described in Building Block 7A.

The main differences were a reduction in the required amount of channel cut, about 5 feet less, and the elimination of the need to lower the S.U.M. Dam crest. The physical features of this alternative are detailed in Table C-34 and the benefits and costs are given in Table C-33.

BUILDING BLOCK 11 - LEVEE/FLOODWALL

A description of the levee/floodwall alternatives that were developed is found in the presentation of Building Block 13 - Levee/Floodwall, Dam and Bridge Modifications since all levee/-floodwall plans considered required dam and/or bridge modifications in order to function as designed. Therefore, Building Block 11 was not considered further as a single measure "Building Block," but rather, was combined with Building Block 4 and analyzed as a combination measure "Building Block."

BUILDING BLOCK 13 - LEVEE/FLOODWALL, DAM AND BRIDGE MODIFICATIONS

As discussed under Building Block 11, another of the local protection plans considered as part of the "Building Block" approach was that of levees and floodwalls combined with dam and bridge modifications. The levels of protection considered recognized the consequences and risks of overtopping.

As indicated in the Plan of Study, riverbank levees were investigated everywhere except in the Central Basin, where the natural storage of the wetlands was preserved wherever possible by providing set-back levees. Levee/floodwall alternatives which were developed to protect against the 100 year and Standard Project Flood were designated as Building Blocks 13A and 13B, respectively, in accordance with Figure C-17.

The initial approach was to provide protection to all structures within the 100 year floodplain by aligning continuous levees and floodwalls for the damage reaches along the Passaic and Pompton Rivers and the lower reaches of the Rockaway, Whippany, Pequannock, Ramapo and Wanaque Rivers. Before investigating further details of this plan (i.e., extensive interior flood control facilities), an economic analysis was performed. This analysis indicated the following: (1) That continuous basin-wide levee/floodwall protection would be prohibitively expensive, since in many areas the protection would be provided only to roads or isolated structures. The benefits obtained from these structures and roads would not justify the high cost of the levees or floodwalls if continuous protection was provided. These structures were considered for other flood damage reduction measures such as nonstructural, which would be more economically viable as part of comprehensive basin-wide plans.

As a result of this economic screening, a series of intermittent levees and floodwalls remained which would protect most of the structures in the 100 year floodplain. An evaluation of the levee/floodwall plan along the Pompton, Pequannock, Ramapo and Wanaque Rivers indicated that not only would the excessive heights of levees and floodwalls required to protect against the 100 year flood event be publicly unacceptable, but such a plan would be economically unjustified.

The levees and floodwalls along these streams would range in height up to 23 feet. Therefore, levees and floodwalls were not considered further as independent local protection measures in this area of the Central Basin. They were considered, however, in combination with other measures, such as tunnel diversions or channel modifications, which would reduce the heights of the levees and floodwalls to more acceptable levels. It should be noted that if such a combination of channel modification and levees and floodwalls was adopted along the Pompton River and its tributaries, the channel work would extend downstream along the Passaic River between Two Bridges and Beatties Dam.

In addition, the economic analysis indicated that providing protection through the use of levees and floodwalls to the Upper Passaic would be infeasible when compared to the scale of potential benefits in this area. Therefore, the Upper Passaic was also eliminated from further consideration as part of a basin-wide levee/floodwall alternative.

Building Block 13A - 100 Year Levee/Floodwall. The intermittent systems in the Lower Valley and Central Basin, not screened as discussed above, comprise Building Block 13A, the 100 year levee/floodwall alternative. The levees and floodwalls were designed with a minimum 3 feet of freeboard. The levees would have a top width of 10 feet and 1 on 3 side slopes. Bridges would be raised where it would be necessary to provide adequate passage of the 100 year stream flow and to maintain the line of protection inherent in the levee/floodwall system. A minimum of 2 feet of freeboard clearance below the low chord of the bridge was provided. Associated interior flood control works combining ponding, pumping and pressure interceptors would be provided behind the levees and floodwalls to carry surface runoff from the protected area to the river.

Descriptions of the levee/floodwall systems are summarized by formulation reaches (Lower Valley and Central Basin) in the following paragraphs while the details of each system are given in Table C-35. Building Block 13A is illustrated in Figure C-27 and the benefits and costs of this alternative are given in Table C-33.

TABLE C-35 - BUILDING BLOCK 13A

100 YEAR LEVEE/FLOODWALL PHYSICAL FEATURES

System	Municipality	Bank	LEVEE Avg. Ht. (ft.)	LEVEE Avg. Base Width (ft.)	LEVEE Length	FLOODWALL Avg. Ht. (ft.)	FLOODWALL Length (ft.)	Bridge Modification #'s	Bridge Modification Ave. Ht. Raised	INTERIOR DRAINAGE Ponding Area #'s Acres	INTERIOR DRAINAGE Pressure Interceptor #'s	INTERIOR DRAINAGE Pipe Size (In.)	INTERIOR DRAINAGE Pumping Sta. #'s	INTERIOR DRAINAGE Pumping Sta. (cfs)	Remark
Kearny Point	Kearny	Left	6.5	49	14,130	6.0	17,600			120 acres					
Doremus Ave.	Newark	Right	5.5	43	2,000	6.0	2,120						(2)	253	2 Gated Structures
Turnpike	Newark	Right	6.0	46	1,200	5.0	1,250			23 acres					
Lister Ave	Newark	Right	5.0	40	4,285	6.5	3,300			43 acres			(2)	270,241 cfs	
Conrail	Harrison	Left	3.5	31	2,750										
South 1st St.	Harrison	Left	5.0	40	3,450	6.5	2,570						(2)	200,257 cfs	
Passaic Ave #1	East Newark	Left	3.0	28	200	5.5	2,180						(2)	44&91	2 Gated Structures
Passaic Ave #2	Kearny	Left	4.0	34	2,760	5.0	1,400			(2) 7.1-8.2			(1)	137	
River Road #1	N. Arlington	Left	6.0	46	1,950								(1)	299 cfs	
Riverside Ave	Lyndhurst	Left	6.0	46	4,550	6.5	350						(1)	429 cfs	
River St.	E. Rutherford	Left	6.0	46	2,000	6.0	660						(1)	62 cfs	
River Drive	City of Passaic	Right	8.0	58	650	8.5	1,250						(1)	358 cfs	
Main Ave	Wallington	Left	8.5	61	2,400	8.0	3,110	2	6.3				(1)	325 cfs	
8th St.	City of Passaic	Right	10.0	70	2,020	17.0	5,170	1	7.9	21 acres					
Midland Ave	Wallington	Left				18.0	770								
River Drive #2	Garfield	Left	11.0	76	800	18.5	3,900						(2) (1)	220 173	

TABLE C-35 BUILDING BLOCK 13A

100 YEAR LEVEE/FLOODWALL PHYSICAL FEATURES TABLE (Cont'd)

System	Municipality	Bank	LEVEE Avg. Ht. (ft.)	LEVEE Average Base Width (ft.)	LEVEE Length	FLOODWALL Avg. Ht. (ft.)	FLOODWALL Length (ft.)	Bridge Modification	INTERIOR DRAINAGE Ponding Area #'s Acres	Pressure Conduit #'s	Interceptor Pipe Size (In.)	Pumping Sta. #'s (cfs)
River Drive #3	Garfield	Left	10.0	70	450	10.0	950					(1) 173 (1) 332
River Drive #4	Garfield	Left	10.0	70	400	18.0	2,130					(1) 173
Ackerman	Clifton	Right	9.0	64	200	22.0	700					
Morlot Ave	Fair Lawn Elmwood Pk.	Left	9.0	64	4,870	11.5	2,540			(1)	72	(3) 109 348
McLean Blvd	Paterson	Right				8.3	600					(1) 49
Range Rd.	Fair Lawn	Left	10.0	70	1,150				(1) 5.3			
1st Ave.	Paterson	Right	1.5	19	120	10.5	2,860					(3) 50,10,78
River St. #2	Paterson	Right				9.5	1,170					(2) 50,10
Wagaraw	Hawthorne Fair Lawn	Left	8.5	61	1,550	8.5	1,600			(2)	36	(2) 209,237
River St. #3	Paterson	Right	9.0	64	1,050	14.0	9,800			(2)	30-66	(2) 148&271
Presidential Blvd	Paterson Prospect Pk.	Left	10.5	73	930	12.5	3,550					(2) 213&226
Totowa Rd.	Totowa Paterson	Left	7.0	52	5,000	8.5	5,480			(1)	42	(2) 254&403
McBride Ave #1	West Paterson	Right	7.0	52	300	11.0	2,000			(1)	60	(1) 192
Norwood Terr.	Totowa	Left	12.5	85	150	13.0	900					(1) 64

TABLE C-35 BUILDING BLOCKS 134
100 YEAR LEVEE/FLOODWALL PHYSICAL FEATURES TABLE (Cont'd)

System	Municipality	Bank	LEVEE Avg. Ht. (Ft.)	LEVEE Average Base Width (Ft.)	LEVEE Length	FLOODWALL Ave. Ht. (Ft.)	FLOODWALL Length (Ft.)	Bridge Modification #'s	Bridge Modification Avg. Ht. Raised	INTERIOR DRAINAGE Ponding Area #'s	Ponding Area Acres	Pressure Interceptor #'s	Pressure Interceptor Pipe Size (In.)	Pumping Sta. #'s	Pumping Sta. (cfs)	Remark
McBride Ave. #2	W. Paterson	Right	9.0	64	2,850	12.0	5,350			(2)	4.4,27	(1)	48	(1)	238	
												(3)	78			
McBride Ave. #3	Little Falls	Right	7.0	52	3,680	9.0	2,600	2	5.6					(2)	48,108	
Riverview Dr.		Left	13.0	88	950	11.0	2,100					(1)	72	(2)	89,126	
CENTRAL BASIN																
Passaic R. #2A	Fairfield	Right	10.0	70	31,220	13.0	700				288 acres					Gated Structures on Culverts
	W. Caldwell		11.0	76	2,550											
Passaic R. #2C	Fairfield	Right	6.0	46	2,270	7.0	1,030				6.8 acres					
	W. Caldwell		6.0	46	1,580											
Passaic R. #3B	Fairfield	Right	17.5	115	3,660											
Passaic R. #5	Montville	Left	12.5	85	1,570					(1)	8.8					
Passaic R. #6	Montville	Left	9.5	67	4,140			2	5.8	(1)	4.5					
Passaic R. #9	E. Hanover	Left	8.5	61	2,550					(1)	4.0					
Passaic R. #9	E. Hanover	Left	9.5	67	1,830					(1)	1.3					

TABLE C-35 - BUILDING BLOCK 13A

100 YEAR LEVEE/FLOODWALL PHYSICAL FEATURES TABLE (Cont'd)

System	Municipality	Bank	LEVEE Avg. Ht. (Ft.)	LEVEE Average Base Width (Ft.)	LEVEE Length	FLOODWALL Ave. Ht. (Ft.)	FLOODWALL Length (Ft.)	Bridge Modification #'s	Bridge Modification Avg. Ht. Raised	INTERIOR DRAINAGE Ponding Area #'s	Ponding Area Acres	Pressure Interceptor #'s	Pressure Interceptor Pipe Size	Pumping Sta. #'s	Pumping Sta. (cfs)	Remarks
Passaic R. #9A	E. Hanover	Left	5.0	40	1,670					(2)	6.7 &7.1					
Passaic R. #10	Livingston	Right	11.0	76	4,450					(2)	8.5 &10. 4					
Passaic R. #11	E. Hanover	Right	7.0	52	2,745	12.0	150	2	4.2	(1)	6.3					
Passaic R. #12	Livingston	Right	7.5	55	3,700											
Passaic R. #15	City of Summit	Right	4.5	37	1,650	1.5	100			(1)	2.3					
Rockaway R. #1	Parsippany	Right	10.5	73	3,880			3	5.4	(6)	3.3-28.1					Gated Structure on Culverts
Rockaway R. #2	Montville	Left	9.0	64	5,110			1	4.3	(2)	10.5&27.5	(4)	36 -48	(1)	148	
Rockaway R. #3	Parsippany	Right	8.5	61	4,410	7.5	470			(1)	26.0	(1)	72	(1)	188	
Whippany R. #2	Hanover	Left	8.0	58	6,440					(1)	7.7					
Whippany R. #3	Hanover	Right	5.0	40	3,030	5.0	510			(1)	5.0					
Pinch Brook	E. Hanover	Right	9.5	67	2,000					(1)	7.2					
Hanover Airport	E Hanover	Right	10.0	70	6,670					(1)	51.8					
Hassock Bk.	Florham Park	Left	6.5	49	1,550											Stop Log Structure

211

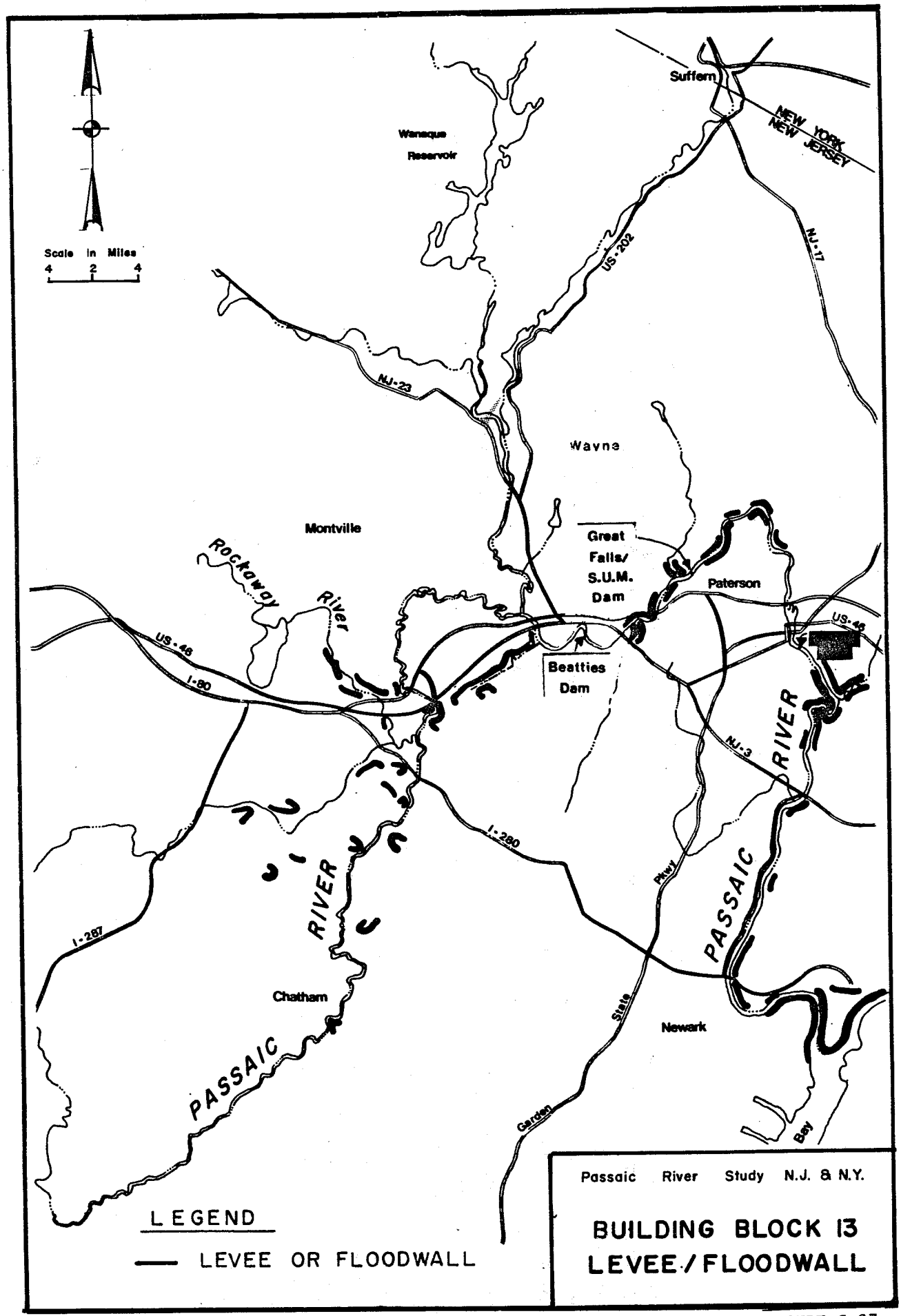

Scale in Miles
4 2 4
Suffern
NEW YORK
NEW JERSEY
Wanaque
Reservoir
US-202
NJ-17
NJ-23
Wayne
Montville
Great
Falls/
S.U.M.
Dam
Paterson
Rockaway
River
US-46
I-80
Beatties
Dam
NJ-3
PASSAIC
RIVER
I-280
I-287
Chatham
PASSAIC
RIVER
Pkwy
State
Newark
Garden
Bay
LEGEND
LEVEE OR FLOODWALL
Passaic River Study N.J. & N.Y.
BUILDING BLOCK 13
LEVEE/FLOODWALL

FIGURE C-27

The Lower Valley portion of the 100 year levee/floodwall alternative would protect residential, commercial, and industrial structures in communities along the Passaic River from its mouth at Newark Bay upstream to Beatties Dam. The plan would protect most of the structures inundated by either fluvial or tidal floods with 100 year recurrence intervals. The protection would be provided to 33 separate areas. Since the Lower Valley of the Passaic is intensively developed, there is generally insufficient space to construct levees. Therefore floodwalls would be predominantly used, though there would be several systems which would consist mainly of levees.

In the lower reach, between Dundee Dam and the mouth of the Passaic River, tidal as well as fluvial effects control water surface elevations. From the mouth upstream to the area of the N.J. Route 3 Bridge in the City of Passaic, tidal elevations with a recurrence interval of 100 years predominate over fluvial events. Upstream of this point, the fluvial events control flood levels but the influence of tides remains evident upstream to Dundee Dam. In the areas controlled by tidal stages, channel modification would be ineffective. From Route 3 to the mouth, therefore, levees and floodwalls would be the only effective local protection measure. Even in this area, however, the levees and floodwalls would not be continuous but would consist of intermittent systems. Floodwalls would extend along both banks of Fleishers Brook in order to protect against backwater flooding. At the Saddle River confluence, floodwalls would be required upstream for approximately 1,500 feet in order to prevent backwater flooding. At the mouth of the Passaic, this alternative includes levees and floodwalls extending along the right bank of the Hackensack River in order to tie back the system in a manner which would protect the structures located at Kearny Point. Between the mouth and Dundee Dam there would be 46,195 ft. of earthen levee and 49,410 ft. of floodwall. The levees would range in height from 3.0 to 10.5 ft., while the floodwalls would range from 5.5 to 22.0 ft. in height. The base width of the levees would vary from 28.0 ft. to 73.0 ft. In addition, three bridges in this reach would be raised.

In the reach from Dundee Dam to Great Falls, a total of 9,670 ft. of earthen levee ranging in height from 8.5 to 10.5 ft., and 22,120 ft. of floodwall ranging from 8.5 to 22.0 ft. in height would be provided. The base width of the levees would vary from 61 ft. to 73 ft. Protection would extend upstream along Goffle Brook to prevent backwater flooding damages.

Between Great Falls and Beatties Dam, a total of 12,930 ft. of earthen levee, ranging from 7.0 to 13.0 ft. in height, and 18,230 ft. of floodwall ranging from 8.5 to 13.0 ft. in height would be provided. The base width of the levees would be from 52 ft. to 88 ft. Included in these systems would be levees and

floodwalls extending upstream along both Molly Ann's Brook and the Peckman River to protect areas along these streams from flooding caused by high water surface elevations along the Passaic River. Additionally, two bridges in this reach would be raised.

As discussed in Section 3, which describes the flooding problem, the Central Basin contains a large amount of natural storage (wetlands) that tends to reduce flood peaks. Therefore, the objective of this alternative was to reduce flood damages in the Central Basin while preserving the natural storage areas. In order to preserve the natural flood detention areas which moderate flows to the Passaic River's Lower Valley, the proposed levees would be set back from the stream where possible. In areas where there is insufficient land for a set back levee, the levees would be aligned along the stream. Due to the close proximity of several structures to the river, in some areas it would be necessary to provide floodwalls in lieu of levees.

Along the main stem Central Passaic River, intermittent levees and floodwalls would be provided in order to protect twelve flood prone areas; along the Rockaway River, three areas would require protection and three areas along the Whippany River would be protected. Additionally, to protect against backwater flooding from the Whippany River, it would be necessary to provide protection to one area along Pinch Brook and one area along Hassock Brook. The following paragraphs describe the required levee systems along each of the aforementioned streams.

The twelve flood prone areas along the Central Passaic River that require protection are concentrated in the Townships of Fairfield, Montville, East Hanover and Livingston, the Borough of West Caldwell and the City of Summit. To protect against flooding in these areas, 65,755 ft. of levees and 1,950 ft. of floodwalls would be required along the Passaic River and Deepavaal Brook. The levees would have an average height that ranges from 4.5 ft. to 17.5 ft. and a base width between 37.0 ft. and 115.0 ft. The floodwalls would vary from 7.0 ft. to 14.5 ft. in height. Levees and floodwalls would be required along both banks of Deepavaal Brook. Deepavaal Brook flows through the Township of Fairfield, from its headwaters near the Passaic River at Bloomfield Avenue to its confluence with the Passaic approximately 4,600 ft. downstream of Two Bridges. The levees and floodwalls would protect against flows from the Passaic River which are normally diverted along the upstream reaches of Deepavaal Brook during periods of flooding and also would provide protection against Passaic River backwater

flooding along the downstream reaches of Deepavaal Brook. As part of this plan, 7 bridges along the Central Passaic River would be raised and 2 bridges along Deepavaal Brook would be replaced. In order to maintain the line of protection it would be necessary to install gated closure structures on the culverts under Route 80 and raise sections of several roads.

Along the lower Rockaway River 13,400 ft. of levees and 470 ft. of floodwalls would be provided to protect the three flood prone areas located in the Townships of Parsippany-Troy Hills and Montville. The average height of the floodwalls would be 7.5 ft. while the average height of the levees would range from 8.5 ft. to 10.5 ft. The base width of the levees would vary from 61.0 ft. to 73.0 ft. Three bridges along the Rockaway River would be raised as part of this plan. In addition, gated closure structures would be provided on the culverts under Routes I-80 and I-280 and portions of several roads would be raised to form part of the line of protection.

In the Townships of Hanover and East Hanover, four flood damage areas would be protected by 16,140 ft. of levees and 510 ft. of floodwalls along the lower Whippany River and 2,000 ft. of levee along Pinch Brook. An additional 1,550 ft. of levee would be required along Hassock Brook to protect a damage area in the Borough of Florham Park. The levees along the Whippany River would have average heights ranging from 5.0 ft. to 10.0 ft. with base widths varying from 40.0 ft. to 70.0 ft. The floodwalls would have an average height of 5.0 ft. The levees along Pinch Brook and Hassock Brook, which would provide protection against backwater flooding from the Whippany River, would have average heights of 9.5 ft. and 6.5 ft., respectively. The corresponding base widths would be 67.0 ft. and 49.0 ft.

There would be a total of 166,390 feet of levees and 94,570 feet of floodwalls in the Lower Valley and Central Basin levee/floodwall systems. The hydrologic impacts on downstream peak discharges resulting from the potential implementation of these levee/floodwall systems were investigated. This analysis indicated that there would be an increase in downstream discharges resulting from the levees along the Passaic River and Deepavaal Brook in Fairfield. This hydrologic impact was accounted for in later iterations of the plan formulation process.

Building Block 13B - SPF Levee/Floodwall. The next iteration consisted of developing a levee/floodwall alternative, known as Building Block 13B, to protect against the SPF in the Lower Valley and the Central Basin along the Passaic River and lower Rockaway and Whippany Rivers. A total of 330,135 feet of levees and 169,900 feet of floodwalls would be required. An analysis of this plan indicated that it is not economically justified. The benefits and costs are given in Table C-33.

BUILDING BLOCKS 17 AND 18 - EXISTING AND NEW RESERVOIRS

This section addresses flood detention which was evaluated both as a flood damage reduction measure and with consideration to fulfilling water supply objectives in conjunction with flood control as noted in HR 94-1702. The measures evaluated included: 1) a review of the management and operation of existing reservoirs; 2) investigation of the potential for structural modification of these reservoirs including the raising of the dam structures or their replacement, and/or the dredging or removal of material below the elevation of the existing reservoir bed to increase the storage capacity for flood control or water supply purposes; and 3) the development of new reservoirs - both single and multipurpose to achieve these objectives. All major and most of the minor dams in the basin have been inspected as part of the National Dam Safety Program. The major dams and all but two of the minor dams were determined to be in generally good condition but, in most cases, do not meet the criteria for spillway capacity. Most of these dams do not have the capacity to pass the Probable Maximum Flood (PMF) depending on the dam classification. Many of the major water purveyors have acted to improve the stability of the dams under those conditions.

Early Screening. The review of the management and operation of existing reservoirs and the investigation of the potential for structural modification of these reservoirs includes those shown in Table C-36. Major reservoirs such as Boonton and Wanaque Reservoirs, and Greenwood Lake and smaller reservoirs such as Butler, Taylortown and Haledon Reservoirs were included. These reservoirs are used for water supply or recreation or both. There are no single purpose flood detention reservoirs in the basin. In addition some existing natural lakes were also listed where there appeared to be a possibility for modifying them for flood control purposes. The development of new reservoirs included undeveloped sites which appear to have a potential to be used for flood detention as listed in Table C-37. Figure C-28 shows the locations of the existing and potential reservoirs. Information regarding both the existing reservoirs and undeveloped sites were gathered from previous reports, suggestions from public meetings, office studies utilizing USGS maps and aerial photography, and from contact with local officials by telephone and field visits.

a. Screening Rationale. A total of over fifty sites were analyzed. The following criteria were used to screen potential reservoirs; existing use, extent of development, drainage area and water surface area. Table C-38 presents that analysis.

TABLE C-36 EXISTING RESERVOIRS

	Reservoir Name	Sub-Basin	Stream Name	County	Storage (AC-FT)
	HIGHLAND AREA				
1.	Tuxedo Lake	Ramapo	Ringwood River	Orange	2,061
2.	Pompton Lake	Ramapo	Acid Brook Ramapo River Pompton River	Passaic Bergen	1,729
3.	Pines Lake	Ramapo	Haycock Brook	Passaic	5,880
4.	Greenwood Lake	Wanaque	Wanaque River Belcher Creek	Orange Passaic	26,880
5.	Sterling Forest Lake	Wanaque	Ringwood Creek	Orange	1,606
6.	Pinecliff Lake	Wanaque	Belcher Creek	Passaic	2,418
7.	Cupsaw Lake	Wanaque	Cupsaw Brook	Passaic	888
8.	Wanaque Reservoir	Wanaque	Wanaque River Ringwood Creek Posts Creek Blue Mine Brook West Brook	Passaic	85,960
9.	Lake Inez	Wanaque	Wanaque River	Passaic	450

TABLE C-36 EXISTING RESERVOIRS (CONT.)

	Reservoir Name	Sub-Basin	Stream Name	County	Storage (AC-FT)
	HIGHLAND AREA				
10.	Clinton Reservoir	Pequannock	Mossmans Brook Clinton Brook	Passaic	10,745
11.	Oak Ridge Reservoir	Pequannock	Pequannock River	Morris Passaic	11,973
12.	Charlotteburg Reservoir	Pequannock	Pequannock River Timber Brook	Morris Passaic	9,210
13.	Butler Reservoir	Pequannock	Apshawa Brook	Passaic	2,763
14.	Henion Pond	Pequannock	N.A.	Passaic	301
15.	Twin Lakes	Pequannock	N.A.	Passaic	170
16.	Cold Spring Lake	Pequannock	N.A.	Passaic	208
17.	Butler Reservoir	Pequannock	Stone House Br.	Morris	N.A.
18.	Taylortown Reservoir	Passaic	N.A.	Morris	N.A.
19.	Deer Pond	Passaic	Stony Brook	Morris	969
20.	Lake Valhalla	Passaic	N.A.	Morris	640
21.	Lake Denmark	Rockaway	Burnt Meadow Br.	Morris	1,157

TABLE C-36 EXISTING RESERVOIRS (CONT.)

RESERVOIR NAME	SUB-BASIN	STREAM NAME	COUNTY	STORAGE (AC-FT)
HIGHLAND AREA				
22. Picatinny Lake	Rockaway	Green Pond Br.	Morris	615
23. White Meadow Lake	Rockaway	N.A.	Morris	1,680
24. Indian Lake	Rockaway	N.A.	Morris	1,056
25. Lake Estling	Rockaway	Den Br.	Morris	N.A.
26. Wildwood Lake	Rockaway	N.A.	Morris	N.A.
27. Mountain Lake	Rockaway	N.A.	Morris	500
28. Rainbow Lakes	Rockaway	N.A.	Morris	N.A.
29. Lake Intervale	Rockaway	Troy Br.	Morris	N.A.
30. Splitrock Reservoir	Rockaway	Beaver Br.	Morris	10,989
31. Boonton Reservoir	Rockaway	Rockaway R.	Morris	23,483
32. Echo Lake	Pequannock	Cotters Br.	Passaic	2,369
33. Canistear Reservoir	Pequannock	Pacock Br.	Sussex	8,100
34. Monksville	Pompton	Wanaque R.	Passaic	21,400

TABLE C-36 EXISTING RESERVOIRS (CONT.)

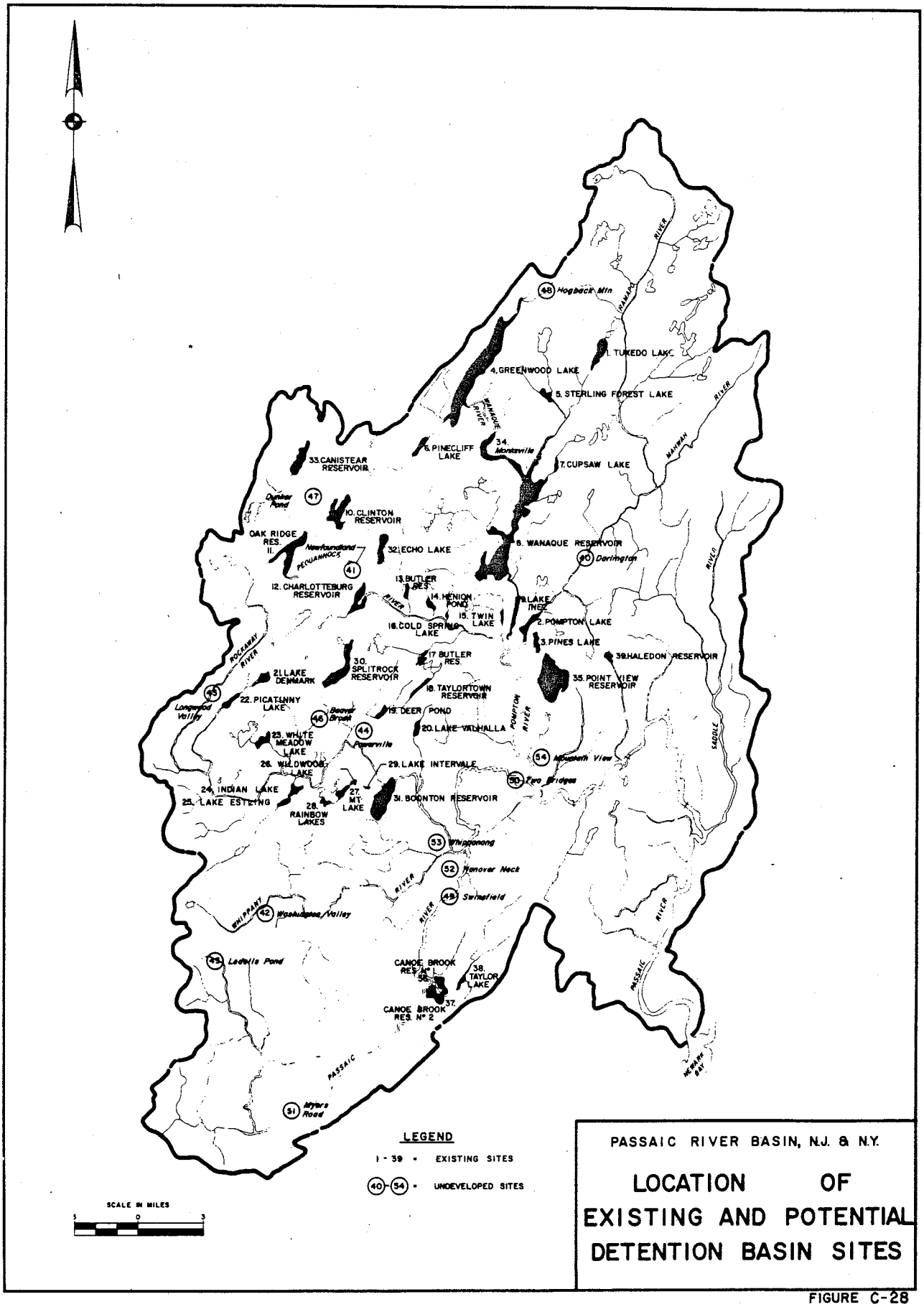
RESERVOIR NAME	SUB-BASIN	STREAM NAME	COUNTY	STORAGE (AC-FT)
CENTRAL BASIN				
35. Point View Reservoir	Ramapo	Haycock Br.	Passaic	9,200
36. Canoe Brook Reservoir No. 1	Passaic	Canoe Br.	Essex	8,596
37. Canoe Brook Reservoir No.2	Passaic	Canoe Br.	Essex	8,596
38. Taylor Lake	Passaic	Canoe Br. Bear Br. Taylor Br.	Essex	N.A.
LOWER VALLEY				
39. Haledon Reservoir	Passaic	Molly Ann's Br.	Bergen	N.A.

TABLE C-37 UNDEVELOPED DETENTION SITES

	RESERVOIR NAME	SUB-BASIN	STREAM	COUNTY	STORAGE (AC-FT)	D.A. (mi.)
	HIGHLAND AREA					
40.	Darlington	Ramapo	Ramapo R.	Bergen	28,200	137
41.	Newfoundland	Pequannock	Pequannock R.	Passaic	25,000	51.9
42.	Washington Valley	Whippany	Whippany R.	Morris	6,100	15
43.	Longwood Valley	Rockaway	Rockaway R.	Morris	20,000	19
44.	Powerville	Rockaway	Rockaway R.	Morris	35,900	119
45.	Leddells Pond	Passaic	Passaic R.	Morris	3,200	4
46.	Beaver Brook	Rockaway	Beaver Br.	Morris	7,500	10
47.	Dunker Pond	Pequannock	Unnamed	Passaic	10,000	5
48.	Hogback Mtn.	Wanaque	Warwick Br.	Rockland	2,500	4

TABLE C-37 UNDEVELOPED DETENTION SITES

	RESERVOIR NAME	SUB-BASIN	STREAM	COUNTY	STORAGE (AC-FT)	D.A. (mi.)
	CENTRAL BASIN					
49.	Swinefield	Passaic	Passaic R.	Morris Essex	56,500	132.9
50.	Two Bridges	Passaic	Passaic R.	Morris Essex		
51.	Myers Road	Passaic	Passaic R.	Somerset Morris	N.A.	N.A.
52.	Hanover Neck	Whippany	Whippany R.	Morris	N.A.	N.A.
53.	Whippanog	Whippany	Whippany R.	Morris	73,000	201.5
54.	Mountain View	Pompton	Pompton R.	Passaic	175,000	377.3



PASSAIC RIVER BASIN, N.J. & N.Y.

LOCATION OF EXISTING AND POTENTIAL DETENTION BASIN SITES

FIGURE C-28

TABLE C-38 DETENTION BASIN SCREENING DATA

	RESERVOIR NAME	EXISTING USE	DEVELOPMENT	DRAIN-AGE AREA (SQ MI)	SURFACE AREA (ACRE)	1) MAX. POOL ELE-VATION	2)DESIGN POOL ELE-VATION	3) VOL(A) (ACRE-FT)	4) VOL(R)	6) VOL(A)/ VOL(R) X100	POSSIBLE RELOCATIONS	REMARKS
1. Ramapo River	Point View Reservoir	Water Supply	Light Development	1.9	399.4	6	1	399	624	63%	Several Structures	a
	Pines Lake	-	Mod. Development	3.7	141.4	10	5	707	1,194	59%	21 Str.,½ Mi.Rd.	a,b,d
	Pompton Lake	Recreation	Heavy Development -NW	160	165.2	5	0	0	51,200	0%	-	a,b,c
	Darlington (5)	Flood Control	Mod. Development	137	-	-	-	44,000	43,840	100%	60 Str.,1½Mi.Rd.	c
	Hogback Mtn.(5)	Water Supply	Undeveloped	4	100	-	-	780	1,280	61%	No Apparent Relocation	a,b,d
2. Wanaque River	Twin Lakes	Recreation	Mod. Development	.6	40	10	5	200	214.4	93%	70 Str.,½ Mi.Rd.	a
	Sterling Forest Lake	Recreation	Undeveloped	2.3	110.1	20	15	1,653	736	225%	-	a,d
	Tuxedo Lake	Recreation	60 Scatter Res. within ½ Mi. of Lake	4.1	280.5	20	15	4,208	1,312	321%	20 Str.,2 Mi.Rd.	a,d
	Cupsaw Lake	Recreation	Heavy Development	4.1	48.6	13	8	390	1,312	30%	50 Str.,1 Mi.Rd.	a
	Pinecliff Lake	Recreation	Heavy Development-SE Mod. Development-NW	6.0	130.4	10	5	652	1,920	34%	40 Str.	a
	Greenwood Lake	Recreation	Heavy Development-NW Mod. Development-SE	27.1	2148.6	6	1	2148.6	8,672	25%	200Str.,25 Mi.Rd	c
	Wanaque Reservoir	Water Supply	Undeveloped	90.4	977.8	10	5	4889.4	28,928	17%	10 Str.	a,d
	Lake Inez	Recreation	Undeveloped	97.8	48.6	20	15	730	31,289	2%	3 Str.	a,d
	Monksville		Water Supply	40	-			21,484	12,800	168%	-	d
3. Pequannock River	Cold Spring Lake	Recreation	Light Development	.3	5.5	-	-		105.6	-	-	a
	Henion Pond	Recreation	Light Development	1.0	38.1	15	10	381.7	340.5	112%	3 Str.	a
	Oak Ridge Reservoir	Water Supply	Undeveloped	33.7	419.6	30	25	10,490	10,784	97%	-	d,e (Newark)
	Clinton Reservoir	Water Supply	Undeveloped	10.5	388.4	10	5	1,942	3,360	58%	-	b,d (Newark)
	Butler Res.	Water Supply	Undeveloped	1.9	31.6	20	15	475	637	75%	-	APSHAWA BROOK , a
	Butler Res.	Water Supply	Undeveloped	5.2	153.3	5	0	0	1,664	-	1/8 Mi. Rd.	STONEHOUSE BR , a
	Charlotte-burg Res.	Water Supply	Undeveloped	56.2	327.3	10	5	1,637	17,984	9%	-	a,b (Newark)
	Dunkers Pond (5)	Water Supply	Undeveloped	5	350	-	-	10,000	1,600	6%	-	a,d,e
	Newfound-land (5)	-	Mod. Development	51.9	-	-	-	25,000	16,608	2%	Several Str. & Rds.	c,d,e

TABLE C-38 DETENTION BASIN SCREENING DATA (CONT.)

	RESERVOIR NAME	EXISTING USE	DEVELOPMENT	DRAIN-AGE AREA (SQ MI)	SURFACE AREA (ACRE)	1) MAX. POOL ELE-VATION	2) DESIGN POOL ELE-VATION	3) VOL(A) (ACRE-FT)	4) VOL(R)	5) VOL(A)/ VOL(R) X100	POSSIBLE RELOCATIONS	REMARKS
4. Pompton River	Mountain View (5)	-	Heavy Development	350	2860	10	5	14300	115000	12%	Several Structures	b,c
5. Rockaway River	Green Pond (Dover)	Flood Detention (5)	Moderate	45.7	45	22	16	510	-	-		d
	Indian Lake	Recreation	Heavy Development	.8	94.5	10	5	472.9	278.4	170%	50 Str. 2½Mi.Rd.	a
	Taylortown Reservoir	Water Supply	Undeveloped	1.6	70.7	10	5	353.6	531	67%	Bridge Needs Removing	a
	White Meadow Lake	Recreation	Heavy Development	2.6	136.6	5	0	0	884.8	0	-	a,c
	Lake Denmark	Water Supply	Undeveloped-Milt. Reservation	4	258.9	10	5	1,294.9	1,280	101%	-	d
	Lake Valhalla	Recreation	Light Development	2.0	63.3	5	0	0	643.2	0	-	a
	Lake Estling	Recreation	Light Development	5.7	74.3	5	0	0	1,851	0	-	a
	Deer Pond	Recreation	Undeveloped	10	33.9	10	5	169.9	3,200	5%	15Str. 1 Mi.Rd.	a
	Split Rock Reservoir	Water Supply	Undeveloped	5	566	20	15	8,490	1,600	530%	No Apparent Relocation	d
	Boonton Reservoir	Water Supply	Mod. Development	119.0	780	10	5	3,900	38080	10%	-	b,c,d
	Longwood Valley(5)	Water Supply	Undeveloped	19	-	-	-	20,200	6,080	332%	-	d,e
	Picatinny Lake	Water Supply	Militar eser-vation	6.5	115	6	1	115	2,106	5.5%	-	a
	Beaver Brook (5)	Water Supply	Undevelo t	10	-	-	-	7,500	3,200	234%	-	d,e
	Powerville (5)	Water Supply	Mod. Development	113	-	-	-	35,900	36160	99%	-	c,f
	Mill Brk (5)	Flood Detention	Moderate	4.9	82	38	30	720	-	-	-	a
6. Whippany River	Lake Intervale	Recreation	Light Development	.5	8.7	0	0	0	179.2	0	-	c
	Mountain Lake	Recreation	Mod. Development	.9	73.4	0	0	0	292	0	-	c
	Wildwood Lake	Recreation	Mod. Development	.2	17.4	0	0	0	57	0	-	c
	Whippanong	Flood Detention	Heavy Development	205.1	-	-		73,000	65632	111%	-	c
	Washington Valley(5)	Water Supply	Undeveloped-Farmland	15	-	-	-	6,000	4,800	125%	30 Str.	d,e

TABLE C-38 DETENTION BASIN SCREENING DATA (Cont.)

	RESERVOIR NAME	EXISTING USE	DEVELOPMENT	DRAIN-AGE AREA (SQ MI)	SURFACE AREA (ACRE)	1) MAX. POOL ELE-VATION	2)DESIGN POOL ELE-VATION	3) VOL(A) (ACRE-FT)	4) VOL(R)	6) VOL(A)/ VOL(R) X100	POSSIBLE RELOCATIONS	REMARKS
7. Passaic River	Taylor Lake	-	Undeveloped	9.0	17.4	20	15	262.2	283.2	13%	5 Str.	a
	Canoe Br. Res. #1	Water Supply	Undeveloped	11	195.1	10	5	975.7	3520	27%	-	a
	Canoe Br. Res. #2	Water Supply	Undeveloped	11	105.6	10	5	528	3520	15%	-	a
	Haledon Reservoir	Water Supply	Mod. Development	1.4	102	20	15	1530	477	320%	10 Str.	c
	Two Bridges (5)	Flood Detention	Mod.Development-Wetlands	740.8	-	-	-	347,000	237,056	146%	-	f
	Swine-field(5)	Flood Detention	Mod.Development-Wetlands	132.9	-	-	-	56,500	42,528	133%	-	f
	Leddells Pond(5)	Water Supply	Undeveloped	4	-	-	-	3,200	1,280	250%	-	a,d,e
	Myers Rd. (5)	Flood Detention	Light Development-Wetlands	82	-	-	-	7,500	26,240	28%	-	b,d,f

1) Maximum Pool Elevation - Estimated elevation to which existing reservoir or lake may be raised without overflowing into an adjacent basin or inundating an intensely developed area.

2) Design Pool Elevation - Level to which flood water is to be contained, based on allowance for 5 feet below the maximum pool for wave run-up and taking of land easements.

3) Volume Available = Surface Area Multiply by the design pool elevation.

4) Volume Required = Storage capacity for six inches of runoff.

5) Potential new sites.

6) VOL(A)/VOL(R) - is the measure of effectiveness of detention basin in controlling drainage area.

REMARKS:

a. Potential storage is small and would not be effective.

b. Vol (A) to Vol(R) percentage is low and site would not be effective in controlling drainage.

c. Extensive development of site limits or may limit expansion and effectiveness for flood control and water supply.

d. May be considered as part of a larger water supply-flood control system.

e. Location is removed from damage centers and would only be marginally effective.

f. Proposed in previous reports and has met strong opposition.

The information in this table was developed in several steps. From USGS maps and other available data, a practical maximum pool elevation was determined for each site. To arrive at the design pool elevation, five feet was subtracted from the maximum pool elevation. This allowed for wave run-up, taking easements, and the level of the PMF (Probable Maximum Flood). Then, the volume available for storage, Volume (A), was calculated by multiplying the surface area of the design pool times the design pool elevation. While recognizing that the surface area increases with elevation, such simplification was adequate for screening of storage potential. A second assumption was to use a flood condition which would require that a reservoir be able to contain 6 inches of rainfall runoff from its drainage area. This assumption would provide a good indication of the capability of the site control on flows from its drainage area. This value is shown as Volume (R). Thus, Volume (R) is a measure of the required storage volume for the detention basin if it is to be effective. Volume A was divided by Volume R and the results were percentages for the various sites. These percentages represent the effectiveness for controlling flooding immediately downstream of the site. Structures and relocations within the "taking" line were also noted in Table C-38 where known. In addition, as another means of estimating the effectiveness of these sites, their proximity to major flood damage centers were evaluated. The ratio of the drainage areas of the reservoir as compared to the drainage area of damage center in percent was determined. The closer this ratio is to 100 percent, the greater the ability of the detention site to minimize flooding.

Finally, the sites were viewed as a potential element of a larger system. Detention sites individually may not be effective, but, as part of a larger system, may become effective in reducing downstream flood flows. For example, it is possible that a system can combine storage at several smaller sites to reduce flood flows at a downstream damage center. Another consideration is to utilize a small reservoir in the upper area of a watershed (determined to be ineffective for flood flow reduction) for water supply storage which can be traded-off for flood detention storage at an existing water supply reservoir located closer to the damage center. The existing water supply pool of the reservoir closer to the damage center would be reduced by an amount equivalent to the volume of water supply provided by the site further away. This would, therefore, be available for flood flow storage at the closer reservoir where it would be more effective. Promising combinations were noted for further study upon completion of the technical models necessary for such analysis.

b. Early Screening Results. The following is a discussion of the early screening results described by subbasin.

i. Ramapo River Subbasin. The Ramapo River Subbasin has three existing reservoirs and two potential sites that have been suggested for flood damage reduction measures. These include: 1) modification of Pompton Lake; 2) modification of Point View Reservoir; 3) modification of Pines Lake; 4) Hogback Mountain site; and 5) Darlington site. Among these only the Darlington site would provide any measure of protection to areas downstream. The remaining four sites are small or far removed from the damage centers.

Point View has a drainage area of less than two square miles and has no potential for flood damage reduction. It is possible that the Hogback Mountain site and Pines Lake could be used to provide water supply in a system, but they are small (under 1000 acre-feet) sites. Pompton Lake is surrounded by development and the existing storage pool elevation could not be raised without a great number of relocations. It has often been suggested that dredging Pompton Lake would provide additional storage for flood detention. To provide this flood detention storage, the reservoir level would also have to be maintained at a lower level. However, even if this were done it would not be effective because of its small size. For example, even if the pool was lowered by 5 feet, as shown in Table C-38, this would only provide storage for 2 percent of the upstream runoff, and would have a negligible effect on the downstream flood problem.

The Darlington site also has drawbacks due to development at the site which would require either reducing the scale of the reservoir or the use of levees. However, in this subbasin, it was determined that the Darlington site has the best potential to be used for flood flow reduction. It was therefore decided to utilize more detailed information to determine the desirability of the Darlington site.

ii. Wanaque River Subbasin. In the Wanaque River Subbasin, there are 9 sites listed in Table C-38. There are three recreation lakes (Cupsaw, Twin Lakes and Pinecliff) that would have minimal potential due to the small size (less than 1000 acre-feet). Sterling Forest Lake and Tuxedo Lake would be effective in controlling their respective drainage areas, however, these drainage areas are small. Analysis indicated that either in combination or as part of a trade-off between water supply and flood control, the use of these lakes would not appreciably effect flood damage reduction plans. Greenwood Lake is a large lake devoted to recreation. Raising the pool of this lake would require extensive land takings due to heavy surrounding development. It is interesting to note, however, that by combining Monksville Reservoir with an enlarged Lake Inez and Wanaque Reservoir as a flood detention system, enough storage is available to retain 70 percent of the flow of the Wanaque River. The new Monksville Reservoir is being utilized

as a water supply reservoir and it may also be possible to develop additional storage for flood control which would be traded-off to the Wanaque Reservoir. The major damage center that would be affected by flood detention in the Wanaque River Subbasin is the Pompton River area, a short distance downstream. It was important to evaluate what the effect of reducing peak flows on the Wanaque River would have on the Pompton River peak flows. The Pompton River flow is also dependent on the Pequannock and Ramapo River flows. Based on this review, Monksville Reservoir and Wanaque Reservoir were selected for future evaluation.

iii. Pequannock River Subbasin. In the Pequannock River watershed, three of the nine reservoirs listed in Table C-38 are owned by the City of Newark and are developed or will be developed for water supply. These reservoirs are Clinton, Oak Ridge and Charlotteburg. Among the remaining sites are two recreation reservoirs, Cold Spring Lake and Henion Pond, both of which drain one square mile or less and have no potential for flood protection on a comprehensive basis.

The Newark reservoirs already moderate flows considerably with about 44,000 acre-feet of storage. Oak Ridge Reservoir could have 10,500 acre-feet additional storage added and would effectively control its drainage area. However, Oak Ridge is a good distance away from any major damage center on the Pequannock and as a result would have minimal effects at downstream flood damage areas. Clinton Reservoir would control 10.5 square miles and has limited expansion capabilities since additional dam structures would be required to create additional storage. Butler Reservoir on Stonehouse (Kikeout Brook) Creek has little available storage, less than that required to establish a flood reduction potential.

Butler reservoir on Apshawa Brook meets the storage requirement, but is a small reservoir and has little effect on flood flows in the nearby Pequannock River. Dunkers Pond site has been proposed by the City of Newark as a water supply reservoir of about 10,000 acre-feet. The drainage area is about 5 square miles. Newfoundland reservoir site on the Pequannock River has a large available storage relative to the flood control requirements, and could be used for water supply as well. However, there is some development located at the site and it may not be feasible for use as a reservoir. The site is also located about 8 to 10 miles upstream of the flood problem centers and may not be effective for flood detention.

Charlotteburg is limited in expansion capability and may not be directly effective for flood flow reductions. However, based upon the early screening results, this site offered the best potential for flood flow reduction in the Pequannock River Subbasin. Charlotteburg Reservoir was, therefore, selected for further analysis.

There was also the possibility for adding water supply storage in the Pequannock River Basin to compensate for providing flood storage in the Wanaque River Subbasin (at Wanaque Reservoir) since Newark receives water from both subbasins.

iv. Pompton River Subbasin. In the Pompton River Subbasin, the Mountain View site is infeasible as a flood detention reservoir due to the extensive development in the area. This plan would consist of a detention structure at Boonton Road with surrounding levees to protect developed areas. The storage area is so limited by development that even with levees this site would not be effective in controlling downstream flooding. No further consideration was given to sites in this subbasin.

v. Rockaway River Subbasin. In the Rockaway River Subbasin, there are 15 reservoir sites listed in Table C-38, of which 11 drain an area of 10 square miles or less. There are also 5 reservoirs where the additional storage would be 1,000 acre-feet or less, and three reservoirs that can not practicably be enlarged (White Meadow Lake, Lake Valhalla, and Lake Estling). There may be potential to raise Lake Denmark and Split Rock Reservoir for water supply to trade-off for flood control storage at Boonton Reservoir. The same trade-off possibility exists between the Beaver Brook and Longwood Valley Reservoir sites if they were to be constructed. Boonton Reservoir appears to have limited expansion potential because of the extensive raising of 2 dams that would be required to gain even a small amount of storage. Raising the dams any further begins to encroach heavily on existing development including road raisings. Powerville Reservoir is also listed in Table C-38. It is noted that although there is adequate storage at this site, this reservoir would encroach on surrounding areas and consequently has generated strong opposition in the past. From this subbasin Longwood Valley and Boonton Reservoirs were selected for further study.

vi. Whippany River Subbasin. The Whippany River Subbasin offers only limited potential at two sites. Three existing sites (Lake Intervale, Mountain Lake and Wildwood Lake) offer no potential because of their small size and their location in the center of a developed area. Of the potential sites, Washington Valley, which offers good potential for development as a flood storage site, is currently agriculturally developed and has been proposed as a water supply reservoir site by Morris County. This site may provide only limited flood protection due to its distance from damage centers. However, it has potential for water supply in a water supply/flood control trade-off, for example, with Boonton Reservoir. The Whippanong

site shown in Table C-38, as presented in earlier studies, can no longer be developed due to the encroachment of extensive development around and within the site by Morristown Airport. This site would require extensive levees and floodwalls to protect the development. Based upon this review, Washington Valley was selected for further investigation.

vii. Main Stem. The Passaic River offers few opportunities for development of detention sites outside of the Central Basin area. Leddells Pond, located in the Highland Area, was considered but it is small and far removed from damage centers. Taylor Lake, in the Central Basin, would provide very little additional supply and would not be feasible. The Canoe Brook Reservoir, also located in the Central Basin, is an off-river pumped storage site that offers no possibilities for flood control. Additional water supply storage at this site would require extensive diking to increase the capacity. Expansion of Haledon Reservoir, situated in the Lower Valley, would require extensive road relocations, possible structural relocations, and also the possible flooding of a large wetland area to the north. It is also a small site with a limited drainage area and would have little impact on downstream flows. Two Bridges and Swinefield Reservoirs are Central Basin reservoirs that have been considered in previous Corps studies, and have been determined to be effective for flood flow reduction from an engineering standpoint. However, the extensive development which has occurred in the past 15 years at these reservoir sites have made these alternatives prohibitively expensive and economically infeasible. For this reason, and in accordance with HR 94-1702, no further consideration was given to these sites. The potential Myers Road reservoir located on the Upper Passaic River, also proposed in previous reports, appears to have a potential to be used for flood flow reduction. This site was selected for further analysis.

c. Early Screening Summary. There are few developable sites in the Basin that are large enough or favorably situated geographically to provide significant flood control benefits at downstream problem areas. There are possible systems that could be developed utilizing a trade-off of flood control and water supply development, particularly in the Pequannock and Wanaque systems, and the Rockaway and Whippany systems.

Formulation of Alternative Plans. The sites identified during the early screening were then analyzed in the initial formulation of plans. Consideration was also given to the possibility of flood damage reduction, water supply and other uses such as hydropower in a multi-purpose project. The approach to these analyses is outlined in the following paragraphs with the results detailed for each of the investigated subbasin areas.

a. Flood Damage Reduction: Potential Sites. Six of the seven subbasins were carried forward and reviewed from a hydrologic perspective for their potential to attain flood damage reduction through the use of detention reservoirs. The Pompton Subbasin was screened from the analysis due to the lack of available sites identified in the initial studies. For each of the other subbasins, at least one potential detention site and/or existing reservoir was examined through the use of HEC-1. Hypothetical events were routed through the sites to provide modified flood flow hydrographs. The sites evaluated were those identified in the early screening process.

b. Flood Damage Reduction: Existing Reservoirs. In addition to further investigation of these potential sites, the re-regulation of existing reservoirs was also considered. Re-regulation was considered for all types of existing reservoirs. Recreation lakes in the region were eliminated from consideration because they are intensively utilized, have little capacity for expansion, and would not appear to be locally acceptable. Consideration was then given to the larger impoundments in the Basin which are primarily water supply impoundments. These reservoirs are limited to light recreational uses and are usually drawn down through normal water supply operations. They also contain significant amounts of storage and are potentially more useful for flood damage reduction. However, the intensive use of these reservoirs for water supply, as illustrated by the recent dry periods in the 1960's the late 1970's, in 1980-81, and most recently in 1985, have highlighted the need to develop additional water supply sources to meet today's needs as well as the growing needs of northern New Jersey. Given the current water supply situation, any reduction in existing water supply storage to set aside storage for flood detention requires that this storage be replaced in both quantity and quality. The equivalent replacement storage should be located where it can drain into or be interconnected to the affected water supply system.

The evaluation of the existing reservoirs, therefore, focused on those reservoirs nearest damage centers. These reservoirs are part of three major water supply systems in the Basin (North Jersey, Newark and Jersey City). The hydrologic analysis was performed with the existing conditions HEC-1 model utilizing flood detention volumes in the reservoir that are roughly equivalent to potential upstream sites available for water supply development. This is the basis for developing the water supply/flood detention trade-off plans.

The reservoirs measured for their effectiveness include Wanaque Reservoir with the Monksville Reservoir on the Wanaque River, Boonton Reservoir with the Longwood Valley site on the Rockaway River, and Charlotteburg Reservoir with Dunkers Pond on the Pequannock River.

c. Water Supply. The development of additional water supply storage in the Passaic River Basin was based on the premise that flood damage reduction is the primary goal of this study. Sites were first reviewed as storage sites for flood detention, including those sites designated for water supply in the New Jersey Statewide Water Supply Master Plan. If this proved to be feasible, then an attempt was made to maximize use of the site by adding water supply as a purpose. This process was followed for the Longwood Valley site where the additional purpose of pumped storage hydropower was also included. In the case of the Monksville Reservoir which was analyzed prior to initiation of its construction by locals, the best trade-off situation is to utilize Monksville for water supply only and lower the water supply storage in Wanaque Reservoir an equivalent amount. This would create flood detention storage in the Wanaque Reservoir which is closer to downstream damage centers. This trade-off would not result in any additional water supply yield. Without the Wanaque flood control element, the purpose of the Monksville Reservoir would be solely water supply, as planned by local interests. The Monksville/Wanaque trade-off is discussed in detail later in this section.

d. Hydropower. A National Hydropower Study preliminary review of hydropower potential indicated little potential for major hydropower (1/2 to 25 megawatts) development in the Passaic River Basin. Run of the river flows are very low during dry periods. There are only a few potential reservoir sites in the Basin and water supply has been determined to be the most efficient use of these sites. However, low-head potential is being considered for development by local interests at the low dams on the Passaic River in the Lower Valley and for at least one water supply reservoir in the Highland area. Longwood Valley, in previous local studies, has been proposed as a pumped storage hydropower site in conjunction with water supply. This form of hydropower does not consume or pass water downstream and it is therefore feasible even in locations of little runoff. A feasibility analysis considering not only hydropower but also potential flood control and water supply indicated feasibility for the Longwood Valley site.

Results. Study results are presented by subbasin, consistent with the earlier discussion. As previously noted, the Pompton Subbasin has been eliminated from further consideration. However, while reservoir sites are not possible in the Pompton River basin, the impacts of upstream reservoirs on Pompton River flood damage areas have been identified. These impacts are significant in determining the effectiveness of the

reservoir sites considered. It should be noted that the stages referred to below do not reflect current hydrology and hydraulics. Nevertheless, the base relationships and resulting decisions still hold.

a. Ramapo River Subbasin. In the Ramapo River Subbasin, only Darlington Reservoir would provide any measure of protection to areas downstream. The Darlington site is located in the municipalities of Oakland and Mahwah, New Jersey with a small portion in Suffern, New York. A flood detention reservoir at this site would control a drainage area of 137 square miles. The dam would be located on the Ramapo River in Oakland, approximately 1,650 feet upstream of Lenape Lane. Information on the size and capacity of the alternatives considered at this site is found in Table C-39.

This site was analyzed for several different storage capacities but only two alternative levels of development were considered in detail. The first alternative investigated was the reservoir that had been proposed in a previous Corps of Engineers report on the Passaic River completed in 1962. This alternative had 43,900 acre-feet of storage. However, because of the substantial development in the watershed since previous studies were completed, a second alternative, which considered a smaller scale design having 28,000 acre-feet of storage to minimize impacts to development, was investigated. It had been determined that a reservoir having less than 28,000 acre-feet of storage would have a minimal effect on reducing the peak flows at downstream locations.

A reservoir at this site would provide some measure of flood protection for Oakland, Pompton Lakes, Wayne, Lincoln Park and Pequannock. The hydrologic effects of these detention alternatives are displayed in Table C-40. Along the Ramapo River, Oakland and Pompton Lakes would benefit considerably from the large scale alternative with the 100 year peak flow reduced between 64 and 79 percent. The hydrologic effects of the smaller scale alternative would also be significant, as noted on Table C-40. Immediately downstream of the confluence of the Pequannock and Ramapo Rivers on the Pompton River, the large size reservoir would reduce the peak 100 year flow by 41 percent, while the smaller scale 100 year reduction at this location would be 21 percent. Smaller reductions occur at this point because the drainage area controlled by the Darlington site is only 39 percent of the drainage area of the Pompton River at Pompton Plains.

TABLE C-39 DARLINGTON RESERVOIR-PHYSICAL FEATURES

	1962 PROPOSAL	REDUCED SCALE PROPOSAL
1. Drainage Area (sq.mi.)	137.0	137.0
2. Spillway Pool		
Elevation (ft.msl.)	273.0	263.0
Water Surface Area (acres)	1,350	950
Water Supply Storage (ac-ft.)	-	-
Flood Detention Storage (ac-ft.)	28,000	15,000
3. Maximum Pool		
Elevation (ft.msl.)	283.0	273.0
Water Surface Area (acres)	1,920	1,350
Water Supply Storage (ac-ft.)	-	-
Flood Detention Storage (ac-ft.)	43,900	28,000
4. Non-Overflow Section		
Elevation (ft.msl.)	288.0	278.0
Water Surface Area (acres)	2,530	1,600
Water Supply Storage (ac-ft.)	-	-
Flood Detention Storage (ac-ft.)	55,000	35,000

TABLE C-40 DARLINGTON RESERVOIR - HYDROLOGIC EFFECTS

LOCATION	50 YR FLOOD EVENT Existing (cfs)	Improved (cfs)	Flow Reduction (%)	100 YR FLOOD EVENT Existing (cfs)	Improved (cfs)	Flow Reduction (%)
1962 PROPOSAL:						
Dam Site: 0.3 mi Upstream of Lenape Lane, Oakland	14618	2852	80	18765	3851	79
Upstream of Pompton Lake, Oakland	15248	4632	70	19608	5558	72
Pompton Lakes Dam, Pompton Lakes, Wayne	15552	5630	64	19985	7184	64
1.6 mi Downstream of Confluence of Ramapo, Pequannock and Pompton Rivers	24638	15370	38	30948	18287	41
REDUCED SCALE PROPOSAL:						
Dam Site: 0.3 mi Upstream of Lenape Lane, Oakland	14618	5889	60	18765	10579	44
Upstream of Pompton Lake, Oakland	15248	6158	60	19608	10979	44
Pompton Lakes Dam, Pompton Lakes, Wayne	15552	6276	60	19985	11147	44
1.6 mi Downstream of Confluence of Ramapo, Pequannock and Pompton Rivers	24638	16897	31	30948	24442	21

Downstream on the Pompton River, 100 year flood stages resulting from the large and smaller scale Darlington Reservoir would be reduced by approximately 2 feet and 1 foot, respectively. A comparison of existing and improved conditions hydrographs indicates that both the peak flows and the resulting flood stages at the mouth of the Pompton River are not significantly reduced but are only delayed about 12 hours. As discussed earlier, the Central Basin flood stages are not so much affected by peak flood discharges as they are affected by the volume of flood flows into this large natural detention area. As a result, the water surface elevations corresponding to the peak flows would be reduced by less than 1 foot in the area between Two Bridges and Beatties Dam. Therefore, Darlington Reservoir would have a minor impact on reducing flooding between Two Bridges and Beatties Dam. In summary, the Darlington site is effective in reducing flood flows only on the Ramapo River downstream of the site in Oakland and Pompton Lakes. On the Pompton River, it is only partially effective on its upper reaches and to a minimal degree downstream.

A major concern associated with the Darlington site includes its encroachment on the development in Mahwah and Suffern that has occurred since this proposal was presented in previous reports. Both alternatives would incur great costs in the required purchases of residential, commercial, and public structures and lands. The number of structures is estimated to be over 800 for the larger site. The alternative to the purchases is to construct extensive and complex systems of levees and floodwalls with interior flood control to protect existing land uses from the ponded waters of the detention reservoir during periods of flooding. In addition, 8 miles of New Jersey Route 202 would also be relocated throughout the length of reservoir ponding area.

Costs for the Darlington Reservoir alternatives would amount to approximately $200 million (October 1985 price level) for the larger reservoir and over $150 million (October 1985 price level) for the smaller site. However, these costs do not reflect the significantly changed conditions in terms of the number and type of residential and commercial structures to be acquired, nor the additional road relocations that would now be required. Considering these changed conditions at a minimum, would increase the costs of these alternatives by approximately $50 million (October 1985 price level). In light of these total costs, the resulting impacts on flood stages along the Ramapo, Pompton, and Passaic Rivers clearly does not provide the significant reduction in flood damages that are necessary to support the costs of development of Darlington Reservoir at either scale.

The smaller Darlington site was then reviewed as to its relationship to other plans affecting the Pompton River and the Passaic from Two Bridges to Beatties Dam. The existence of Darlington Reservoir would reduce the size and extent of these potential works which include a tunnel on the Pompton River or at Two Bridges, or a channel modification plan for this area. It was determined that the reservoir would reduce the tunnel diameter from 40 to 35 feet causing a savings of $70 million in tunnel costs (October 1985 price level). In combination with a smaller size of channel modification, the reservoir would reduce channel costs $30 to $50 million (October 1985 price level). In both cases the cost of the reservoir clearly outweighs the cost savings achieved with the smaller tunnel or channel.

b. Pequannock River Subbasin. After review of the existing reservoirs and assessment of their potential, Charlotteburg Reservoir owned by the City of Newark and currently used for water supply storage, was analyzed for its potential as a flood control reservoir. The major damage centers that would be affected by flood detention on the Pequannock are located along the Pompton River.

Charlotteburg Reservoir, located in Rockaway Township and Kinnelon Borough, controls a drainage area of 56.2 square miles. The Pequannock watershed upstream of the Charlotteburg Reservoir includes three additional water supply reservoirs owned by the City of Newark as well as several additional lakes developed for recreation. This intensive watershed development currently has a great moderating effect on flows in the Pequannock River.

The flood detention storage in Charlotteburg Reservoir would utilize 4,300 acre-feet of water supply storage. This is a small site limited both in storage and in expansion capability due to surrounding development. Lost water supply storage was assumed to be replaced by new water supply storage at a site elsewhere, but accessible to the City of Newark. Additional details are shown in Table C-41.

The results of the hydrologic analysis indicate that upstream of the confluence of the Pequannock and Wanaque Rivers, the peak 100 year flow would only be reduced by 7 percent. This occurs because the intensive reservoir development for water supply and recreational purposes already moderates flood flows,

TABLE C-41 CHARLOTTEBURG RESERVOIR-PHYSICAL FEATURES

	EXISTING OPERATION	REREGULATED OPERATION
1. Drainage Area (sq.mi.)	56.2	56.2
2. Spillway Pool		
Elevation (ft.msl.)	738.0	738.0
Water Surface Area (acres)	312	312
Water Supply Storage (ac-ft.)	7,400	7,400
Flood Detention Storage (ac-ft.)	-	-
3. Maximum Pool		
Elevation (ft.msl.)	748.0	748.0
Water Surface Area (acres)	450	450
Water Supply Storage (ac-ft.)	11,000	7,500
Flood Detention Storage (ac-ft.)	-	3,500
4. Non-Overflow Section		
Elevation (ft.msl.)	750.0	750.0
Water Surface Area (acres)	450	575
Water Supply Storage (ac-ft.)	11,800	7,500
Flood Detention Storage (ac-ft.)	-	4,300

only a small amount of storage is available for flood detention, and Charlotteburg Reservoir only controls about half of the Pequannock watershed. This site, representing the most likely opportunity for flood detention, therefore clearly demonstrates that there is no potential for flood detention in the Pequannock River Subbasin.

c. Wanaque River Subbasin. In this subbasin, the Monksville Reservoir, currently under construction, and Wanaque Reservoir, currently used for water supply, were analyzed for their flood flow reduction potential. The major damage center that would be affected by flood retention on the Wanaque River is the Pompton River area, a short distance downstream. It was important to evaluate what the effect of reducing peak flow on the Wanaque River would have on the Pompton River peak flows. The Pompton River flow is also dependent on the Pequannock and Ramapo River flows, which are equally significant to the flood problem along the Pompton River.

Monksville Reservoir is located in the Borough of Ringwood and the Township of West Milford in Passaic County, N.J. The reservoir controls a drainage area of 40.0 square miles and has approximately 7 billion gallons or 21,400 acre-feet of storage at spillway level. The dam is located on the Wanaque River in the Borough of Ringwood approximately 1,600 feet downstream of Stonetown Road and immediately upstream of Wanaque Reservoir. Specific details describing Monksville are shown in Table C-42.

The effects of Monksville Reservoir as an independent flood detention reservoir (with Wanaque Reservoir under existing conditions) was investigated. As a flood detention reservoir Monksville would reduce the peak 100 year flow by 24 percent just upstream of the confluence of the Wanaque and Pequannock Rivers. Monksville Reservoir would only have a moderate effect on reducing peak flows on the Wanaque River because most of the floodwaters controlled by its drainage area are already being attenuated through above spillway surface storage in the existing Wanaque Reservoir. The effect further decreases as the Wanaque River enters the Pequannock River where the 100 year peak flow is reduced only 14 percent. These results are shown in Table C-43.

The combined effects of the Monksville site and the large Darlington site on the Pompton River peak flows were also investigated. This combination showed a total reduction in the peak 100 year flow of 47 percent as compared to the 41 percent

TABLE C-42 MONKSVILLE AND WANAQUE RESERVOIRS-PHYSICAL FEATURES

	MONKSVILLE REREGULATED OPERATION	WANAQUE EXISTING OPERATION	WANAQUE REREGULATED OPERATION
1. Drainage Area (sq.mi.)	40.0	90.4	90.4
2. Spillway Pool			
Elevation (ft.msl.)	400.0	300.3	300.3
Water Surface Area (acres)	505	2,305	2,305
Water Supply Storage (ac-ft.)	-	81,000	62,000
Flood Detention Storage (ac-ft.)	21,480	-	19,000
3. Maximum Pool			
Elevation (ft.msl.)	409.0	308.8	308.8
Water Surface Area (acres)	570	2,590	2,590
Water Supply Storge (ac-ft)	-	103,500	62,000
Flood Detention Storage (ac-ft.)	23,350	-	41,500
4. Non-Overflow Section			
Elevation (ft.msl.)	414.0	310.0	310.0
Water Surface Area	625	2,620	2,620
Water Supply Storage (ac-ft.)	-	106,000	62,000
Flood Detention Storage (ac-ft.)	29,470	-	44,000

TABLE C-43 MONKSVILLE AND WANAQUE RESERVOIRS-HYDROLOGIC EFFECTS

LOCATION	50 YR FLOOD EVENT Existing (cfs)	Improved (cfs)	Flow Reduction (%)	100 YR FLOOD EVENT Existing (cfs)	Improved (cfs)	Flow Reduction (%)
MONKSVILLE RESERVOIR						
Dam Site: 0.3 mi Downstream of Stonetown Rd on Wanaque R.	4673	500	89	5587	500	91
Raymond Dam on Wanaque Reservoir	6935	4974	28	8573	6040	30
Upstream of Confluence of Wanaque and Pequannock Rivers	7773	6014	23	9421	7207	24
Pequannock River Upstream of Confluence with Ramapo and Pompton Rivers	12453	10738	14	15050	12926	14
MONKSVILLE WITH DARLINGTON RESERVOIR						
1.6 mi Downstream of Confluence with Ramapo and Pompton Rivers	24638	13770	44	30948	16252	47
WANAQUE RESERVOIR						
Raymond Dam	6935	616	91	8573	1973	77
Wanaque River Upstream of Confluence with Pequannock River	7773	2415	69	9421	2777	71
1.6 mi Downstream of Confluence of Pequannock and Pompton Rivers	24638	19488	21	30948	24775	20

reduction by the Darlington site alone, as noted earlier. Therefore, this combination of reservoirs would not be significantly more effective for flood detention than Darlington Reservoir alone.

The effectiveness of using Wanaque Reservoir for flood flow reduction was analyzed by assuming the trade-off of a portion of existing water supply storage for floodwater detention. This volume was assumed to be replaced by new water supply storage developed at Monksville or other sites.

This reservoir is located in the Boroughs of Wanaque and Ringwood and controls a drainage area of 90.4 square miles. Raymond Dam on the Wanaque River is located approximately 7 miles upstream of the confluence with the Pompton River.

The analysis showed that as a flood control reservoir, the Wanaque Reservoir would be effective in reducing peak flows only on the Wanaque River upstream of the confluence of the Wanaque and Pequannock Rivers. The peak 100 year flow would be reduced by 71 percent. However, on the Pompton River, the Wanaque is one of three major tributaries and this effect results in a 20 percent reduction in the 100 year flow. In summary, the results of the hydrologic analyses of the Wanaque River Subbasin indicated that the Monksville site is minimally effective on the Wanaque River and would have virtually no effect on flood flows in the Pompton River. Use of a flood detention/water supply trade-off in Wanaque Reservoir is very effective along the Wanaque River but has a very minimal effect on the upper Pompton River.

Furthermore, Wanaque Reservoir is operated by the North Jersey District Water Supply Commission (NJDWSC) which provides an average annual water supply safe yield of 94 mgd. The just completed Monksville Reservoir is being utilized as a water supply storage reservoir as part of the Wanaque South Project. This project is jointly sponsored by the NJDWSC and the Hackensack Water Company to supplement their systems with an additional yield estimated to be 79 mgd. Other components of the project include a 250 mgd pumping station at Two Bridges, near the confluence of the Passaic and Pompton Rivers, which would deliver the pumped water through a force main to Wanaque Reservoir. The Ramapo Pumping Station at Pompton Lakes would also be upgraded for increased pumping capacity. This new system would also be connected to the Hackensack Water Company facilities. No opportunities exist at these sites for flood-

water detention when the system operates as designed. With no other major water supply storage locations in the Pequannock, Wanaque, and Ramapo Basins, the trade-off of water supply storage for the provision of flood control storage in the Wanaque Reservoir is not possible.

d. Rockaway River Subbasin. The Rockaway River Subbasin has been developed with many small recreation lakes located on tributaries. Boonton Reservoir has been developed for water supply by Jersey City and is located on the Rockaway River upstream of the Central Basin with a drainage area of 119 square miles. Several small sites are available for development. The only major site available for development in the subbasin is the Longwood Valley site on the Upper Rockaway River with a drainage area of 22 square miles. This site was first proposed for development as a water supply reservoir site by Jersey City. About 20 years ago, Jersey Central Power and Light Company joined the venture and expanded the project to include pumped storage hydroelectric power. Flood flow reduction was to be an incidental purpose. The hydropower purpose required an additional reservoir to be developed to serve as an upper pool while the original Longwood Valley site would serve as a lower pool. The upper pool, with a drainage area of 2.0 square miles, is located in the Delaware Basin, which is outside of the Rockaway and Passaic Basins and, therefore, outside of the Passaic River Basin study area. The project was nearly built in the early 1970's but political circumstances halted the project shortly before its scheduled construction and no additional work has been done since that time.

The Longwood Valley site was first evaluated for its flood flow reduction potential on the Rockaway River. Total active storage in the lower reservoir would be about 6,000 acre-feet and can not be increased without inundating Upper Longwood Lake and the many homes that line its shores. The upper pool of this project is outside the basin and its storage would not affect flows on the Rockaway River. It was therefore assumed that the total storage in the lower reservoir would be utilized for flood flow reduction. The major damage centers are downstream at Dover and Denville on the Rockaway River.

Preliminary hydrologic studies indicate that peak flood flows for the 50 and 100 year frequency flood events would be reduced by about 23 percent in Dover and about 9 percent in Denville as shown in Table C-44. If these reductions are translated into flood stages, the effect is to reduce flood flows about 2.0 feet in Dover and less than 1.0 foot in Denville for the 100 year event. The reduction in flood stages does prevent enough damages to justify the construction of a detention reservoir

TABLE C-44 LONGWOOD VALLEY - HYDROLOGIC EFFECTS

LOCATION	50 YR FLOOD EVENT			100 YR FLOOD EVENT		
	Existing (cfs)	Improved (cfs)	Flow Reduction %	Existing (cfs)	Improved (cfs)	Flow Reduction %
Dover	3,440	2,680	22	4,140	3,170	24
Denville	5,960	5,450	9	7,080	6,450	9
Upstream of Boonton Reservoir	6,660	5,980	10	8,050	7,280	10

TABLE C-45 LONGWOOD VALLEY RESERVOIR - PHYSICAL FEATURES

	Proposed Operation
Lower Pool	
1. Drainage Area (sq. mi.)	22.0
2. Pool	
Elevation (ft. msl.)	735.0
Water Surface Area (acres)	410.0
Flood/Hydropower Storage (ac-ft.)	6,000
Dead Storage (ac-ft.)	1,500
Upper Pool	
1. Drainage Area (sq. mi.)	2.0*
2. Pool	
Elevation (ft. msl.)	1,125.0
Water Surface Area (acres)	550.0
Water Supply Storage (ac-ft.)	9,300
Hydropower Storage (ac-ft.)	6,000
Dead Storage (ac-ft.)	1,500

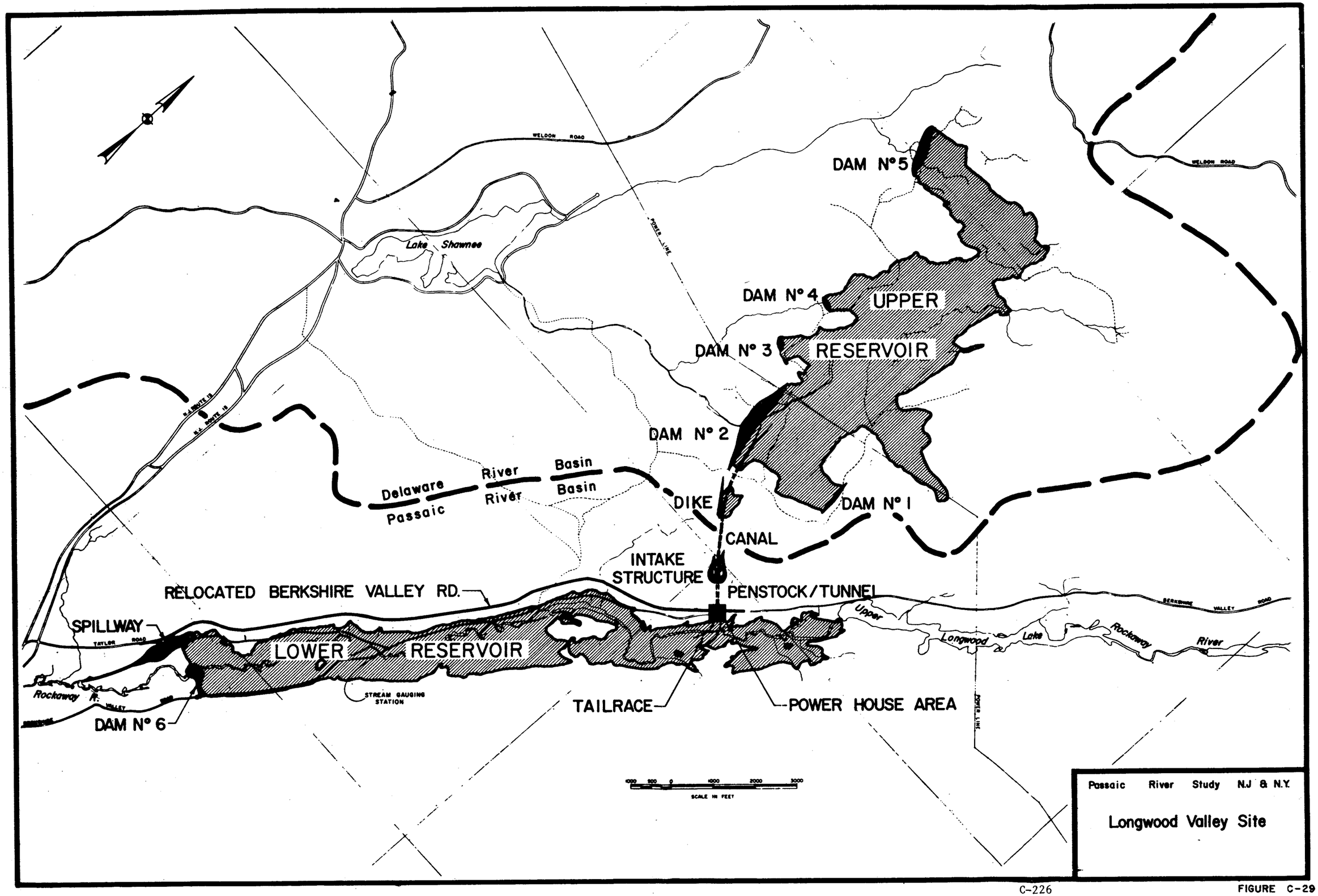
* Located in Delaware River Basin

solely for decreasing flood flows, but the level of protection is not very high. The addition of a second small detention reservoir at the confluence of the Rockaway River with Green Pond Brook in combination with the Longwood Valley site, would further reduce flood stages. The reductions would range from up to 4.0 feet in Dover to 2.0 feet in Denville for the 100 year event.

Longwood Valley was also evaluated for water supply as an additional purpose. In 1981, the State of New Jersey in its water supply master plan considered development of a single reservoir at Longwood Valley for water supply only to produce an additional safe yield of 12 mgd when used in conjunction with the existing Boonton and Split Rock Reservoirs in the Rockaway River Subbasin. This single purpose use of the site is costly when compared with other potential sources in the Northern New Jersey area. The master plan ranked this alternative fifth in terms of cost per mgd yield and, therefore, placed it low in priority for development.

Multiple purpose use of the site would enable the sharing of the total cost between purposes and would result in lower costs for each purpose. As previously discussed, the project was proposed as a multiple purpose water supply and pumped storage hydroelectric power plan with incidental flood flow reduction. A review of this plan was conducted to determine its current feasibility. The plan was reviewed, not only as originally proposed, but also in several different configurations which vary the size of both upper and lower reservoirs to test the plan for different project scales. Several alternatives are feasible based on preliminary estimates of benefits and costs. An evaluation of benefits and costs suggest that the value of hydropower storage is greater than storage for water supply and flood damage reduction. It is also noted in the hydropower analysis of Longwood Valley that the hydropower benefits are sensitive to generation and nighttime pumping cycles as well as fuel costs, and to the future need of pumped storage hydropower in the region. Because hydropower benefits range from 80 to 90 percent of the total project benefits, detailed studies were necessary to further define these benefits.

Congressional authority was given to expand the scope of the Passaic Basin Phase I Study to include the Longwood Valley Study. It has been determined that construction of the Longwood



C-226

FIGURE C-29

247

Valley Reservoir would provide flood damage reduction benefits only along the upper Rockaway River. Therefore, the Longwood Valley results will not be presented as a "Building Block" plan later in this report, but the results will be presented as a separate interim report currently scheduled for completion in March 1988.

The plan which maximizes net benefits has been carried forward and is being studied as part of the Upper Rockaway River Subbasin study. The plan calls for the construction of two multi-purpose reservoirs, a water conduit connecting them, a powerhouse containing reversible pump turbines, and the necessary valves, gates, and control equipment. The lower reservoir would be created by constructing a single earth dam with outlet works and concrete spillway. The reservoir would extend two miles upstream to the existing dam creating Longwood Lake, Figure C-29. This lower site would be operated for flood detention and pumped storage hydropower.

The upper reservoir would be created by constructing five earth dikes or dams in or near the headwaters of Weldon and Beaver Brooks, which are tributaries to the Delaware River. This upper reservoir would be operated for both water supply and power storage in a manner that would not divert water from the Delaware River Basin.

Topography and plans were originally developed by Jersey City and Jersey Central Power and Light Company in the late 1960's. These served as a starting point for the investigation. In addition, in 1980, the North Pacific Division of the Corps of Engineers prepared a study that focused on the hydropower element of the study in recognition of the large proportion of costs and benefits associated with this purpose. The Philadelphia District of the Corps of Engineers reviewed and updated this report in 1985 and conducted a power marketability study with the Southeastern Power Authority (SEPA). Updated topographic mapping was also prepared in 1985. The following description summarizes the physical properties of the reservoir plan, costs and benefits.

The plan provides for power operation and flood detention jointly using the full 6,000 acre-feet of lower reservoir storage. A similar volume of power storage would also be provided in the upper reservoir with water supply storage using 9,300 acre-feet. No water supply storage is provided in the lower reservoir. The plan would yield 7 mgd for water supply and a capacity of 246 MW for hydropower. The cost of this plan is estimated to be $329 million (October 1986 price level). The annual cost is $41.9 million. The benefits, comprised of water

TABLE C-46 WASHINGTON VALLEY RESERVOIR-PHYSICAL FEATURES

	PROPOSED OPERATION
1. Drainage Area (sq.mi.)	15.0
2. Spillway Pool	
Elevation (ft.msl.)	337.0
Water Surface Area (acres)	450
Water Supply Storage (ac-ft.)	-
Flood Detention Storage (ac-ft.)	3,900
3. Maximum Pool	
Elevation (ft.msl.)	340.0
Water Surface Area (acres)	465
Water Supply Storage (ac-ft.)	-
Flood Detention Storage (ac-ft.)	5,275
4. Non-Overflow Section	
Elevation (ft.msl.)	345.0
Water Surface Area (acres)	550
Water Supply Storage (ac-ft.)	-
Flood Detention Storage (ac-ft.)	7,620

TABLE C-47 WASHINGTON VALLEY SITE - HYDROLOGIC EFFECTS

LOCATION	50 YR FLOOD EVENT Existing (cfs)	Improved (cfs)	Flow Reduction (%)	100 YR FLOOD EVENT Existing (cfs)	Improved (cfs)	Flow Reductic %
Dam site: Upstream of Sussex Ave. Bridge	979	238	76	1155	272	76
Whippany River downstream of confluence w/Watnong Brook	2182	1567	28	2568	1843	28
Whippany River downstream of Lake Pocahontas Morristown	2252	1694	25	2654	1994	25

supply, flood damage reduction and hydropower production, are $56.6 million. As mentioned earlier, the addition of another smaller reservoir site in combination with the Longwood Valley site would provide additional flood control benefits. Table C-45 describes the physical features of the plan.

e. Whippany River Subbasin. The Whippany River Subbasin offers only limited potential for the development of a floodwater detention site. In this subbasin, the feasibility of developing Washington Valley as a flood storage reservoir was investigated. This site is currently being studied as a potential water supply storage reservoir by the Morris County Utilities Authority.

The Washington Valley reservoir would be located on the Whippany River upstream of its confluence with Watnong Brook. The proposed dam location would be approximately 1,000 feet southwest of Sussex Turnpike in Morris Township and would control a drainage area of 15 square miles. Data on the proposed operation of the Washington Valley site is contained in Table C-46. Based on the hydrologic simulation, the 100 year peak flow would be reduced by 76 percent at the dam site and only by 28 percent downstream of Watnong Brook, a tributary which drains about 8 square miles. At the damage center in Morristown, flows would be reduced by only 25 percent where the drainage area is 29 square miles. These flows are summarized in Table C-47. This reduction of flows would provide for only a moderate reduction in damages and the benefits would not support the costs for development of Washington Valley for flood detention.

f. Passaic Main Stem. Along the main stem, the undeveloped Myers Road Reservoir was analyzed for its flood flow reduction potential. The proposed site would be situated in portions of the Great Swamp and the Dead River wetland area and would control a drainage area of 82.0 square miles. The dam would be located on the Upper Passaic River about 1,500 feet, upstream of Myers Road near Millington, Morris County, New Jersey. Additional information on this site is shown in Table C-48.

This site had been proposed in previous Corps' reports as a multiple purpose reservoir. Hydrologic studies contained in the previous reports indicated that natural detention of floodwaters in the Great Swamp area on the Upper Passaic River, upstream of Millington, plays a small part in reducing flood flows on the Central and Lower Passaic River and a significant role in the reduction of flood flows upstream of Chatham. In order to

TABLE C-48 MYERS ROAD RESERVOIR

PHYSICAL FEATURES

	PROPOSED OPERATION
1. Drainage area (sq. mi.)	82.0
2. Spillway Pool	
Elevation (ft. msl.)	225.0
Water Surface Area (acres)	2,700
Water Supply Storage (ac-ft.)	-
Flood Detention Storage (ac-ft.)	23,000
3. Maximum Pool	
Elevation (ft. msl.)	232.4
Water Surface Area (acres)	7,500
Water Supply Storage (ac-ft.)	-
Flood Detention Storage (ac-ft.)	57,000
4. Non-Overflow Section	
Elevation (ft. msl.)	237.4
Water Surface Area (acres)	11,100
Water Supply Storage (ac-ft.)	-
Flood Detention Storage (ac-ft.)	105,000

HYDROLOGIC EFFECTS

	50 YR FLOOD EVENT			100 YR FLOOD EVENT		
LOCATION	Existing (cfs)	Improved (cfs)	Flow Reduction (%)	Existing (cfs)	Improved (cfs)	Flow Reduction (%)
MYERS ROAD						
Dam Site: 0.3 mi Upstream of Myers Rd, Warren Twp.	3008	156	95	3518	159	95
Mountain Ave., Warren Twp.	2516	1862	26	2908	2175	25
Upstream of Passaic St. Bridge, New Providence Boro.	3389	3315	2	3954	3878	2
Boundary of Chatham Boro. and Chatham Twp. (Chatham Gage)	3484	3403	2	4053	3960	2

increase the effectiveness of the available natural storage of the Great Swamp, additional detention storage would be provided by the Myers Road site. The hydrologic studies also indicated that, in addition to flood storage, sufficient conservation storage could be developed at the site for water supply purposes and other water uses.

The current hydrologic analysis examined the site only from the perspective of flood damage reduction. The hydrologic analysis revealed that most of the floodwaters in the drainage area controlled by the reservoir are already being attenuated by the Great Swamp and Dead River Wetlands. Therefore, the additional detention storage provided by the reservoir has minimal effect in reducing flood flows. At Mountain Avenue in Warren Township, the peak 100 year flow would only be reduced by 25 percent. In addition, tributaries flowing into the main stem in the area between the reservoir and Chatham offset any reduction in flood flow peaks obtained by the reservoir. As a result, the reservoir would have an insignificant effect on controlling floodwaters in the damage areas of New Providence and Chatham. Upstream of the Passaic Street Bridge, the reduction in the 100 year peak flow would only be 2 percent. The hydrologic effects of a reservoir at this site are summarized in Table C-48.

Summary. From the viewpoint of flood damage reduction, several potential reservoir sites and two existing reservoirs were evaluated hydrologically to determine their effectiveness in reducing flood flows within their subbasin. All sites had minimal beneficial effects on downstream damage areas. From the multiple purpose perspective, the Longwood Valley site may have potential feasibility for the purposes of hydropower and water supply along with flood damage reduction. Re-regulation of existing Pequannock and Wanaque River Subbasins reservoirs in a water supply/floodwater detention trade-off scheme did not produce flow reductions which are significant for a comprehensive basin-wide plan.

BUILDING BLOCK 20 - PRESERVATION OF NATURAL STORAGE AREAS

The purpose of this measure is to reduce future increases in flood damages by preventing the future development and filling of floodplain lowland areas. Currently, these areas are primarily undeveloped and store large volumes of floodwater. The loss of these areas to development would reduce the volume available for flood storage and would worsen the existing flood problems downstream. In addition, the preservation of such natural storage areas would also maintain the existing environmental characteristics of the basin by preserving wetlands, open

space, and fish and wildlife habitats. This measure is generally applicable throughout the watershed, but is of special significance within the Central Passaic Basin because of the presence of 11 major wetlands and other intermittent pockets of open space floodplain in this area. This measure does not address the existing flood problem, but rather would reduce potential future increases in flooding. Therefore, it could be implemented separately or in conjunction with other alternatives as a mechanism to maintain project integrity by preventing the loss of floodplain storage. The role of this alternative is also related to the implementation option selected, as discussed later in this section.

The initial step in the analysis was to inventory the Basin's natural storage areas and their protective status since this alternative is to be directed at natural storage areas not preserved under existing Federal, State and local law. The natural storage areas in the inventory include frequently inundated areas of the floodplain, and the wetlands of significant size contained therein, located in the Central Passaic Basin. Eight wetlands of significant size are indicated on the Passaic River Basin map shown on Figure C-30. Other significant wetlands include those along the Upper Passaic River, the Dead River and in the Great Swamp area. The acreage and protective status of the major natural storage areas of the Central Basin are shown on Table C-49. A detailed discussion of the protective status of these areas is contained in SECTION 2 - WITHOUT PROJECT CONDITIONS.

The hydrologic and hydraulic analyses of preserving natural storage areas involved predicting the increase in flows and stages if the natural storage areas were lost to development in accordance with the most probable future conditions. Eliminating natural storage areas, which attenuate flood flows, would increase both discharges and water surface elevations at downstream areas. As the natural storage is eliminated along the entire river, the adverse impacts are compounded.

For this analysis, the loss of storage areas were considered in the following areas: Passaic River from Pompton River confluence at Two Bridges upstream to the Dead River confluence, Pompton River from the mouth upstream to the Ramapo River confluence, Rockaway River from the mouth upstream to the Vail Road Bridge in Lake Hiawatha; and Whippany River from the mouth up to the Morristown border.

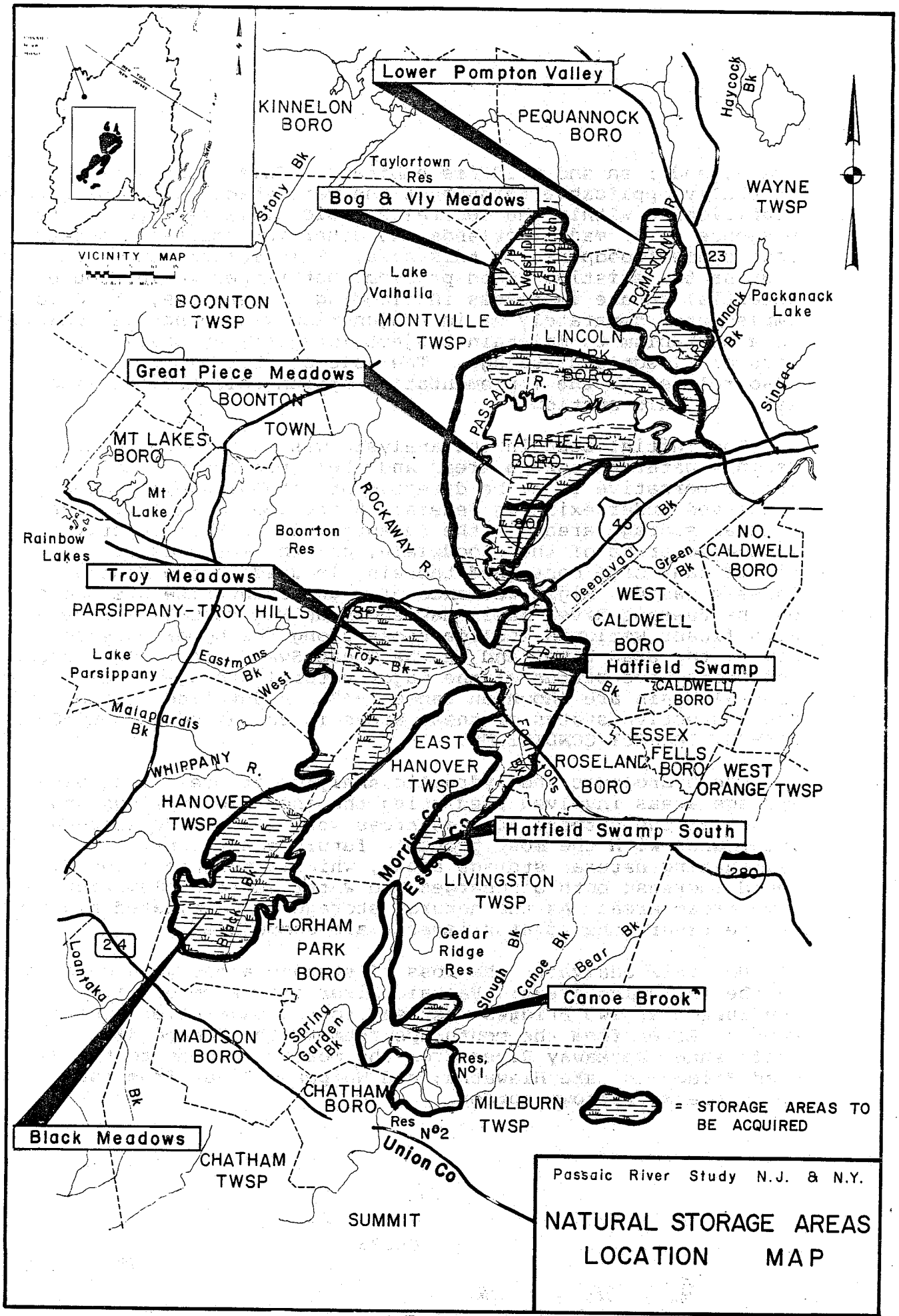

Lower Pompton Valley
Bog & Vly Meadows
Great Piece Meadows
Troy Meadows
Hatfield Swamp
Hatfield Swamp South
Canoe Brook
Black Meadows
KINNELON BORO
PEQUANNOCK BORO
WAYNE TWSP
BOONTON TWSP
MONTVILLE TWSP
LINCOLN PK BORO
FAIRFIELD BORO
BOONTON TOWN
MT LAKES BORO
NO. CALDWELL BORO
WEST CALDWELL BORO
PARSIPPANY-TROY HILLS TWSP
EAST HANOVER TWSP
ESSEX FELLS BORO
ROSELAND BORO
WEST ORANGE TWSP
HANOVER TWSP
LIVINGSTON TWSP
FLORHAM PARK BORO
MADISON BORO
CHATHAM BORO
MILLBURN TWSP
CHATHAM TWSP
SUMMIT
Lake Valhalla
Taylortown Res
Boonton Res
Lake Parsippany
Mt Lake
Rainbow Lakes
Cedar Ridge Res
Res. No 1
Res No 2
Packanack Lake
Stony Bk
Haycock Bk
Singac
Green Bk
Deepavaal
Eastmans Bk
West Troy Bk
Malapardis Bk
Whippany R.
Passaic R.
Rockaway R.
Pompton R.
Morris Co
Essex Co
Union Co
Loantaka Bk
Spring Garden Bk
Slough Bk
Canoe Bk
Bear Bk
23
24
46
80
280
VICINITY MAP
= STORAGE AREAS TO BE ACQUIRED
Passaic River Study N.J. & N.Y.
NATURAL STORAGE AREAS
LOCATION MAP

TABLE C-49 - Central Basin Natural Storage Areas
of the Passaic River Watershed 1/

Name	Acres	Acres 2/ Protected	Percent Protected
Great Piece Meadows	4125	2405	58%
Troy Meadows	2390	1120	47%
Canoe Brook	1245	885	71%
Upper Passaic River	2200	1605	73%
Hatfield Swamp	1775	1250	70%
Black Meadows	1300	40	3%
Great Swamp	8500	7500	88%
Dead River	850	180	21%
Bog & Vly Meadows	650	205	32%
Hatfield Swamp (South)	605	395	65%
Lower Pompton	845	280	33%
TOTAL	24,485	15,865	65%

1/ Storage areas are not always analogus to wetland designations because of boundary definitions and development patterns.

2/ Acreage consists of FEMA floodways, including those which have been delineated but not yet adopted, and areas expected to remain as park/and or open space.

The loss of natural storage areas to development would result in two types of impacts that were modeled. These impacts are: (1) the change in unitgraph parameters and loss rates at the natural storage areas which are eliminated would result in increases in streamflow derived from the hydrologic (HEC-1) model; and (2) the loss of natural storage would change the storage vs. discharge relationships used in the HEC-1 flood routing and reflected in the hydraulic model (HEC-2) encroachments.

Based on previous analysis in the Central Passaic Basin it was suspected that the effect of (1) above was not significant as compared to the increase that would result from (2) above, since the relative area affected (natural storage areas to be developed) was small compared to the total area considered. Therefore, impact (1) was tested through a sensitivity analysis to confirm the magnitude of its maximum effect.

In this test it was assumed that all of the wetlands in the Central Basin (including those outside the Central Basin area of interest) become commercial development sites in the computation of the revised unitgraph lag times and loss rates when determining the increased area runoff. The acreage of wetlands in the entire basin far exceeds the natural storage area of the Central Basin. Thus, if such a test for the entire basin did not produce significant increases, the impact within the Central Basin natural storage areas would clearly not be significant. This test was similar to the method used in predicting future land use runoff as described in the URBANIZATION section of this report. Basically, the land use in all areas in the Passaic Central Basin which contain wetlands were converted to commercial development in the grid cell data bank. The HEC program, HYDPAR, accesses the data bank and yields the increased ratio of imperviousness and decreased lag time for each change or adjustment in the routing of floods between any nodes. The results show that for the 100 year flood, there is only a very small increase in discharge (by the time the peak flow is in the Central Basin). With only a small increase at Little Falls, it is demonstrated that the impacts due to runoff changes in the natural storage areas are not significant compared to the increases due to potential changes in flood storage. Thus, the remaining analysis focused on the storage changes due to development.

The storage method of analysis involved first identifying the total available natural storage in the Central Basin, and then testing the potential impact of eliminating storages. In accordance with the most probable future conditions, developers are faced with two primary constraints in planning future development: (1) the lowest floor of new structures must lie at

elevations at least one foot higher than the flood hazard area design flood elevation (based on the 100 year storm plus 25% in areas delineated by NJDEP and the 100 year flood in areas where NJDEP delineations are not available); and (2) the volume of fill to be placed on an applicant's site is limited to occupying 20 percent of the total volume between the natural ground surface of the property and the level of the flood hazard design elevation. The impact of these Flood Hazard Area Regulations is to limit the amount each site can be filled and reduce the areal extent of new buildings. Based on past experience it is anticipated that developers will place the fill in a manner to maximize the area of the site at elevations above the design flood level and, therefore, suitable for building. This is accomplished by strategically placing the fill on portions of the property at the highest topographic elevations, i.e. generally the outward fringe of each site. Therefore, development is expected to occur over a number of years and would take place on the outer portions of the natural storage sites, depending on the ease of obtaining building permits and the cost of extending roads and utilities. Development in the storage areas was simulated by taking 45 percent of the distance between the floodway delineation and flood hazard fringe encroachment. The 45 percent figure was geometrically determined to be equivalent to the 20 percent fill volume that could be placed in the fringe area as part of New Jersey Flood Hazard Area Regulations (FHAR). Based on the most probable future analysis, by the year 2040 approximately 3,870 acres of Central Basin storage areas would be filled within the overall risk pool of 8,620 remaining unprotected natural storage acres. A preliminary hydraulic (HEC-2) run was then made to obtain revised storage vs. discharge relationships for the hydrologic (HEC-1) analysis. The increased discharges obtained from the resulting HEC-1 analysis, using the revised storage-discharge curves, were then input into the hydraulic model to obtain final HEC-2 water surface profiles, reflecting the projected development.

Analysis of the future without project condition shows that projected development of the Central Basin natural storage areas will have a significant impact on increasing stream discharges along the Passaic River downstream of Pine Brook. At Little Falls, development and filling of 3,870 acres of unprotected Central Basin natural storage areas would cause the 100 year flow to increase from 28,156 cfs to 33,053 cfs under 2040 conditions. This results in a 17.4% increase from existing conditions (see Table C-4 and the discussion in SECTION 2 - WITHOUT PROJECT CONDITIONS).

The next step in the analysis involved testing various degrees of preserving Central Basin natural storage. For each extent of acreage protected from development, the corresponding extent of fill which developers are allowed to place in the floodplain in accordance with the NJDEP Flood Hazard Regulations was evaluated. The resulting impact of such potential storage losses were each translated into incremental increases in stream flow, water surface elevations and future flood damages for the full range of hypothetical events. The benefits for each preservation extent are the incremental increase in future flood damages that would occur if these natural storage areas are developed and not fully available for flood storage. See SECTION 8 - OPTIMIZATION for a full discussion of this analysis.

Even though, New Jersey's FHAR would allow only 3,870 of the 8,620 developable storage acres in the Central Basin to be filled, it would not be feasible to preserve only 3,870 acres since in such a plan the remaining 4,750 acres would not be fully protected and would still be subject to development and partial filling under the 20% rule. It would also be impossible to predict the exact locations in the Central Basin where development would take place. Therefore, the optimization of the preservation element for the Passaic Central Basin considered all 8,620 acres of developable storage areas identified in the major wetlands.

Based on the results of the analysis, as discussed in Section 8, it was determined that the preservation of 5,350 acres of natural storage would maximize net benefits based on balancing reductions of future flood damages versus the cost of acquiring the natural storage areas (see SECTION 8). Figure C-30 shows the areas (dark shading) which would be protected. Of the 5,350 acres to be preserved, approximately 2,410 acres are projected to be filled under New Jersey's Flood Hazard Area Regulations and the remaining acreage is at risk for inclusion in development plans. The area proposed for preservation was formulated to insure that the most significant areas in terms of available storage are included. Table C-50 presents a summary of the Central Basin flood storage for the most probable future conditions for the years 1990 and 2040, and for 2040 conditions in which the 5,350 acres of natural storage areas are preserved. As shown on this table, the preservation of the identified 5,350 acres (which is 62% of the 8,620 acres that remain unprotected) would result in maintaining 25,800 acre-feet of 100 year flood storage, which is 82% of the storage that would otherwise be lost under 2040 conditions (31,300 acre feet). This would maintain approximately 96% of the total 100 year flood storage available under 1990 conditions. Data for the 10, 50 and 500 year events are also presented. The preservation of the flood storage associated with these 5,350 acres would result

TABLE C-50
IMPACT OF PRESERVATION OF CENTRAL
BASIN NATURAL STORAGE AREAS

CENTRAL BASIN FLOOD STORAGES (ACRE-FEET)

CONDITION	10YR	50YR	100YR	500YR
1990 WITHOUT PROJECT	66,600	113,000	136,000	203,900
2040 WITHOUT PROJECT	57,100	85,300	104,700	165,200
2040 WITH PRESERVATION OF 5,350 ACRES	65,300	109,900	130,500	195,100

PEAK DISCHARGES AT LITTLE FALLS (CFS)

CONDITION	1YR	10YR	50YR	100YR	500YR
2040 WITHOUT LOSS OF ANY NATURAL STORAGE AREAS	6,153	14,159	23,583	28,156	45,201
2040 WITH PROJECTED LOSS OF NATURAL STORAGE AREAS	6,232	15,323	27,416	33,053	51,565
2040 WITH PRESERVATION OF 5,350 ACRES	6,182	14,247	23,799	28,398	45,753

in significantly reducing future increases in flood flows in the Central Basin and Lower Valley, with the peak discharge presented for Little Falls in Table C-50 typical for the affected area. Table 34 and 38 of Supporting Documentation, Part I - Hydrology, provide a summary of the flow impacts throughout the study area. The annual benefits provided by the preservation of the 5,350 acres totals $3.7 million (October 1985 Price Levels; 1990 Base Year), resulting in an approximately 75% reduction in future increases in annual damages due to natural storage losses. See SECTION 8 - OPTIMIZATION for a full discussion of the economic analysis.

Another criteria in the decision of what lands to preserve was that areas which were contiguous to other protected areas would be a high priority. This would accomplish several purposes. First and most important, ensuring large, contiguous tracts remain undeveloped would preserve the greatest amount of storage. It would also preserve significant tracts of wildlife habitat, help protect more sensitive species, and maintain a buffer against non-point sources of pollution.

A variety of potential Federal and/or non-Federal implementation options are available which would preserve the identified 5,350 acres of unprotected storage areas. The alternatives include:

Option 1. Preservation by Federal Interest through: (a) acquisition in fee or permanent "flowage" or "storage" easements; or (b) control of wetland development through the provisions of Section 404 of the Clean Water Act (PL-92-500).

Option 2. Preservation by the non-Federal sponsor. The non-Federal mechanism for preservation could take several forms: (a) State of New Jersey's flood hazard regulations; (b) direct acquisition in fee or easement by the State; (c) local/municipal zoning; (d) creation of a State commission whose responsibility would rest in their authority to regulate development in unprotected natural storage areas; or (e) a construction moratorium or legislative action which prevents development of wetlands.

The feasibility of each of these implementation options is discussed below.

Option 1(a) - Federal Acquisition. The annual benefits and costs for the preservation of the 5,350 acres of natural flood storage, which comprise Building Block 20, presented in Table C-33 reflect the Federal acquisition of these lands. This measure would accrue benefits of $3.7 million and have annual costs of $1.4 million (October 1985 price level), based on "in fee" acquisition, resulting in a benefit-to-cost ratio of 2.6 to 1. The Federal acquisition option is considered viable and such

acquisition is within the Federal interest because the preservation of natural storage in the Passaic River Basin is economically feasible, environmentally sound, and qualifies as a nonstructural flood damage reduction measure based on guidelines in the Principles and Guidelines and the Corps Planning Guidance Notebook. Lands so acquired could be managed by the Corps, or the U.S. Fish and Wildlife Service, possibly in cooperation with the State of New Jersey. Federal acquisition in fee is considered preferable to obtaining permanent flowage easements. These easements would be so limiting in the use and/or development of the land that the cost was found to be very close to that of "in fee" acquisition. In addition, easements would not prevent changes in the environmental character of the land and could result in further loss of wetlands (though not natural storage). Also, with permanent flowage easements the lands would remain in the hands of the private owners, and management of the wetland wildlife habitats by either FWS or NJDEP would be impractical.

In recognition of the natural storage loss rate of approximately 70 acres per year under the without project condition, two implementation scenarios were examined for this option. These two scenarios consisted of "early action" as an advance part of a main stem project or in conjunction with a main stem project.

The early action scenario was determined to be more responsive to the watershed's need for preservation. However, both of these implementation scenarios involve significant Corps' report preparation and/or chain of command report processing, in addition to Congressional authorization and appropriation actions. It is estimated that an early action Federal acquisition plan could be implemented in 1990, while the timing would realistically be 1995-2000 for implementation in conjunction with a main stem project.

Option 1(b) - Section 404 Regulatory Program. The preservation of flood control storage areas under Section 404 of the Clean Water Act was found not to be possible.

Section 404 of the Clean Water Act (PL 92-500) gives jurisdiction to the Corps of Engineers to issue permits within wetlands adjacent to rivers whose flow is greater than five cubic feet per second (cfs). The Corps' regulatory program issues 404 permits for development only after the applicant receives a water quality permit from the State of New Jersey. Many times local and state permits are granted to applicants prior to Corps involvement. In addition to the individual permit determinations under the regulatory program, two preservation alternatives exist via the 404 authority. These alternatives include "advanced non-designation" and "discretionary authority."

The alternative "advanced non-designation" is a concept specified in PL 92-500, Section 404(c). This section of the Clean Water Act authorizes the Administrator of the Environmental Protection Agency, in consultation with the Secretary of the Army and after public notice and hearings, to designate areas where 404 permits cannot be granted. However, this section addresses the discharge of materials that would have an unacceptable adverse effect on municipal water supplies, fishery areas (including spawning and breeding areas), wildlife, or recreational areas, and is not applicable to adverse impacts to natural flood storage areas.

Where the flow of a stream is less than 5 cfs, and the size of the wetland is less than 1 acre, the Nationwide permitting process can be used. The final rules, which became effective on January 12, 1987, define methods by which the Division Engineer may exert discretionary authority under the Nationwide permit regulations. These methods include individual conditions on a case by case basis in which the permittee and the District agree that certain goals are to be met or the District may consult with the State 401 program where a state individual permit is required. Another method is to regionally condition the Nationwide permit. Here the Division Engineer can require that certain activities, or specific geographic areas, meet given criteria to protect the aquatic environment. Again, however, the focus of these rules is not on flood damage reduction and they are not the vehicle for permanently maintaining natural flood storage areas beyond the State's existing flood hazard regulatory program.

Option 2. The five non-Federal alternatives considered for preserving flood storage areas can be executed either prior to the implementation of a potential Corps project, or as part of the non-Federal items of local cooperation for a main stem project in order to maintain the design integrity of a Phase 1 project recommendation.

Implementation by the non-Federal sponsor prior to a Corps project was considered because: it would require a significantly shorter implementation time when compared with Federal acquisition; the responsibility for providing real estate and implementing land use controls is traditionally within the purview of local interests; and the scope of the acquisition is clearly within the current direction and means of the non-Federal sponsor.

A disadvantage to this implementation scenario is that any lands preserved by the State as a nonstructural flood damage reduction initiative would become part of the without project condition. These lands cannot be later considered as part of

the Federal project for cost-sharing purposes, unless such lands were also required for fish and wildlife mitigation, or otherwise needed for implementation. Implementation as an item of local cooperation as part of a Phase I project recommendation is not recommended, since the findings of this report demonstrate that a Federal interest exists for the preservation of natural storage areas as a nonstructural project element, rather than as an item of local responsibility. The option would only be recommended if, based on future Federal policy revisions or changed conditions, the degree of Federal interest changes, and it is found that non-Federal interests should be responsible for part or all of the preservation. Each of the non-Federal alternatives is summarized below.

Option 2(a) - State of New Jersey Flood Hazard Regulations. Currently the State's revised flood hazard regulations would act to preserve approximately 6,380 acres of storage area by the inclusion in protected floodways, and another 4,750 acres through the 20% net fill rule. However, as discussed previously, the 4,750 acres are not any discrete, identifiable lands. Until such time as lands are filled to the limits allowed by the 20% rule, these lands will be made up of portions of the areas not yet developed. These regulations, in addition to the 7,500 acres protected as part of the Great Swamp Refuge/ Lord Sterling Park complex, protect approximately 75% of the wetland storage areas in the Central Basin. Therefore, the State's regulatory program already has made a significant step towards preserving flood storage areas. The protection of additional areas by further strengthening these regulations is not a realistic option without additional legislation, which is the same as Option 2(e).

Option 2(b) - State Acquisition. With regard to the 5,350 acres in question, the non-Federal option for the acquisition of the land in fee or via permanent easement is considered to provide the most practical and certain non-Federal avenue for flood storage preservation. However, the State of New Jersey, through its Green Acres program, has traditionally allocated limited funds for land acquisition. In addition, a key question involving lands preserved by the State is whether lands purchased prior to the implementation of a potential Corps main stem project could later be included, partially or wholly, to fulfill the non-Federal requirements of the Federal project. A portion of any lands so preserved by the State may be eligible to be included in the apportionment of costs when the exact amount of non-Federal contributions for all project purposes are determined by the Chief of Engineers, depending on the final project recommendation.

Option 2(c) - Local/Municipal Zoning. 1,985 acres, or approximately 8%, of the Central Basin natural storage areas are currently protected through local zoning ordinances. However, based on a review of the zoning for the balance of the storage areas, protection of additional lands through locally initiated changes of zoning ordinances is not a likely option when considering the intense developmental pressures in the basin. In fact, given the tenuous nature of zoning restrictions, the maintenance of the existing 1,985 acres as open space areas will be a significant accomplishment. The non-Federal sponsor is encouraged to maintain these areas for preservation.

Option 2(d) - State Commission. It is considered that the enforcement of the existing regulations by NJDEP would not be improved significantly by the establishment of a commission to do the same unless accompanying legislation empowered the authority to exert greater control on local land use planning decisions within the basin. However, based on New Jersey's historical role as a state with strong home rule it is not likely that a potential Passaic River Flood Control Commission would be entitled with such unilateral decision making power.

Option 2(e) - State Moratorium/Legislation. In light of the rate at which natural storage loss is proceeding in the Passaic River Central Basin, the issue of enacting a moratorium on construction in wetlands and other flood storage areas has been raised throughout this study. Subsequent to the completion of the Draft Feasibility report, the State of New Jersey declared a moratorium on development within the State's remaining unprotected freshwater wetlands and in July 1987 enacted the Freshwater Wetlands Protection Act. Since the State regulations to enforce this law have not yet been developed, the long-term impact on future loss of natural flood storage is unknown. In view of the uncertainty of its effectiveness, Option (2e) is not recommended as part of this study as the primary mechanism for preserving natural flood storage areas. However, as the regulation of wetlands under this law evolves over the next several years, it is recommended that any resulting overlapping preservation provided by the law be used to adjust the application and extent of other recommended options.

Conclusion. Of the options described above, Federal "in fee" acquisition is considered the most prudent course of action to guarantee the preservation of the critical 5,350 acres of Central Basin natural storage. As noted above, it would be economically feasible and in the Federal interest to acquire these lands. Aside from being the most reliable method of accomplishing the primary purpose of preserving natural storage areas, it would also ensure the preservation of the wetland character of these areas (a vast majority, although not all, of the remaining natural storage areas are wetlands), and allow the possible enhancement of these areas as wildlife habitats through

the management by either the Fish and Wildlife Service (FWS) of the U.S. Department of the Interior or the Fisheries and Game Division of the New Jersey Department of Environmental Protection (NJDEP). In conjunction with the acquisition of the 5,350 acres of natural storage, the existing floodways must be maintained in these areas.

BUILDING BLOCK 21 - AQUIFER RECHARGE

As required by the Congressional guidance, the evaluation of the potential for recharging floodwaters in the buried valley aquifers of the Passaic River Basin for the primary purposes of reducing flood flows and stages in the Central Basin and Lower Valley has been completed. The alternative is presented as Building Block 21 in Figure C-17. Additional purposes considered in the study included recharge of the aquifer for water supply purposes and for maintenance of flows in the streams during periods of little precipitation. It was determined early in the study, however, that the purpose of flood flow reduction is in direct conflict with recharge for water supply because one use requires that the aquifer be drawn down to be available for flood storage while the other use requires that the aquifer storage be kept at maximum levels to make best use for water supply and maintenance of low flows. Initially, the study proceeded on the premises that all assumptions should be made liberally toward giving this measure a best chance for success for the flood control purpose. If this test was passed, then additional studies would have been necessary.

Initially, previous studies by the USGS and others were reviewed and existing data collected to develop a map defining the geographic coverage and the thickness of the aquifer which lies in the Central Basin in eastern Morris and western Essex Counties. The aquifer was also defined in terms of hydrogeologic and hydraulic parameters. Several techniques of recharge were then reviewed which included spreading, ponding, and injection. In general, these techniques are designed to augment groundwater storage in partially depleted aquifers and not necessarily for real time recharge of storm water. It was noted that turbidity is a major design, operational, and maintenance problem. The expected high turbidity in surface waters diversion of overland runoff to a recharge facility would affect the reliable performance of the recharge facility system.

In considering application of these techniques to the buried valley aquifer, it was found that potential recharge areas are located where unconsolidated deposits are saturated over their entire thickness and any significant recharge to these deposits could only be accomplished by dewatering the aquifer through increased pumping in conflict with current usage for water supply. This concept is also limited by the gross volume and

permeability of the aquifer formation in East Hanover which cannot accommodate the anticipated storm water volume even if the water table is lowered by pumping. Therefore, real time recharge in the Passaic Basin even under ideal conditions is not feasible and diversion of storm peaks would have to be accomplished through increased gross storage capacity.

From a hydrogeologic viewpoint, the most favorable area for recharge (Hanover Airport area) is not in a strategic geographic location to produce the most favorable hydrologic reduction in flood flows (the Pompton River flows). The most effective location for recharge, from a surface hydrology standpoint, of the peak flow on the Passaic River is at Little Falls. However, at this location, the geologic conditions are highly unfavorable. Moreover, where some hydrogeologic factors tend to be favorable (i.e., less than 30 feet of till over permeable deposits), other factors are not (i.e., high water table and/or insufficient thickness of permeable deposits); and where a sufficient thickness of permeable unsaturated deposits exists, the glacial till is too thick to remove. Therefore, the practicability of such a venture in any one area is not feasible.

Aside from these findings, it is also necessary to consider the potential impacts of water quality on a storm water recharge system. Water quality can impact both on the reliability of system operation and on the existing quality of the groundwater in the aquifer. High turbidity and coliform levels, likely high suspended sediment concentration, and possible high inorganic and organic contaminant levels characteristic of storm waters will necessitate pretreatment before artificial recharge. The pretreatment could include sedimentation by adding chemical flocculants, and chlorination. Additional lands for pretreatment detention basin areas will greatly increase the cost of this flood control alternative.

The buried valley aquifer has been designated as a Sole Source Aquifer in accordance with provisions established by the Safe Drinking Water Act (PL 93-523) as amended by PL 95-190 in 1977, and again in May 1980. Since one of the major purposes of this designation is to preserve water quality in certain selected and highly critical aquifers, it is extremely unlikely that the recharge of raw river water into such a system would be accepted by the several communities that sought this designation. The purposeful diversion, and its adverse water quality impacts on the buried valley aquifers, would increase the costs of local water supply treatment and could foreclose the aquifer's continued use as a potable supply.

The available information is sufficient to support the conclusion that the recharge of large volumes of storm water diverted from the Passaic River and/or from surface runoff is not a feasible approach to flood control in the study area and is no longer considered as a flood damage reduction measure in this study. For this reason, "Secondary" Plans 22, 25 and 26 in Figure C-17, which include aquifer recharge in combination with other measures, have also been eliminated from further consideration.

BUILDING BLOCK 23 - TUNNEL DIVERSIONS

HR 94-1702 mandated that a tunnel diversion plan and a system of tunnels addressing the needs of the entire Basin be investigated as part of this Phase I Study. Several tunnel routes and combinations of tunnel routes were evaluated early during the development of alternatives to determine engineering feasibility. Some of these routes were derived from previous Corps of Engineers' studies while others are modifications or new routes suggested by this office and its contractors. Finally, there are plans suggested by the public through correspondence and public meetings. The following discussion describes the formulation process by which an array of several tunnel routes was narrowed to the three basic routes which formed the basis for alternative plans. It includes a description of the tunnel routes, the technical considerations reviewed in developing the building blocks, and how these results relate back to the array of suggested tunnel routes. At the end of this section basic tunnel diversion building blocks are described. Other alternatives which include tunnel diversion building blocks are described in the next section which describes the intermediate plans.

General. The diversion of flood flows in the Passaic River through a tunnel is a concept that has been often considered in the past. Tunnel diversion alternatives were first investigated by the Corps' in its 1948 Survey Report. However, this alternative was found to be more costly than local protection works and was not considered as a viable alternative plan. In 1962, a tunnel diversion was included in the recommended plan in conjunction with major upstream reservoirs. However, divergent views by local interests and economic deficiencies in the plan caused the study findings to be revised. Tunnel plans were reviewed in the 1972 report, but were not included in the recommended plan due to high cost. Since the completion of these reports, however, advances in tunneling technology, such as Tunnel Boring Machines (TBMs) capable of efficiently boring large sized tunnels, have made tunnels feasible elements once again.

The function of a tunnel diversion plan would be to bypass floodwaters around damage centers via tunnels, either to a point downstream or outside of the Basin. Diversions may also reduce backwater stages upstream of the tunnel inlet, thus reducing flood damages upstream. The size of the diversion depends upon the hydraulic characteristics of the tunnel and the allowable bypass flow to continue downstream of the tunnel inlet in the existing channel. A constraint on the operation of these potential diversions is that nominal flows are to be maintained in the existing channel downstream and the wetlands of the Great Piece Meadows are to be preserved. In this study, tunnels were considered with diameters up to 50 feet and lengths ranging up to 20 miles. Because a tunnel diversion by itself is not capable of providing uniform protection to all of the damage centers in the Basin, tunnel building blocks must be combined with other flood damage reduction measures to provide basin-wide protection.

In the discussion that follows concerning the results of early studies, diversion alternatives were categorized by the route numbers as designated in the initial planning stage. However, in the documentation presented later in the text, the alternatives were refined in detail and assembled into single measure building blocks in accordance with the classification system presented in Figure C-17.

Development of Alternatives - Technical Considerations. During early planning studies, tunnel diversion alternatives were characterized as generalized routes with the formulation emphasis on engineering feasibility from both construction and cost standpoints. In formulating plans, however, the emphasis expanded to include other technical considerations which were important to the development of alternatives. These technical factors were the primary focus of the screening and evolution of the generalized routes into "Building Blocks." These considerations included: (1) the effects of the Basin's hydrology on inlet/outlet location decisions; (2) the impact on construction cost of siphon vs. hydraulic grade tunnel designs; and (3) the costs associated with tunnel construction techniques. The way in which each of these factors related to plan formulation is discussed below.

1. Hydrologic Considerations In Determining Inlet/Outlet Locations: Previous discussions in SECTION 4 - PLAN FORMULATION APPROACH - "Technical Basis for Plan Formulation" clearly concluded that the major causes of flooding in the Central Basin are flows from the Pompton River which inundate the lowland areas and adjacent development. While the Passaic River upstream of Two Bridges is of comparable size in drainage area to the Pompton watershed, its flows are greatly attenuated by the Great Swamp and other wetland areas along the river. This

factor greatly reduces the Passaic River contribution to both Central Basin and Lower Valley flooding. In the Lower Valley there is a first flood peak caused by Lower Valley tributary inflows and a larger second peak which results from peak flows originating in the Central Basin. This double peak phenomenon is depicted in hydrographs of the Lower Passaic River. Figures C-19 and C-31, respectively, indicate that this phenomenon extends from the upstream segments of the Lower Valley downstream to the mouth of the Passaic River.

These hydrologic conditions were considered in determining the location of potential tunnel inlets. Various inlet sites were considered for the Lower Valley and the Central Basin, including the Pompton River. The tunnel inlets, shown on Figure C-32 were selected in order that they represent, as nearly as possible, all of the locations proposed by local interests as well as those suggested by hydrologic and engineering conditions.

The following text discusses the effectiveness of the inlet locations in reducing flood stages.

Of the inlets considered, one located near Beatties Dam in Little Falls would provide the most flood protection to the Lower Valley. Because of its location at the upstream boundary of the Lower Valley, it would be effective in diverting Central Basin flows which cause the dominant second peak in the Lower Valley.

Five Central Basin inlets, four located along the Passaic River and one on the Pompton River, were evaluated to determine which locations would be most effective in terms of reducing flood stages in both the Central Basin and Lower Valley. While flood damages occur throughout the Central Basin, the major concentrations of damages in the Central Basin are along the Pompton River and the Passaic River between Beatties Dam and Two Bridges. Table C-51 compares the flood stage reductions at various locations that would result from several of the Central Basin tunnel inlets.

The Great Piece Meadows, the Three Rivers (i.e., where the Whippany, Rockaway and Passaic Rivers merge) and the Chatham tunnel inlet sites would reduce flood stages only in the vicinity of the inlets.

Inlets at the Two Bridges and Pompton sites would be more effective in reducing flood stages. These inlet locations would not only reduce stages in the Lower Valley but would also have limited effects on the Passaic River upstream of Two Bridges. The Pompton inlet, however, would also reduce stages considerably on the Pompton River. Since the major centers for flood

47 1973

K&E 12 x 20 TO THE INCH • 10 x 15 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

100 YEAR STORM
HYETOGRAPH
OVER 934 sq. miles
RAIN TOTAL = 6.02 INCHES
LOSSES = 2.01
EXCESS = 4.01

RAIN INTENSITY, inch/hour

1.0

2.0

50000

27,258 cfs.

40000

30000

20000

10000

0

DISCHARGE, (cfs.)

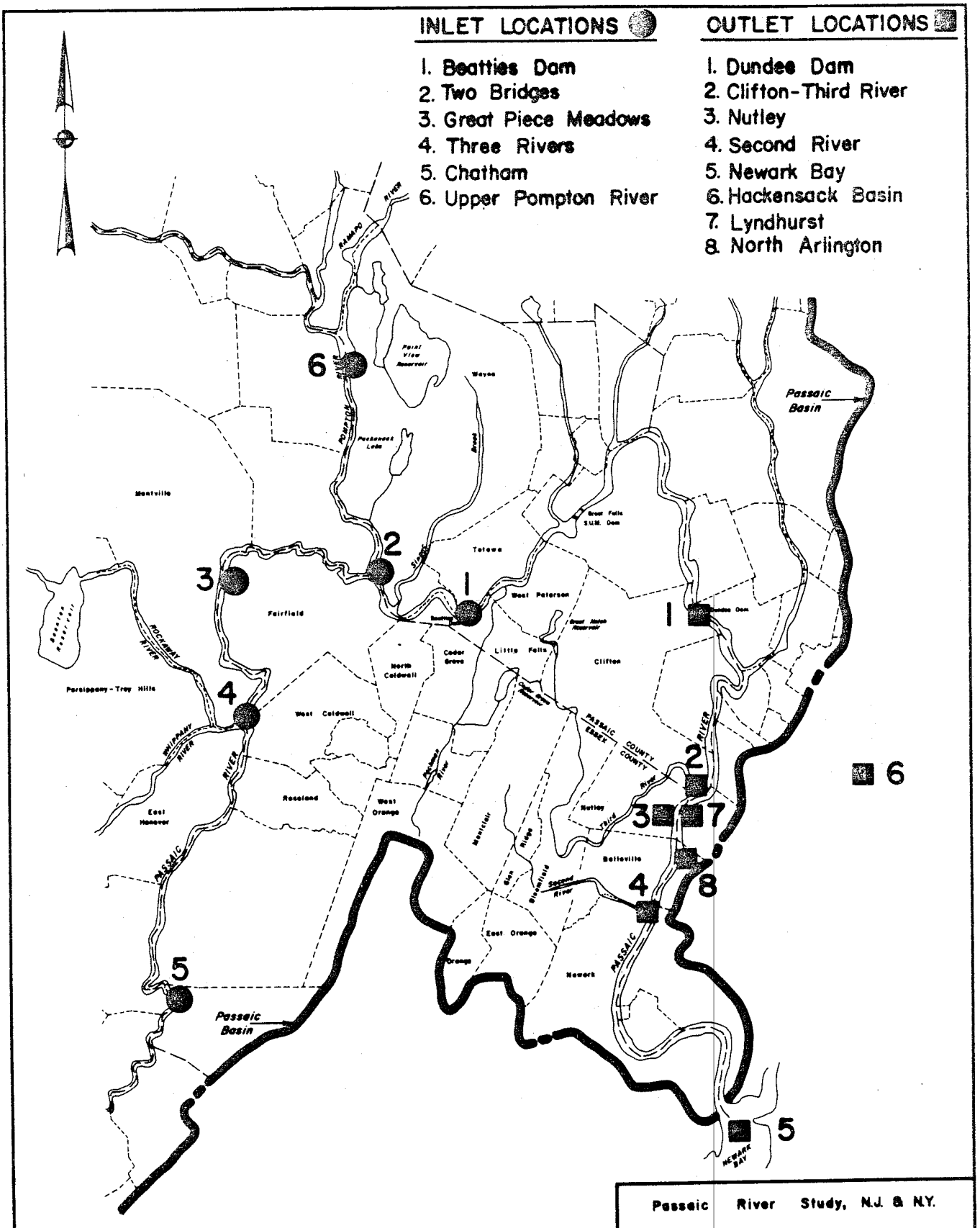
HYDROGRAPH

0 10 20 30 40 50 60 70 80 90 100 110 120

TIME, HOURS

Passaic River Study, N.J. & N.Y.
SIMULATION OF
THE 100 YEAR FLOOD
PASSAIC RIVER
AT MOUTH

FIGURE C-31



Passaic River Study, N.J. & N.Y.

POTENTIAL DIVERSION
INLET & OUTLET LOCATIONS

FIGURE C-32

TABLE C-51 COMPARISON OF FLOOD STAGE REDUCTIONS FOR VARIOUS CENTRAL BASIN TUNNEL INLETS

LOCATION	Existing Conditions	Two Bridges Inlet	Great Piece Meadow Inlet	Three Rivers Inlet	Pompton River Gage Inlet
	70 Year Flood Event Stages (Feet-NGVD)*				
Passaic River					
STA 2420+00 (Three Rivers Vicinity)	172.3	171.9	171.6	167.1	171.5
STA 1940+00 (Great Piece Meadows)	172.0	171.1	169.8	169.1	170.0
STA 1740+00 (Two Bridges)	171.3	169.6	170.2	170.0	166.0
STA 1568+65 (Beatties Dam)	166.0	161.0	164.9	164.5	162.0
Pompton River					
STA 348+40 (Upper Reaches)	186.5	186.5	186.5	186.5	167.8
STA 181+85 (Middle Reaches)	179.7	179.7	179.7	179.7	167.7
	70 Year Flood Event Discharges (cfs)				
STA 1568+65 (Beatties Dam)	22,750	5,770	18,280	17,530	8,180

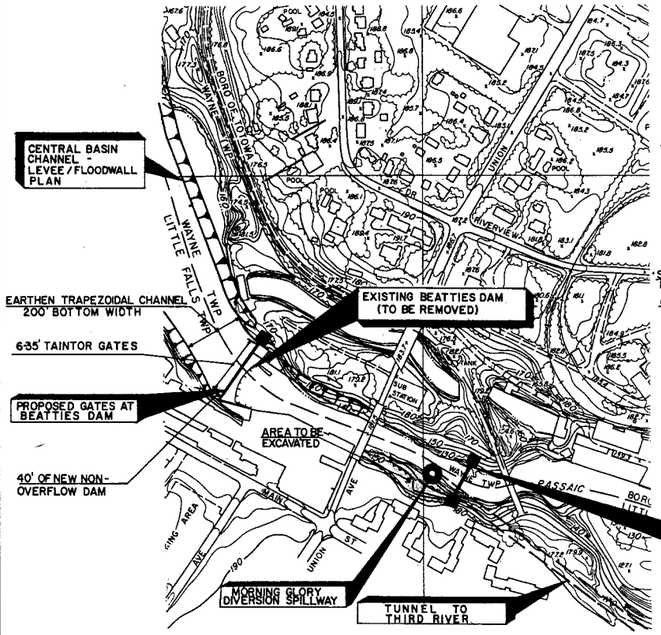
*Information is based on preliminary hydrology and hydraulics.

damages are located along the Pompton River and downstream of Two Bridges on the Passaic River, the Pompton inlet appears to be the most effective overall location in the Central Basin from the view of potential damage reduction. The Two Bridges inlet site ranked second of the Central Basin inlets in terms of effectiveness in reducing flood damages. This site, however, could have increased effectiveness if channel modifications are included in combination with tunnels. The function of such channel modification is twofold: (1) to lower flood stages in the Central Basin; and (2) to direct flood flows away from damage areas to the tunnel inlet.

With the exception of the Chatham inlet site, which was the least effective in reducing flood damages, all of the inlet sites considered were utilized in developing the initial tunnel routes. The three inlet locations (Beatties Dam, Two Bridges and Pompton River), identified as most effective in providing flood protection, were also used in the formulation of "Building Block" and intermediate plans. Criteria for selection of the particular inlet sites included access to site, availability of land, and constructibility. Specific maps of the three most effective sites are included on Figures C-33, C-34 and C-35.

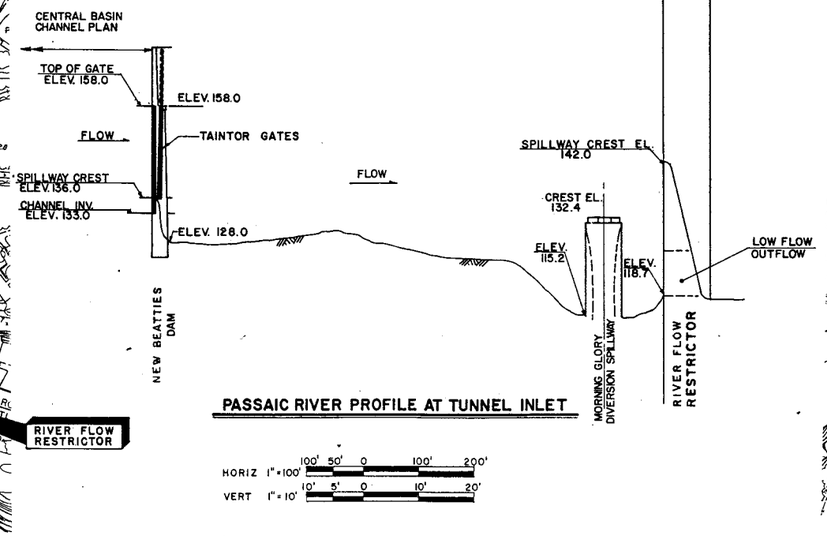
The first site is located in Little Falls near Beatties Dam (Inlet 1, Figures C-32 and C-33) on the Passaic River above Route 46 and just below the Union Street Bridge in Little Falls. The Wanaque Aqueduct crosses the stream just below the inlet area. Several hundred yards upstream of this point, the Passaic River flows over Beatties Dam and descends rapidly through the basalt gorge over minor falls and rapids. Gradients in the stream above Beatties Dam and below the Wanaque Aqueduct crossing are extremely low. The location of the proposed inlet is favorable in that the site contains a steep-walled, exposed basalt rock face, about 30 to 40 feet in height which confines the inlet within the riverbed area.

The second site is located in Wayne Township near Two Bridges where the Pompton River joins the Passaic River about 2 miles upstream of Beatties Dam (Inlet 2, Figures C-32 and C-35). The inlet would lie on the east bank of the Passaic River adjacent to Fairfield Road about 1500 feet downstream of Two Bridges and 500 feet upstream of Interstate 80. To utilize this site, a bridge for Fairfield Road would be built over the inlet structure with raised approaches. The surrounding area is lightly developed for residential use but mostly consists of undeveloped low-lying wetlands.



INLET LOCATION

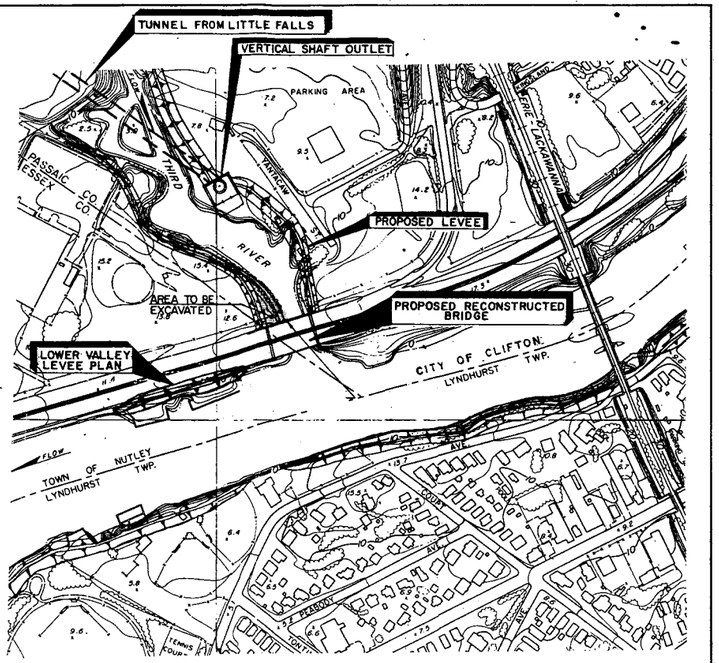
200' 100' 0 200' 400'



PASSAIC RIVER PROFILE AT TUNNEL INLET

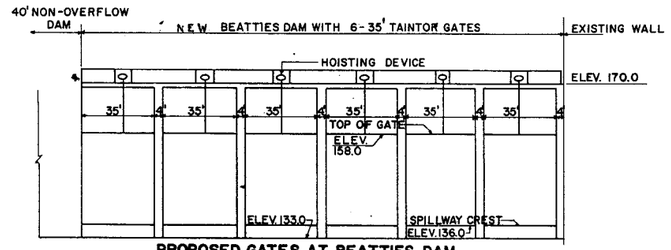
HORIZ 1"=100' 100' 50' 0 100' 200'

VERT 1"=10' 10' 5' 0 10' 20'



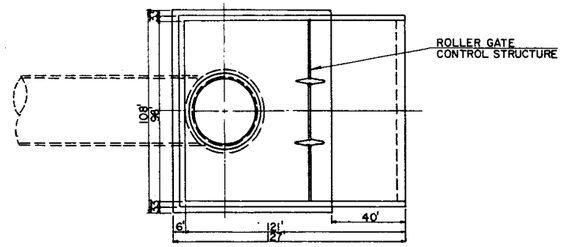
OUTLET LOCATION

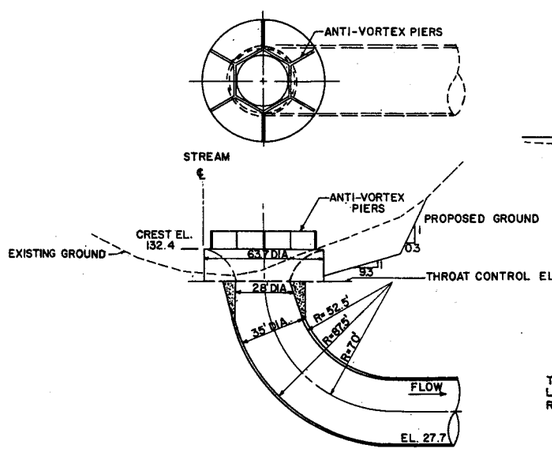
200' 100' 0 200' 400'



PROPOSED GATES AT BEATTIES DAM

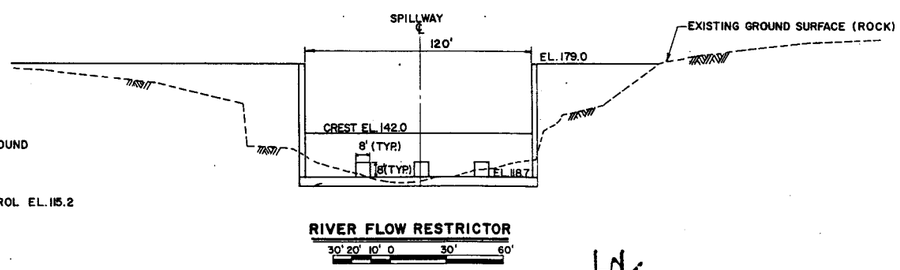
NOT TO SCALE





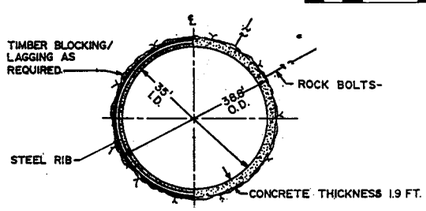
MORNING GLORY SPILLWAY

30' 20' 10' 0 30' 60'



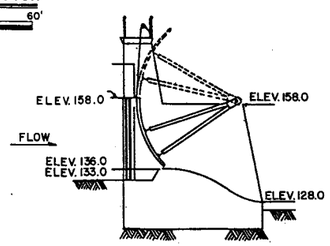
RIVER FLOW RESTRICTOR

30' 20' 10' 0 30' 60'



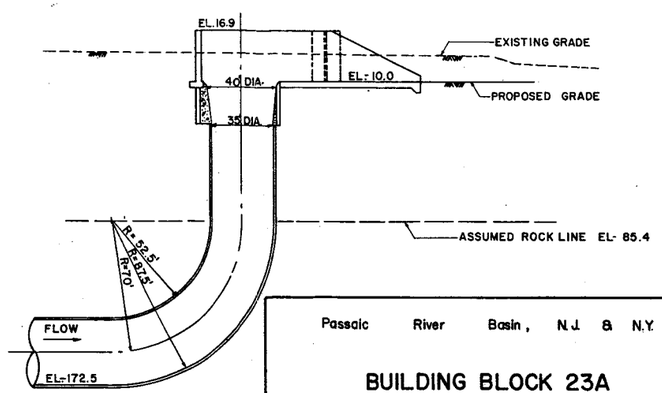
CIRCULAR TUNNEL SECTION

NOT TO SCALE



TAINTOR GATE SECTION

NOT TO SCALE



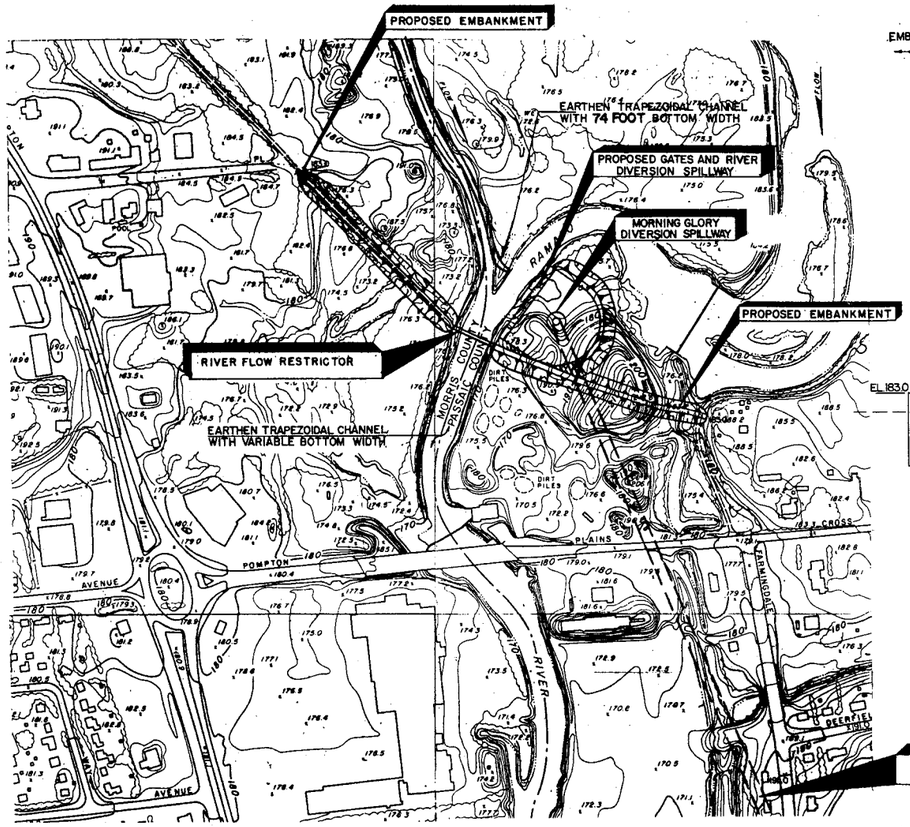
VERTICAL SHAFT OUTLET

30' 20' 10' 0 30' 60'

Passaic River Basin, N.J. & N.Y.

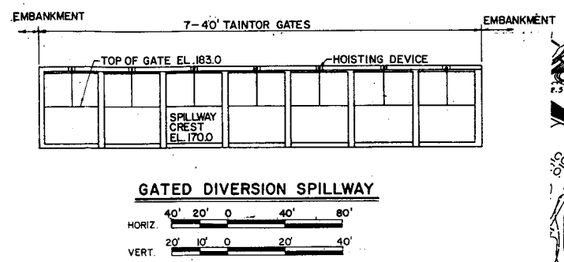
BUILDING BLOCK 23A 35 FOOT LITTLE FALLS TO THIRD RIVER TUNNEL INLET, OUTLET SKETCHES

FIGURE C-33



INLET LOCATION

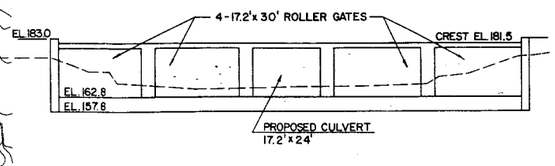
200' 100' 0 200' 400'



GATED DIVERSION SPILLWAY

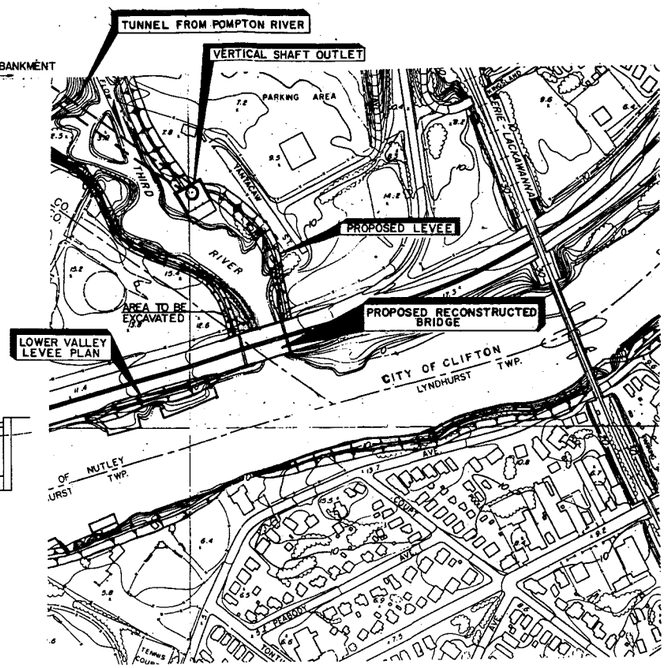
HORIZ. 40' 20' 0 40' 80'

VERT. 20' 10' 0 20' 40'



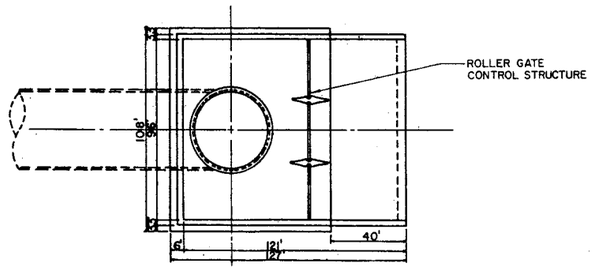
RIVER FLOW RESTRICTOR

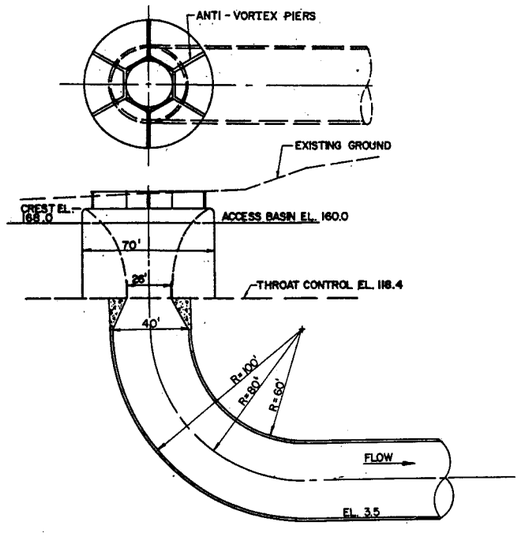
20' 10' 0' 20' 40'



OUTLET LOCATION

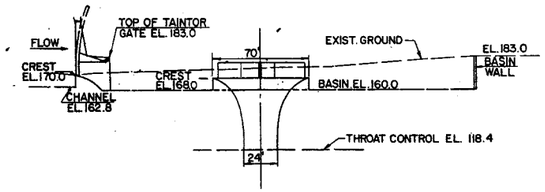
200' 100' 0' 200' 400'





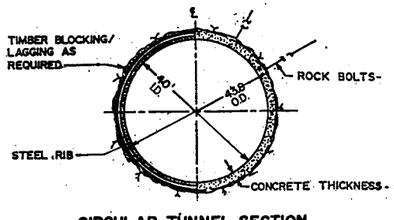
MORNING GLORY SPILLWAY

30' 20' 10' 0' 30' 60'



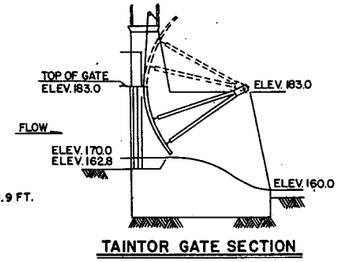
DIVERSION INLET SECTION VIEW

40' 20' 0 40' 80'



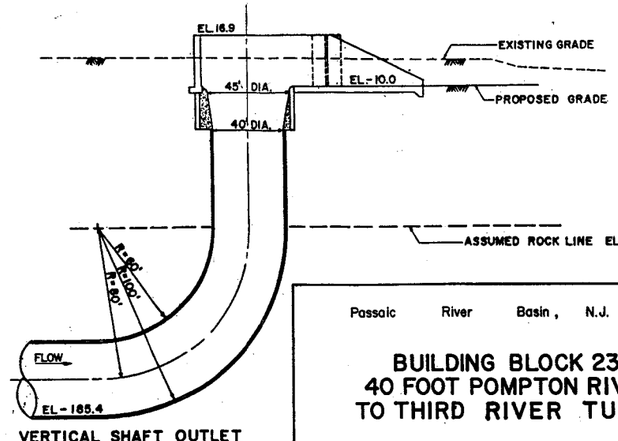
CIRCULAR TUNNEL SECTION

NOT TO SCALE



TAINTOR GATE SECTION

NOT TO SCALE



VERTICAL SHAFT OUTLET

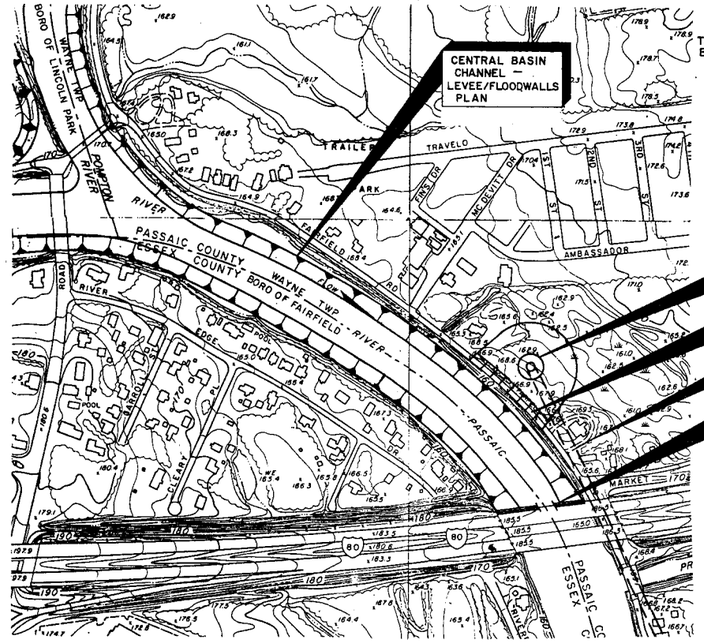
30' 20' 10' 0 30' 60'

Passaic River Basin, N.J. & N.Y.

BUILDING BLOCK 23C
40 FOOT POMPTON RIVER
TO THIRD RIVER TUNNEL

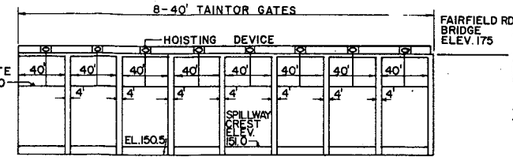
INLET & OUTLET SKETCHES

FIGURE C-34



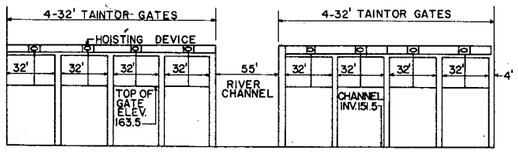
INLET LOCATION

200' 100' 0' 200' 400'



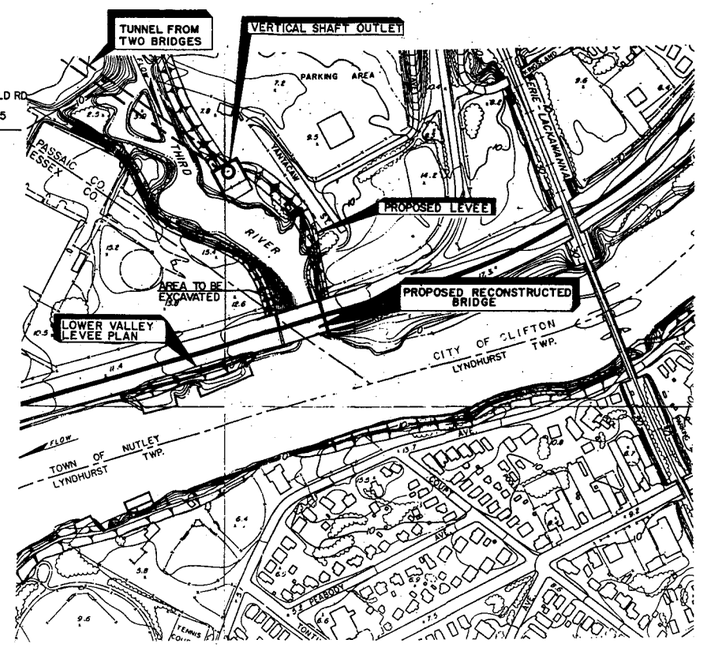
GATED DIVERSION SPILLWAY

NOT TO SCALE



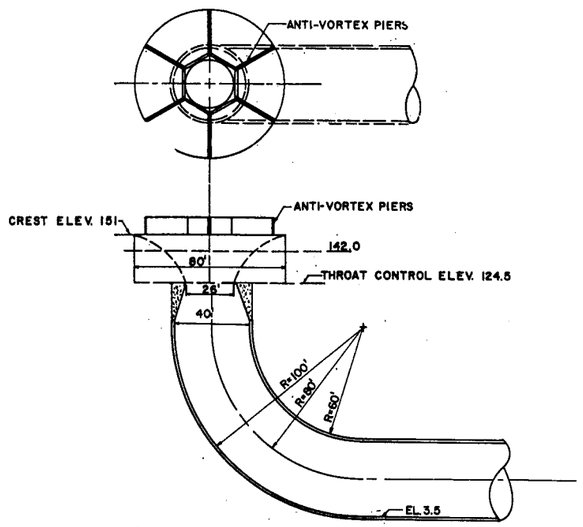
RIVER FLOW RESTRICTOR

NOT TO SCALE



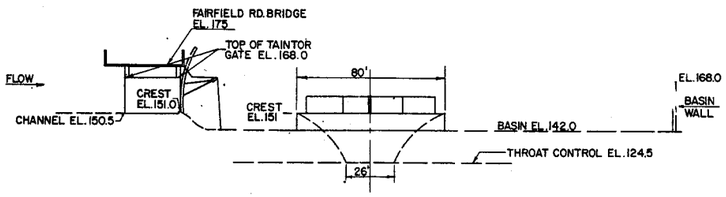
OUTLET LOCATION

200' 100' 0' 200' 400'



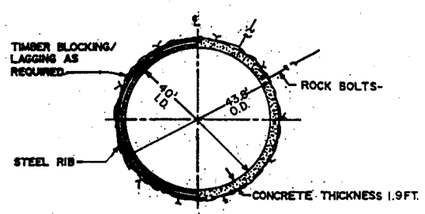
MORNING GLORY SPILLWAY

30' 20' 10' 0 30' 60'



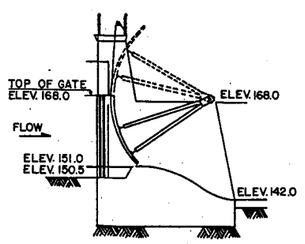
DIVERSION INLET SECTION VIEW

30' 20' 10' 0 30' 60'



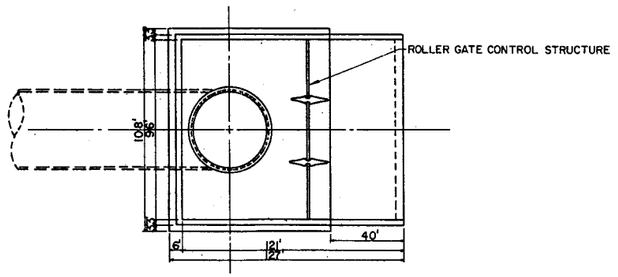
CIRCULAR TUNNEL SECTION

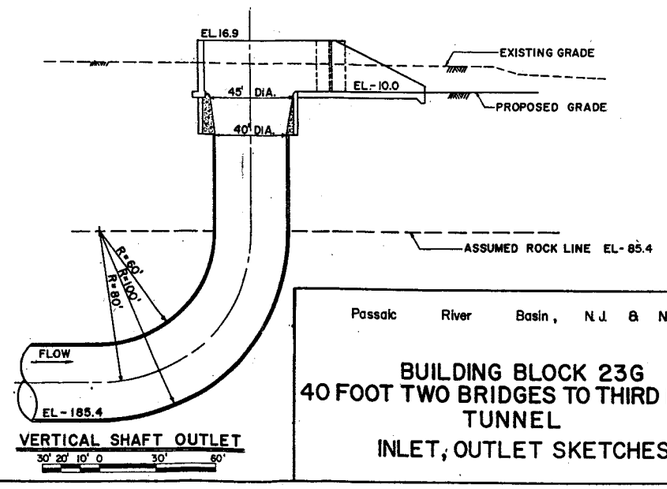
NOT TO SCALE



TAINTOR GATE SECTION

NOT TO SCALE





VERTICAL SHAFT OUTLET

30' 20' 10' 0 30' 60'

Passaic River Basin, N.J. & N.Y.

BUILDING BLOCK 23G
40 FOOT TWO BRIDGES TO THIRD RIVER TUNNEL
INLET, OUTLET SKETCHES

FIGURE C-35

278

The Pompton River inlet site is located in Wayne Township at the confluence where the Ramapo and Pequannock Rivers join to become the Pompton River (Inlet 6, Figures C-32 and C-34). This site is about 1000 feet upstream of Pompton Plains Cross Road and the Passaic Valley Water Commission water supply intake pumping station. The site lands are currently used as a sand and gravel quarry. Surrounding lands are undeveloped floodplain or agricultural lands.

Eight outlet locations, seven in the Lower Valley and one in the Hackensack Basin, have been evaluated, Figure C-32. The seven Lower Valley sites are located downstream of Dundee Dam. In this 17 mile reach, the Passaic River is a tidal estuary. Extreme high tides, such as those induced by northeaster type storms and hurricanes, influence flood stages upstream to Dundee Dam. The channel capacity for containing fluvial flow increases as the river flows downstream from Dundee Dam. At the Second River in Newark and Belleville, all fluvial flows up to the SPF are contained at non-damaging flood stages. However, the influence of tidal and fluvial flooding overlaps to a significant degree from the Second River upstream for a distance of about 8 miles to the Saddle River in Garfield.

Locating the tunnel outlet downstream of the point where river stages are significantly influenced by fluvial flows would reduce flood stages downstream of Dundee Dam, minimizing local protection required in that reach. It would also allow the discharge of the tunnel flows into the river with a minimal raising of river stages at the outlet locations because the capacity of the river channel increases towards the mouth where the required channel depths and widths are maintained for navigation purposes. The further downstream the outlet is located, however, the longer and, therefore, more costly the tunnel.

An analysis was made to locate an outlet that would result in a lower tunnel cost but still minimize fluvial flood protection works. Based upon this analysis, it appears that the best location in the Lower Valley for the tunnel outlet is somewhere in the reach between the Second (mile 8) and Third Rivers (mile 11). Within this area the channel capacity is adequate to receive the discharge flows from the tunnel with the addition of local protection works.

Outlet sites on both the east and the west banks of the Passaic River were considered. Specific sites reviewed in this reach included two sites on the Passaic River's east bank, and two on its west bank. On the east bank of the Passaic River, the alternatives included a site in Gallager Memorial Park in Lyndhurst (Outlet 7) and in Riverside County Park in North

Arlington (Outlet 8). These potential sites are primarily in parks and are adjacent to residential areas. In addition, the topography is relatively flat and any outlet works would also require channel work and walls. These sites would also increase tunnel lengths and require an additional river crossing.

The west bank sites were the original Route 1 tunnel outlet sites near River Road and Grant Avenue in Nutley (Outlet 3) and an area near the mouth of the Third River (Outlet 2). On the west bank, Route 21 parallels the River throughout this reach and any outlet location must minimize the disturbance to this major highway. The original Route 1 tunnel outlet location would place the outlet in a residential area just west of Route 21. A new bridge structure and channel would be needed to allow outlet discharges to pass under Route 21.

The area near the Third River confluence with the Passaic River is in a wide portion of the Third River and in a well defined valley of the stream. Flows exiting the tunnel could be directed to the Passaic River through the Route 21 bridge. Although the existing bridge is inadequate for tunnel discharges, it is the largest bridge under Route 21 in the area and it could be enlarged to accommodate design flows. The outlet site is well away from residential development. The potential site is currently used as an equipment and materials yard for a construction company. The PVSC Yantacaw pumping station is located downstream of the site. Because this site is the furthest north in the favored river reach, it would also provide for the shortest tunnel length to the proposed inlets. Therefore, this site was used in the evaluation of all "Building Block" and intermediate plan analyses. Site maps are shown on tunnel plan maps included later in this report.

2. Siphon vs Hydraulic Grade Tunnel. The tunnel plans recommended in previous reports were developed on the basis that they would flow along the hydraulic grade line as shown in Figure C-36. These plans required several thousand linear feet of cut-and-cover construction and stilling basin structures. Cut-and-cover construction would be necessary because the topography of lands and overlying thickness of bedrock is not great enough along the entire route to allow underground tunneling. Generally, the minimum allowable cover of bedrock for underground construction is one tunnel diameter over the crown of the tunnel. Cut-and-cover construction would require the taking of properties in fee and severely disrupt the neighborhoods through which the tunnel passes, both during construction and in the long term because of the removal of residential or commercial structures. All tunnel routes

considered during the initial planning studies, with the exception of the Spook Rock route, pass under highly urbanized areas for a good portion of their length. Therefore, cut-and-cover construction would be very costly and unacceptable to the communities involved.

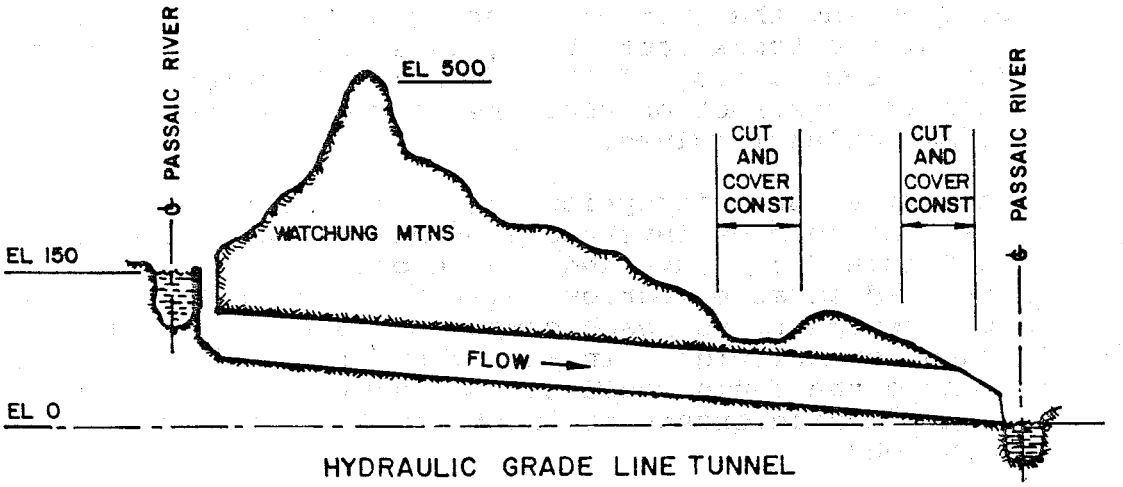
To minimize this disruption, alternatives to the grade tunnels in the form of inverted siphons were considered. As shown in Figure C-36 (inverted siphon profile), the tunnel would be constructed at an elevation lower than its outlet structure, to a depth necessary to reach competent rock, allowing underground construction. In this situation, those occupants located above the route would not be physically aware of the tunnel construction except at inlet, outlet, and construction shaft locations.

The siphon alignment lies deeper in the bedrock, and would, therefore have lower costs due to greatly reduced improved subsurface conditions, elimination of cut-and-cover type construction and the accompanying real estate takings when compared to the grade alignment.

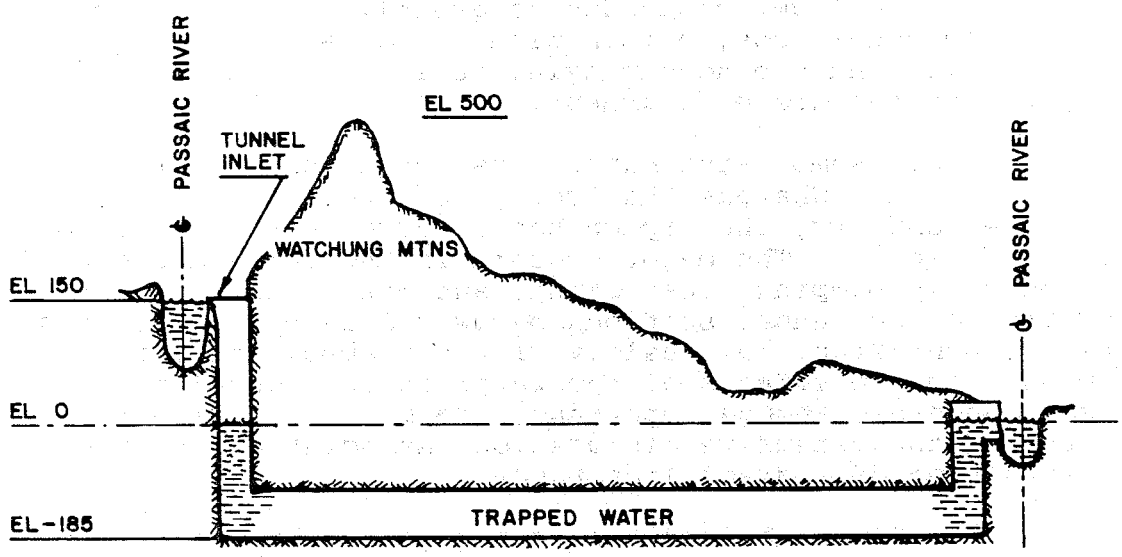
There are some maintenance considerations with the inverted siphon tunnel. Whereas the hydraulic grade line tunnel is above sea level and dry, the siphon has a large section that would be below sea level. The major concern is the costs associated with periodically pumping, inspecting, and making any necessary repairs to the tunnel sections below sea level. Other concerns are sedimentation, the quality of the trapped water in the siphon, and the effects of the water on the tunnel lining. These concerns, though important, are minor relative to the costs and the extensive dislocations associated with the construction of a grade line tunnel.

Table C-52 summarizes the advantages and disadvantages of these tunnels in general terms. While the summary highlights several negative features of the hydraulic grade line tunnel, the increased construction costs and the severe disruption of a community which receives little benefit from the plan would be a severe drawback in terms of the plan's acceptability. For these reasons, the alternative plans developed utilize the siphon configuration.

3. Construction Techniques and Considerations. The state of the art in tunneling has advanced rapidly in recent years with the development of Tunnel Boring Machines (TBM). This has resulted in lowered construction costs. Presently the upper size limit on available TBM's is about 37 feet in diameter. However, a 45-foot limit is forecast by engineers and manufacturers in the near future (5-10 years). A tunnel bore this size would allow a finished tunnel diameter of 40 feet



HYDRAULIC GRADE LINE TUNNEL



INVERTED SIPHON TUNNEL

Passaic River Study N.J. & N.Y.

PROFILES OF
HYDRAULIC GRADE LINE
AND
INVERTED SIPHON TUNNELS

TABLE C-52 INVERTED SIPHON VS HYDRAULIC GRADE TUNNEL

INVERTED SIPHON TUNNEL

ADVANTAGES

- o No construction is apparent along entire length of tunnel except at inlet, outlet and work shafts.
- o Tunnel outlet structure is relatively small compared to that required for a grade tunnel.

DISADVANTAGES

- o Approximately 18,000 feet of tunnel length is below sea level and would be filled with water at all times. This may increase maintenance requirements for tunnel lining.
- o Maintenance and inspection of submerged section would require periodic pumping out of trapped water (at least once in 10 years).

HYDRAULIC GRADE TUNNEL

ADVANTAGES

- o Tunnel is above sea level and is dry along entire length. Maintenance and inspection is easily accomplished.
- o Tunnel construction can be done from the portal without a shaft and ease the handling of excavated materials.
- o Slightly shorter construction period because open cut and cover can be constructed simultaneously with the underground tunnel construction.

DISADVANTAGES

- o Approximately 4700 feet of the tunnel length most be constructed by cut-and-cover method.
- o Requires costly aquisition of businesses and residences along 4,700 length of tunnel.
- o Blasting in this exposed section will be controlled and will be permitted only in the daytime due to urban nature of area.
- o Heavy machinery operation in the exposed section will be allowed only during daytime due to urban nature of area.
- o Severe disruption to businesses and residents along open excavation during 15 month construction period of the exposed section.
- o Large open stilling basin structure needed about 500 feet in length at outlet of tunnel to reduce horizontal momentum of tunnel discharge.
- o Construction costs of open cut are greater per linear foot than underground construction.

including a concrete lining. Subsurface data gathered to date indicates that conditions are suitable for the use of a TBM. It was also determined that conventional drill and shoot tunnel construction techniques would cost from 20 to 50 percent more than TBM methods. (Therefore, all tunnels carried forward have a circular diameter of 40 feet or less and, use a TBM as the method of construction). Cost estimates were developed on this basis. Other technological advances are occurring in the form of hydraulic drills, shotcreting techniques, muck handling, and methods for the construction of concrete linings, including segmented precast concrete tunnel linings. Only methods tested through actual field experience in large tunnel construction were used in the cost estimates.

The cost of basin-wide plans utilizing tunnel diversion "Building Blocks" is largely determined by the cost of the tunnel component. The percentage of cost attributed to the tunnel component ranges from a low of 30% for plans with a Little Falls inlet to a high of 75% for plans with a Pompton River inlet. The cost of these tunnels basically increases in proportion to length. Tunnel costs also increase an additional three percent for each one foot increase in diameter in the plans being considered. The tunnel's diameter is also related to its length. Longer tunnel routes will have increased hydraulic losses and reduced carrying capacities. To divert the same amount of water will then require a larger diameter tunnel for the longer tunnels. In addition, the longer a tunnel is, the longer it takes to construct, which adds to costs through increased interest during construction. This impact, however, can be minimized by utilizing more than one machine.

The geology of the area is most important because it defines the possible construction methods and gives an indication of costs. Important parameters include: the type, depth and condition of bedrock groundwater conditions; condition of fault and contact zones, which can pose problems in construction; and the nature of any soft ground conditions along the tunnel route.

Generally, the alignment of each of the tunnel routes requires passage through two distinctly different rock conditions. Each passes through basalt (the Watchung Mountains) and though the interbedded sandstones and shales. In addition, some routes pass through areas where the top of bedrock is below the crown of a hydraulic grade tunnel or is very fractured through the depth of such a tunnel. Construction in those areas would rely on cut-and-cover methods. However, by constructing the tunnel deeper, as an inverted siphon, these problem areas can be avoided as discussed previously. Furthermore, by aligning routes to minimize the length of tunneling through basalt and maximizing the length through slate and sandstone would also offer significant cost reductions, since basalt is harder and has a higher unit excavation cost.

In view of these relationships between length, diameter, construction time, alignment and costs, the routes utilized in the building block and intermediate plans are essentially straight line routes unless other considerations require modification to this approach. If so, they are noted in the plan description.

Screening of Tunnel Routes. The complete range of tunnel routes considered during the initial planning studies, and the areas protected by each route, are detailed in Table C-53. This section summarizes the integration of hydrology, technical considerations, construction methods, costs, and inlet and outlet locations resulting from previous discussions on these subjects. This was the basis for narrowing the list of alternative tunnel routes to three which are defined primarily by inlet and outlet locations. These routes are the Little Falls to Third River (Route 1a), the Pompton River to Third River (Route 4a), and the Two Bridges to Third River (Route 8a) Tunnel Routes. These routes were developed into the "Building Blocks," as described in the next section, and then combined with other measures to form plans. The following discussion summarizes the screening of tunnel routes. Table C-54 is a brief summary of each tunnel route and its disposition.

Routes 1 and 1a (Figure C-37) were developed to represent a Little Falls diversion to the Passaic River in the vicinity of the Third River in Nutley and Clifton, New Jersey. Route 1 was proposed in reports by this office in 1948 and in 1962. It was originally proposed as a grade tunnel which would be located near the surface in Nutley and would require cut-and-cover construction. Route 1 had the largest amount of geological investigative work performed as part of the Corps' 1962 Passaic River Study. That work indicated that construction of the Route 1 tunnel was both topographically and geologically feasible. The rock is of sufficiently favorable character and an adequate cover of firm bedrock is available over the crown of a hydraulic grade tunnel along most of the route, the only exceptions being the Nutley Memorial Park Valley and outlet areas. Under today's conditions this construction would disrupt an almost mile long strip of highly urbanized land. This route, as discussed earlier, was also analyzed utilizing a siphon. Construction of a siphon is less costly and less disruptive, since it requires no cut-and-cover excavation. The required tunnel length was reduced by straightening the alignment of the route, since with a siphon it was no longer necessary to develop an alignment that minimizes surface disruption. The outlet was moved to a more suitable site at the mouth of the Third River (Route 1a). This resulted in reducing the overall route length by 4.2 percent from 38,000 to 36,400 feet. Route 1a is one of the three routes utilized in the subsequent development of tunnel "Building Blocks."

TABLE C-53 DIVERSION TUNNEL ROUTES

	Tunnel Route	Route Description	Length	Diameter	Remarks
1	Little Falls to Nutley	From Little Falls, above Beatties Dam, southeast to a point southwest of Cedar Grove Reservoir and thence eastward to Nutley and the Passaic River near the Passaic County boundary.			Reduces flood damages in highly urbanized area downstream from Little Falls to Dundee Dam at head of tide on Passaic. Route studied extensively in 1948 and 1962 Passaic River survey reports.
	Gravity		36,900'	37'	
	Siphon		38,000'	35'	
1a	Little Falls to Third River	From Little Falls, above Beatties Dam, straight to outlet location at Third River.	36,400'	32'-40'	This route protects the same river reaches as Route 1.
2	Little Falls to Second River	This route follows Route 1 to a point below Cedar Grove reservoir and then proceeds south-easterly to the Second River at the Belleville-Newark border and then along the Second River to the Passaic River.			This route protects the same river reach as Rt. 1 but follows a different route to take advantage of public land for purposes of construction in the probable cut & cover areas near the Passaic River and use of Second River channel as a right-of-way for outlet structure.
	Gravity		45,100'	37'	
	Siphon		44,700'	35'	
3	Little Falls to Below Dundee Dam	Intake would be located above Beatties Dam as in Tunnel Rt. 1 & 2 and follow a straight-line route to a point downstream of Dundee Dam in Clifton	30,000'	35'-45'	This tunnel discharges into the upper end of the tidal reach of the Passaic. This plan reduces flood damages between Little Falls and Dundee Dam as in Rt. 1 & 2.
4	Pompton River to Little Falls to Nutley	This route would begin below the confluence of the Pequannock and Ramapo Rivers or the beginning of the Pompton River in Wayne and go eastward toward Packanack Mountain, then south along a straight route to Little Falls upstream of Beatties Dam. It would then follow Route 1.	72,000'	40'-50'	The flood flows diverted from the Pompton River would provide flood protection to Wayne, Lincoln Park and Pequannock. These flows would be conveyed to Little Falls where connection would be made to a Route 1 tunnel.
4a	Pompton River to Little Falls to Third River	This route would begin below the confluence of the Pequannock and Ramapo Rivers or the beginning of the Pompton River in Wayne and proceed directly to Beatties Dam. It would then follow Route 1a to the Third River outlet.	70,800'	35'-40'	This route protects the same river reach as Route 4.

TABLE C-53 (CONT.)

Tunnel Route	Route Description	Length	Diameter	Remarks
5 Tri-County Plan	This plan consists of a main tunnel and spur. The main tunnel would follow a route beginning at a point on the Passaic River at the boundary of Fairfield and North Caldwell south to the Second River, as described in the Little Falls to Second River route. The spur will begin in Hatfield Swamp in the vicinity of the intersection of the Whippany and Passaic River and then proceed via the shortest route to the main tunnel. Includes an independent segment from Rockaway River below Boonton Res. to Passaic River through Hook Mt.	73,000'	35'-45'	Protection will be afforded to the Central Basin and Lower Valley from Hatfield Swamp to Dundee Dam along the Passaic river. This plan was proposed by local interests.
6 Three Rivers Plan	Intake would be located on the Passaic River near Swinefield Bridge then follow Interstate Route 280 to Newark and the Passaic River.	59,000'	35'-45'	Protection would be provided to the meadows areas along the Passaic in the Central Basin. Compared to previous routes there would be less protection downstream from Two Bridges to Dundee Dam because this plan would not affect Pompton River flows.

TABLE C-53 (CONT.)

Tunnel Route	Route Description	Length	Diameter	Remarks
7 Little Falls to Newark Bay	This route would follow Route 2, but instead of the outlet discharging into the Second River, the tunnel would be extended in a straight line into Newark Bay.	72,600'		This route would eliminate the need for levees and floodwalls to protect reaches downstream of outlets for Routes 1 or 2 from flooding form tunnel discharge. This would only be hydraulically feasible in combination with a tidal barrier.
8 Central Basin to Nutley	This route would have its inlet in one of three locations. a. Junction of Rockaway, Whippany and Passaic Rivers b. Great Piece Meadows			These routes would protect: 1. Upper part of Central Basin 2. Two Bridges to Beatties and Lower Valley.
8a Two Bridges to Third River	This route follows a straight line to a point near Cedar Grove Reservoir then follows a straight line (same as Route 1a) to Third River.	46,100'	40'	This route reduces flood stages in the Central Basin and Lower Valley.
9 Spook Rock	The intake is located upstream of Suffern. The tunnel follows the right-of-way of the New York State Thruway to Nyack where it discharges the water into the Hudson River.	75,000'	30'-35'	This tunnel would divert over 70% of the Ramapo River drainage area through intakes on the Ramapo upstream of Suffern and the Mahwah River. This reduction in flows would affect the damage centers at Mahwah, Suffern, Oakland and the Pompton River area. Effects further downstream would minimal.

TABLE C-53 (CONT.)

Tunnel Route	Route Description	Length	Diameter	Remarks
10 Little Falls to Nutley via Public Rights of Way	This route has the same inlet and outlet locations as Route 1a but the alignment follows existing highway and RR rights of way.	43,000'	35'-45'	This route protects the same river reach as Route 1.
11 Pompton River to Nutley via Public Right of Way	This route has the same inlet and outlet location as Route 4 but follows existing highway and RR Rights of Way.	78,500'	35'-45'	This route protects the same river reach as Route 4.

TABLE C-54 - SCREENING OF TUNNEL ROUTES

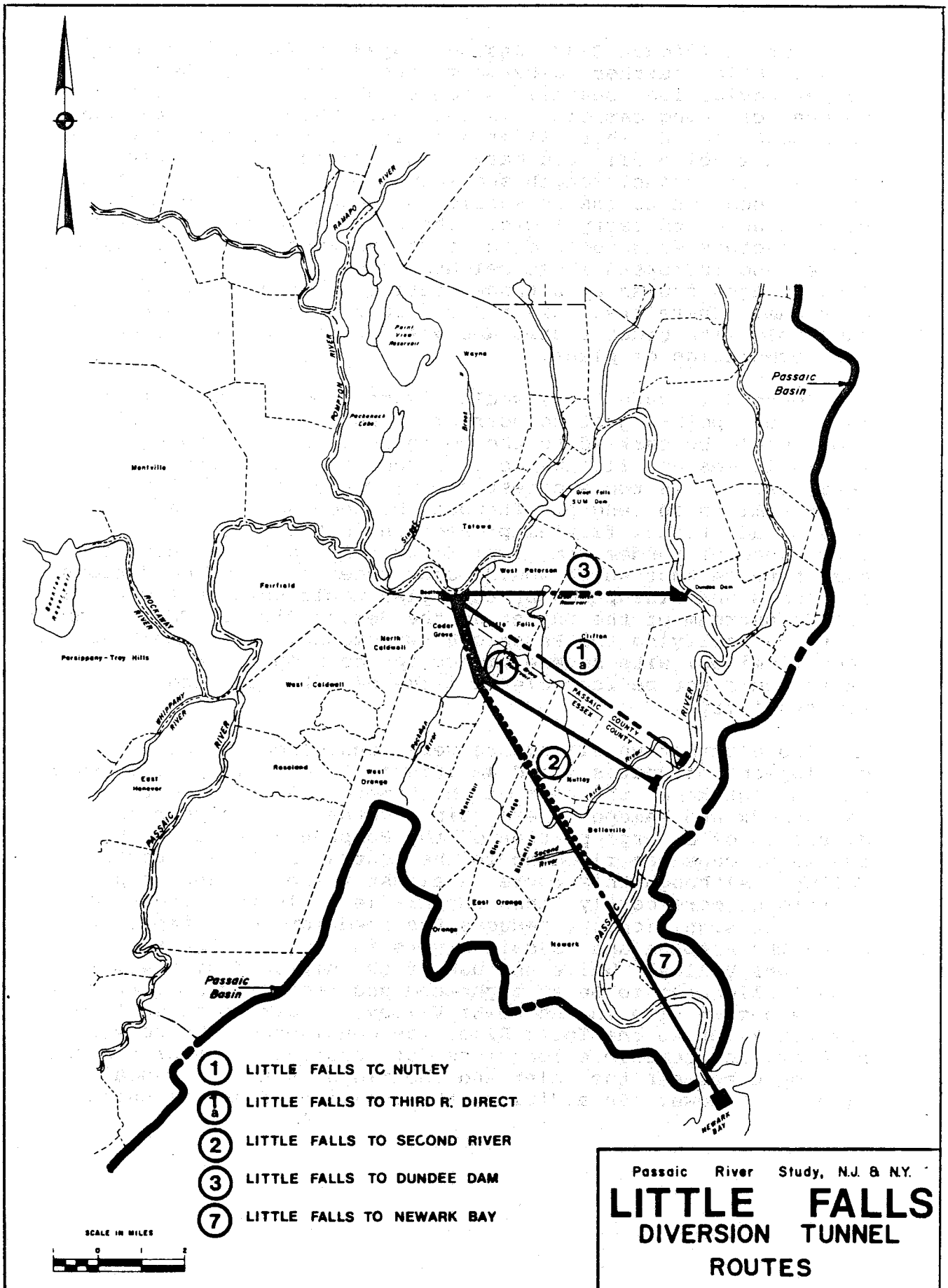
TUNNEL ROUTE (1)		PURPOSES OF TUNNEL ROUTE	REMARKS ABOUT SCREENING
1	Little Falls to Nutley	Recommended plan in 1962 COE Report	Third River outlet location is preferable (Route 1a) and straight line route is lower in cost (Route 1a.).
1a	Little Falls to Third River	Route developed for Third River outlet	Included in several basin-wide plans
2	Little Falls to Second River	Discharges flows into Lower Passaic where there is very large channel capacity.	Other plans more effective and more economical in producing similar flood damage reduction (Route 1a).
3	Little Falls to below Dundee Dam	Shortest route from Little Falls to Passaic River estuary.	Would require extensive levee floodwall protection downstream of Dundee Dam to protect against induced damages from the tunnel outlet discharge. Route 1a is preferable.
4	Pompton River to Little Falls to Nutley	Diverts Pompton upstream of all major damage reaches. Incorporates Route 1.	Third River outlet location is preferable (Route 4a). As a deep siphon, this route can be straightened and therefore Route 4a is preferable.
4a	Pompton River to Little Falls to to Third River	Incorporates Third River outlet into Route 4 and provides option for second inlet at Little Falls.	Included in several basin-wide plans.
5	Tri-County Plan	Recommended by engineers from Morris, Essex, and Passaic Counties.	Some tunnel inlets not favorably located for reducing flood stages. The several tunnel lengths are not cost effective for damages reduced.
6	Three Rivers Plan	Route would divert Passaic River from Central Basin wetlands.	Inlet location is not effective for reducing flood damages.
7	Little Falls to Newark Bay	Route would divert flows to Newark Bay to eliminate all effects of tunnel discharge in Lower Passaic River.	Tunnel is costly because of length. Other plans accomplish this more effectively (Route 1a).
8	Central Basin to Nutley	Routes developed to evaluate best alternative for Central Basin.	All but Two Bridges inlet location are infective. Third River outlet is preferable, see Route 8a.
8a	Two Bridges to Third River	Most effective of Central Basin inlets with Third River outlet.	Included in several basin-wide plans.
9	Spook Rock	Route developed to determine effects of a Ramapo River diversion.	Beneficial effect are minimal for basin-wide plans. Good for Ramapo River at Mahwah-Suffern area but not cost effective.
10	Little Falls to Nutley via Public Rights-of-Way	Route developed to measure effects of reduced real estate requirements.	Cost of additional tunnel length compared to Route 1a does not outweigh savings in real estate acquistions.
11	Pompton River to Nutley via Public Rights-of-Way	Route developed to measure effects of reduced real estate requirements.	Cost of additional tunnel length is much greater than savings in real estate costs compared to Routes 4a.

(1) NOTES: Tunnel route number referred from Table C-53 and Figures C-37 and C-38.

Route 2 (Figure C-37) was developed to evaluate placing the tunnel outlet further downstream within the reach where the deeper navigation channel, which significantly increases the channel carrying capacity, is located. This changed the outlet location from the Third River vicinity to the Second River on the Newark-Belleville boundary. This route would, however, increase the tunnel length and require extensive works at the outlet location to insure sufficient capacity of the Second River channel to carry flows. The cost increase associated with these factors would exceed the cost increment for additional levees and increased levee heights required to offset increased flood stages caused by a tunnel outlet location further upstream. Therefore, this tunnel route does not compare favorably with other routes and was not considered further in the formulation of plans.

Route 3 (Figure C-37) would divert flood flows from Little Falls to a point, just downstream of Dundee Dam, where flood flows would be carried to the mouth in a modified channel or within levees and floodwalls or a combination of these two measures. It is the shortest of all routes at 30,000 feet or under 6 miles in length. It would be necessary, however, to provide additional fluvial protection in the Lower Valley, downstream of Dundee Dam, from flows that would be increased to almost twice that which would occur under existing conditions. The costs and disruption by this plan would be significant as far downstream of the outlet as the Second River. The extensive costs of modifying the Passaic River channel over almost 31,000 feet (6 miles) with severe disruption to properties on both banks would not be feasible in terms of both cost and acceptability.

Two alternative alignments were considered in the development of Routes 4 and 4a (Figure C-38). These routes all have an intake at the head of the Pompton River where the Pequannock and Ramapo Rivers join together. This permits a diversion of a large portion of the Pompton River flow which is the major cause of flooding in the Central Basin and Lower Valley. Although this route is almost twice as long, and therefore, more costly, than the Little Falls to Third River route, it significantly reduces the need for local improvements along the Pompton and Passaic Rivers in both the Central Basin and Lower Valley. While the use of the siphon design allows the tunnel alignment to be straightened and provide a shorter route to the outlet site in the Lower Valley, a direct route from the Pompton River to the Third River was considered. There was, however, no accessible locations for construction shafts along the route between the inlet and the midpoint at the Passaic River in Totowa. In addition, the location of a work shaft in



Passaic River Study, N.J. & N.Y.

LITTLE FALLS DIVERSION TUNNEL ROUTES

FIGURE C-37

the highly urbanized areas south of the Passaic River in Clifton would be very disruptive. Alternative Routes 4 and 4a also allow the option to divert water from the Passaic River in the vicinity of Little Falls as well as the upper Pompton River through a second inlet. Because of the effectiveness of these alignments, Route 4a was utilized in several "Building Blocks", and intermediate plans.

Route 5 (Figure C-38), the Tri-County proposal, is almost 14 miles in length and does not affect the major damage areas on the Pompton River. The inlet in the vicinity of the Rockaway River only produces locally beneficial effects and the inlet at Two Bridges protects only areas downstream of the inlet. This route was not developed in more detail because preliminary cost estimates and assessments of flood damages indicated that other routes are significantly more cost effective.

Route 6 (Figure C-38), the Three Rivers Plan, would have an inlet located near the junction of the Rockaway, Whippany and Passaic Rivers. An inlet at this site was previously demonstrated to be only locally effective in reducing flood stages. It was eliminated from further formulation.

Route 7 (Figure C-37) extends Route 2 into Newark Bay to eliminate the negative effects the other routes have in the Lower Valley by the return of the tunnel discharge to the Passaic River. The cost of extending the tunnel an additional 27,900 feet would cost more than $250 million and far exceed the cost of providing additional local protection for tunnel discharges. This route was not considered further.

Route 8 (Figure C-38) attempts to develop an optimum route from the Central Basin to the Lower Valley. Both the Rockaway-Passaic Rivers confluence and the Great Piece Meadows sites were documented previously in the inlet discussion as having localized effects which do not produce benefits in the major damage areas along the Pompton River or the Passaic River downstream of Two Bridges. Without benefits from these reaches, the tunnel costs of these lengths are not justified. A third alternative inlet at Two Bridges, however, will benefit these reaches and will also provide an intermediate length tunnel for cost comparison with the longer Route 4a and shorter Route 1a to better define the cost trade-offs associated with the levee/floodwall and channel improvements which supplement these routes. Route 8a with a Two Bridges inlet and a Third River outlet is, therefore, represented in the "Building Blocks" and intermediate plans.

Route 9 (Figure C-38) is the Spook Rock route which diverts flows of the Ramapo River upstream of Suffern, N.Y. and conveys them to the Hudson River. Although this route is effective for protecting the Mahwah-Suffern area, it would only control approximately 118 square miles of the Central Basin drainage

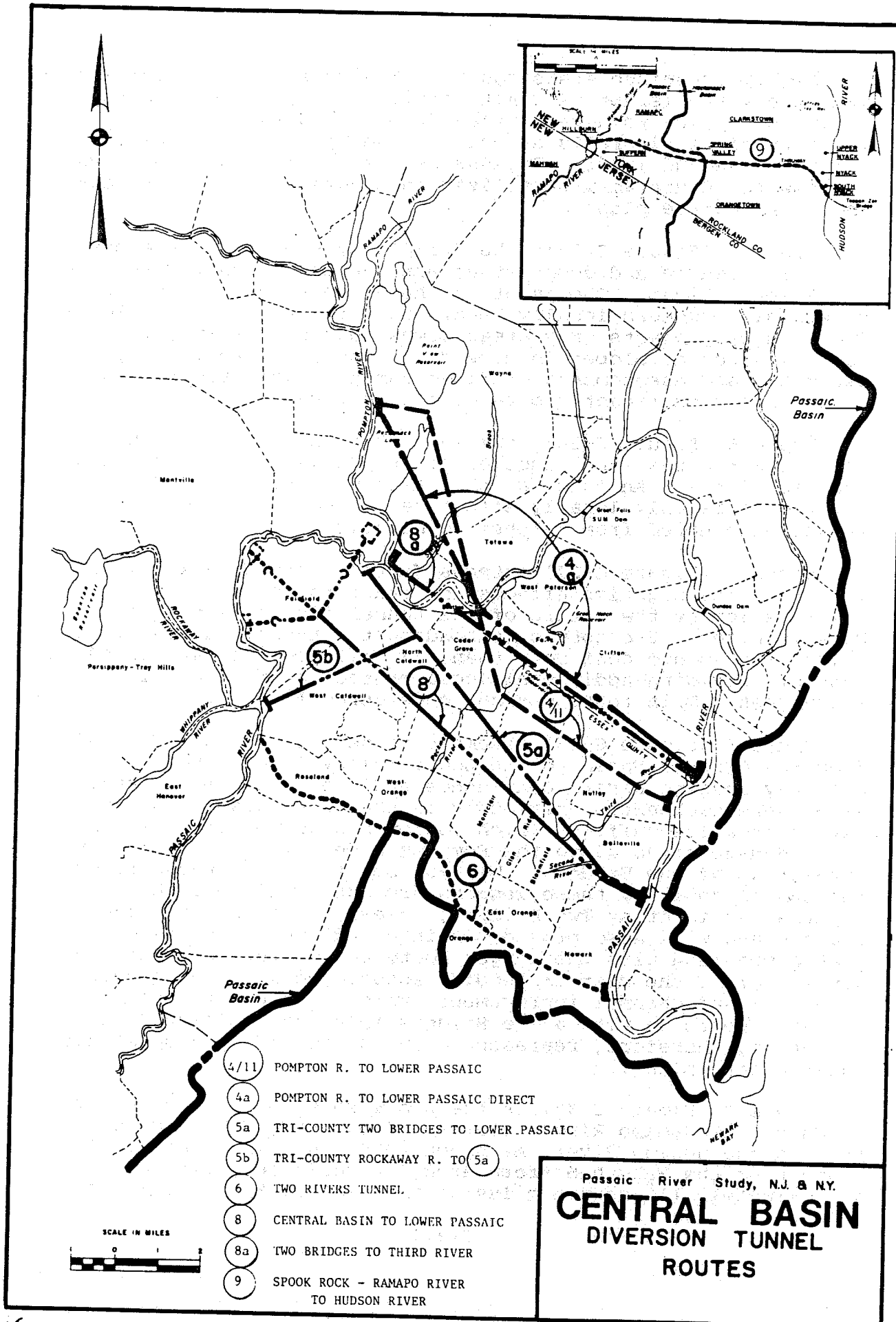

Passaic Basin
Passaic Basin
4/11 POMPTON R. TO LOWER PASSAIC
4a POMPTON R. TO LOWER PASSAIC DIRECT
5a TRI-COUNTY TWO BRIDGES TO LOWER PASSAIC
5b TRI-COUNTY ROCKAWAY R. TO 5a
6 TWO RIVERS TUNNEL
8 CENTRAL BASIN TO LOWER PASSAIC
8a TWO BRIDGES TO THIRD RIVER
9 SPOOK ROCK - RAMAPO RIVER TO HUDSON RIVER
SCALE IN MILES
0 1 2
Passaic River Study, N.J. & N.Y.
CENTRAL BASIN
DIVERSION TUNNEL
ROUTES

FIGURE C-38

area of 762 square miles and would have only minimal hydrologic effects at the major damage centers in the Central Basin and Lower Valley. The cost of this route would be more than $300 million which would far surpass the beneficial effects along the Ramapo and upper Pompton Rivers.

Routes 10 (Figure C-37) and 11 (Figure C-38) came about as a means of comparing the advantages of following major public rights of way with the more direct routes that pass under hundreds of individual pieces of private property. For Route 10, the cost reduction for real estate acquisitions for a siphon plan would, however, only amount to about $1.5 million, while the additional tunnel length would cost over $75 million compared to Route 1a. The time reduction for the acquisition process resulting from the right-of-way route would be about 18 months and, therefore, benefits foregone would not be a major beneficial effect. No further consideration is given to these routes in the formulation of "Building Blocks" and intermediate plans.

Formulation of Tunnel Plans. This section brings into focus the tunnel component of the tunnel "Building Blocks". The elements of a tunnel component are each briefly discussed with regard to their function. There is also a summary of the hydrologic analyses of the three basic tunnel routes as well as modifications that were also tested with the expectations of making these routes more effective. The end result is the definition of seven building blocks which form the basis of all intermediate plans that contain tunnel components.

Plan Components. All of the tunnel plans developed have common components which are necessary to the functioning of a tunnel diversion plan given the physical constraints specified for minimum flows and maintenance of existing water surface elevations in the Central Basin, under normal conditions as described earlier. These components could include a main channel spillway or flow restrictor to pond flows for diversion, an intake structure, a tunnel, an outlet structure, and local protection to mitigate flood damages that would be caused by the increased flows in the vicinity of the tunnel outlet. In addition some plans require channel modifications, levees and floodwalls improvements to direct flows into the tunnel inlets in order to cause them to function at a large enough capacity to be feasible.

The purpose of the main channel flow restrictor is to allow flows to pass downstream under normal conditions while ponding larger flows to the elevation of the intake structure for diversion through the tunnel.

Tunnel intake design options are either a morning glory or a side channel spillway configuration. The morning glory spillway discharges over a horizontally positioned circular weir into a shaft which funnels down to the diversion tunnel. A side channel spillway discharges flow over a straight weir set parallel to the direction of flow. Flow can discharge on one side or several sides into a channel which flows parallel to the spillway toe. The channel would convey the discharge into the diversion tunnel channel spillway. In terms of specific application to the Passaic tunnels, the side channel spillway must be used with a hydraulic grade line (gravity) tunnel. It requires less depth in transitioning to a horizontal tunnel alignment allowing the tunnel slope and the head between the tunnel intake and outlet to be maximized. Since, as previously discussed, the siphon design is the basis for the tunnel alternatives, the morning glory inlet is more desirable because it reaches maximum discharge more quickly under relatively low head and requires less surface area for construction. The morning glory inlet is used in all plans and is shown on sketches on the tunnel plan figures (e.g., Figure C-35).

The tunnel itself, which is the major component of the plans, carries the flood waters from inlet to outlet and accounts for the major portion of the construction cost. Previous discussions regarding design and construction techniques have adequately addressed this plan component.

The outlet structure design depends upon the discharge exit conditions of the tunnel. For the gravity tunnel a stilling basin would be used to convey the diverted discharge from the tunnel exit to the natural river. For the inverted siphon tunnel, flows will be exiting the outlet shaft in a vertical direction and there will be no momentum in the horizontal direction. Thus flow will rise above the outlet shaft to a depth equal to the difference between the total head across the tunnel. Since no momentum exists in the horizontal direction, there is no need to provide energy dissipators or a stilling basin at the outlet to the tailwater depth at the receiving body of water. The size and height of the outlet plume is controlled by the surrounding topography at the outlet and design of the outlet structure will assure that the plume size is not excessive. Figure C-33 illustrates the configuration of this type of outlet. By comparison, the required land area is considerably smaller for the vertical shaft outlet than for the stilling basin, therefore, imposing much less potential disruption of established land uses at the tunnel exit.

In the vicinity of the tunnel outlet, flows will be greatly increased by the addition of tunnel flows to the Passaic River Lower Valley flows and, therefore, will increase flood stages in this area. Therefore, all tunnel plans include levees and floodwalls in this area upstream of the Second River to the 8th Street Bridge in Wallington to protect these areas against the increased flood stages and the damages they would cause.

Channel improvements are also an essential component in some plans. Early in this study, it was determined that a tunnel with an inlet at Little Falls or Two Bridges could not be effective at lowering damage stages at major damage reaches in the Central Basin because of the hydrologic and hydraulic characteristics of this region. In addition, the flood damages reduced in the Lower Valley alone would not justify the expense of a tunnel diversion. This led to the inclusion of channels in these plans which would lower flood stages along the major damage reaches in the Central Basin and also direct flows efficiently to the tunnel inlets. Therefore, all plans with a single inlet at Little Falls or Two Bridges require channels for feasibility and are included where appropriate in the following analyses.

Plan Development. Several diversion alternatives were incorporated into the Passaic River Basin HEC-1 hydrologic model. These plans were tested for a design storm condition (e.g., 100-year frequency storm) to measure their effect on Central Basin and Lower Valley flows when compared to the same occurrence under existing conditions. Initially, an assumption was made that tunnel inlet locations could carry all flows arriving at the inlet location. This test indicates the maximum beneficial effect that could be developed at an inlet location. Then operating rules, tunnel sizes (20 to 40 feet in diameter), multiple tunnels, multiple inlets, and tunnel/channel combinations were tested to arrive at the several plans presented in this section. The end result was that, although there were over 35 sets of conditions tested, the effects of these plans fell very closely together with only a few definable sets of effects in both the Central Basin and in the Lower Valley between Beatties Dam (Little Falls) and Dundee Dam at the head of the Passaic River estuary. Selected hydrologic tests are presented to illustrate these effects. The following discussion summarizes the process through which the basic tunnel routes evolved into the "Building Blocks" and alternative plans. It should be noted that discharges and stages discussed below do not reflect current hydrology and hydraulics. Nevertheless, the base relationships and resulting decisions still hold.

(a) Little Falls Inlet. The first tunnel route to be tested was the Little Falls (Beatties Dam) to Third River alignment. In order to determine the maximum effectiveness possible for a tunnel inlet at Little Falls, the Lower Valley hydrologic model was utilized with the total diversion of all

flows allowing no flow to enter the Lower Valley over Beatties Dam. The basis for evaluating the effectiveness of a plan was to compare it with the existing conditions flows for the Lower Valley. There are two flood peaks that occur in the Lower Valley as explained earlier in this report. This first peak is caused by the local drainage of the tributaries in the Lower Valley within the first 30 hours of the 100-year storm as shown on Table C-55. The second peak is caused by the Highland and Central Basin runoff which occurs as a peak of long duration over the 40th to the 100th hours. Under existing conditions at the mouth of the Saddle River, it is 31% larger than the first and at the S.U.M. Dam and Great Falls in Paterson the second peak is 127% greater than the first peak. A diversion tunnel at Little Falls would only affect the second peak, and therefore, the diversion becomes progressively less effective moving downstream, toward the mouth of the Passaic River. This is apparent when the total diversion scheme is compared with existing conditions.

The total diversion test indicated the limit for controlling flows downstream at Little Falls. The input flow to the tunnel for this case and for all Little Falls to Third River tunnel plans is the flow which would enter the Lower Valley as a result of the construction of the Central Basin channel plan (Plan 15a) to funnel these flows out of the Central Basin to the tunnel inlet. The literal shut-off of flows by this test reduces the 100-year flows between Little Falls and Dundee Dam to almost zero damage levels in most reaches. Table C-55 compares these flows with existing conditions flows and tunnel plans.

At the Third River, the diverted flow is reintroduced into the river and Passaic River flows are almost doubled. This occurs because it takes two to three days for the Central Basin peak to develop upstream of Beatties Dam under existing conditions. The channel improvement in the Central Basin moves the flows more quickly causing the peak to occur sooner and also causes the peak to be greater than under existing conditions. Travel time through the tunnel for flows from Beatties Dam to the Third River is about one half hour for the 100 year flood event which, combined with the reduced travel time of the Central Basin channel, has the effect of causing the Central Basin peak to arrive in the Third River area much sooner. This essentially has the effect of superimposing the Central Basin peak on top of the Lower Valley peak flows. Therefore, this tunnel, as well as the other tunnel plans, would cause flows to almost double from what occurs under existing conditions at the outlet. Consequently, it would be necessary to mitigate these adverse effects with some form of local protection at the outlet. This protection will subsequently be described in detail under specific plans.

TABLE C-55 LITTLE FALLS TUNNEL BUILDING BLOCK FLOW ANALYSIS
100 YEAR FLOOD EVENT

	Existing Condition		Total Diversion			32 Foot Dia. Tunnel			Building Block 23A 35 Foot Dia. Tunnel			Building Block 23B 40 Foot Dia. Tunnel		
1/ Lower Valley	Flow (cfs)	Hour	Flow (cfs)	Hour	% Red. 2/	Flow (cfs)	Hour	% Red. 2/	Flow (cfs)	Hour	% Red. 2/	Flow (cfs)	Hour	% Red. 2/
Beatties Dam	8100	21	36375	45	+39	36375	45	+39	36375	45	+39	36375	45	+39
- Little Falls	26111	58	0	-	-	-	-	-	-	-	-	-	-	-
Tunnel Diversion - Little Falls	-	-	36375	45	-	18197	45	-	23635	29	-	31137	45	-
Flow Downstream of Tunnel	8100	21	0	-	100	18178	45	30	12740	45	51	5238	45	80
- Little Falls	26111	58	-	-	-	-	-	-	-	-	-	-	-	-
Below Peckman River	8100	21	3610	18	86	8080	20	-	4206	18	-	4105	18	-
- West Paterson	26146	58	-	-	-	18280	45	30	12654	45	52	5367	45	79
Below S.U.M. Dam	11548	21	7620	18	71	10734	20	-	8639	18	-	8437	18	68
- Paterson	26212	60	-	-	-	18467	46	30	12811	46	51	5530	45	-
Below Dundee Dam	14501	22	11836	21	55	13484	22	-	12295	21	-	12065	20	54
- Garfield	26281	63	-	-	-	18793	48	28	13144	48	50	5899	47	-
Below Saddle River	20500	22	18006	21	33	19435	21	-	18708	21	30	18422	21	31
- Wallington	26846	63	-	-	-	23585	41	12	17957	42	-	11639	37	-
Below Third River	22500	23	45525	30	+69	42128	43	+57	43813	23	+63	42941	23	-
(includes Tunnel discharge)	26861	65	-	-	-	-	-	-	41937	44	-	42998	39	+60
- Nutley, Clifton														
Below Second River	24500	23	46850	27	+73	42741	44	+58	44897	23	+66	44120	25	+63
- Newark	27010	67	-	-	-	-	-	-	42531	45	-	43807	40	-

NOTES:

1/ Flows are given for the first and second peaks occurring in the Lower Valley where they are distinguishable.

2/ Percent Reduction - Indicates percent reduction in peak flow resulting from tunnel compared with existing condition peak flow. A plus sign (+) indicates an increase in flow.

Additional tests considered varying operating rules and tunnel sizes. Based upon the hydrology discussed earlier, there are the first peak from the Lower Valley tributaries and the second peak caused by Central Basin flows. Optimization of the tunnel size requires that the tunnel divert enough flow to reduce the size of the dominant second peak to the size of the first peak. This maximizes the effectiveness of local protection that must be designed to protect against flood stages caused by the first peak. In this manner, the tunnel size is balanced with the design of the local protection works. A full range of tunnel diameters were evaluated ranging up to 45 feet in diameter. However, because of high costs for the larger tunnels, the diameter of tunnels in cases discussed here will be 40 feet or less.

Tunnels with 32-foot, 35-foot and 40-foot diameters extending from Little Falls to the Third River were tested for effectiveness in reducing flood flows. The 32-foot tunnel has the effect of reducing peak flows by about 30 percent upstream of Dundee Dam and by about 12 percent upstream of the tunnel outlet. With this tunnel the second peak would still be substantially greater than the first. Supplemental local protection in the Lower Valley would be necessary for the 32-foot tunnel which reduces the improved 100-year flow to approximately the equivalent 25 year flow under existing conditions. As a result, a larger tunnel to take a larger portion of the second peak flow was developed. An analysis of the 35-foot tunnel (Building Block 23A) determined that it would still allow the second peak to dominate. For the 35-foot tunnel, only some isolated locations would require local protection under conditions where the 100-year is reduced to the equivalent of less that a 10 year flood. A larger diameter tunnel was then developed. The 40-foot tunnel (Building Block 23B) would reduce the second peak from 57 to 79 percent and would require very little supplemental local protection upstream of Dundee Dam. In earlier studies it was determined that the cost of local protection combined with the 32-foot diameter tunnel would be much greater than the 35- or 40-foot tunnel with equivalent level of protection in these reaches. In all cases, local protection works are required below Dundee Dam because tunnel outlet discharges increase Passaic River flows downstream of the Third River and also create a hydraulic backwater condition that increases flood elevations along the Passaic River upstream of its confluence with the Third River. This protection against the effects of the tunnel discharge is included in all plans.

As noted earlier, it is necessary to include channel modifications upstream of Little Falls to effect flood damage reduction in the Central Basin. The channel modification included with the Little Falls to Third River tunnel is described in detail elsewhere but its effects are shown in terms

of flood stages which can be compared with the existing conditions in Table C-56. The channel improvement (Building Block 15A) is the base condition for flows entering the Lower Valley for the Little Falls to Third River plans.

(b) Pompton River Inlet. A similar procedure was utilized to evaluate the effects of a Pompton River inlet. First, a test was made of a full diversion of Pompton River flows at the upper reach of the river where the Pequannock and Ramapo Rivers join to become the Pompton River. The nature of flooding on the Pompton and Passaic Rivers was discussed earlier along with the unique character of the flooding situation in the Central Basin. A major point of that discussion was the large role that flows from the Pompton River play both in terms of Central Basin and Lower Valley flooding. Table C-57 highlights this point in the comparison of the existing conditions and the total diversion of Pompton River flows test. Flows are reduced by 85 percent on the Pompton River, 62 percent at Beatties Dam and by 46 to 62 percent between Beatties Dam and just below Dundee Dam. There are significant effects in both the Central Basin and the Lower Valley with essentially complete protection from the 100-year flood on the Pompton River. A 35-foot tunnel (Building Block 23D) was then tested for effectiveness. Flows were reduced by 53 to 65 percent in the Pompton River and the reductions on the Passaic River ranged from 29 to 36 percent between Two Bridges and just downstream of Dundee Dam. While this case reduces flows significantly along the Pompton River, it would be necessary to include a channel modification to bring flows within stream banks. In addition, this plan would require significant supplemental protection in the Lower Valley as well as in the Central Basin.

A 40-foot tunnel (Building Block 23C) was then tested and was found to be very effective with flow reductions of 77 to 84 percent along the Pompton River. On the Passaic River, this tunnel causes reductions of about 52% between Little Falls and upstream of Dundee Dam in the Lower Valley. These effects in this reach are very similar to the 35-foot tunnel between Little Falls and the Third River (Building Block 23A) which shows flow reductions of 51 to 52 percent in Table C-55. This flow, as mentioned earlier, is approximately equivalent to less than a 10 year flow under existing conditions and would still require some local protection at isolated locations.

The Pompton tunnels also have significant beneficial effects on the Passaic River upstream of Two Bridges which are related to flood stages in the Two Bridges area. Because the flows of the Pompton are so significant in this area, the dramatic lowering of flows and flood stages by both tunnel tests has a ripple effect upstream on the Passaic River, lowering flood stages for the 100-year event to 169.1 feet compared to 173.4

TABLE C-56

COMPARISON OF CENTRAL BASIN FLOOD STAGES RESULTING FROM TUNNEL AND CHANNEL IMPROVEMENTS

100 YEAR FLOOD EVENT

Location	Existing Conditions	Little Falls Inlet (1)	Two Bridges Inlet (2)	Pompton River Inlet (3)
Three Rivers Vicinity Passaic	174.3	173.7	173.4	173.1
Great Piece Meadows Passaic	173.4	168.6	169.4	169.1
Pompton River Upper Reach	182.5	179.5	179.5	172.2
Middle Reach	177.5	172.2	172.2	166.0
Passaic River Two Bridges	173.2	165.0	164.8	162.1
Beatties Dam	168.5	156.1	161.7	156.1

(1) Beatties Dam modified and 100 year channel improvement upstream to Two Bridges and along Pompton River
(2) Pompton River channel modification with levees
(3) 40 foot tunnel with channel modification along Passaic River between Little Falls and Two Bridges.

TABLE C-57 POMPTON RIVER TUNNEL BUILDING BLOCK FLOW ANALYSIS
100 YEAR FLOOD EVENT

	Existing Conditions		Total Diversion			Building Block 23D 35 Foot Dia. Tunnel 2/			Building Block 23C 40 Foot Dia. Tunnel		
	Flow (cfs)	Hour	Flow (cfs)	Hour	% Red. 1/	Flow (cfs)	Hour	% Red. 1/	Flow (cfs)	Hour	% Red. 1/
CENTRAL BASIN											
Pompton River	30875	33	30875	33	0	30875	33	0	30875	33	0
Tunnel Diversion	-	-	30875	33	-	19932	33	-	26002	33	-
Flow Downstream of Tunnel	30875	33	0	-	100	10943	33	65	4873	33	84
Below Packanack Brook	30189	40	4624	20	85	12639	34	58	6395	20	79
Mouth of Pompton River	27795	49	4012	22	86	13195	35	53	6323	40	77
Passaic River Downstream of Two Bridges	25407	55	9688	93	62	16169	36	36	12004	86	53
LOWER VALLEY 3/											
Beatties	8100	21	8020	26	-	14605	21	-	12441	85	52
- Little Falls	26111	58	10048	92	62	17796	36	32	-	-	-
Below Peckman River	8100	21	8920	24	-	16481	21	-	-	-	-
- West Paterson	26146	58	10047	93	62	17994	37	31	12442	85	52

TABLE C-57 (CONT) POMPTON RIVER TUNNEL BUILDING BLOCK FLOW ANALYSIS
100 YEAR FLOOD EVENT

	Existing Conditions		Total Diversion			Building Block 23D 35 Foot Dia. Tunnel 2/			Building Block 23C 40 Foot Dia. Tunnel		
	Flow (cfs)	Hour	Flow (cfs)	Hour	% Red. 1/	Flow (cfs)	Hour	% Red. 1/	Flow (cfs)	Hour	% Red. 1/
Below Great Falls	11548	21	11188	19	57	17381	22	-	12012	19	-
- Paterson	26212	60	10059	94	-	18256	38	30	12465	85	52
Below Dundee Dam	14501	22	14087	21	46	18401	25	-	16412	20	38
- Garfield	26281	63	10080	98	-	18564	77	29	12520	86	-
Below Saddle River	20500	22	20118	21	25	23693	26	-	22640	21	16
- Wallington	26846	63	10080	98	-	23977	41	11	12621	84	-
Below Third River (includes tunnel discharge) - Nutley,	22500	23	46973	32	+75	44448	28	+65	42620	33	+59
- Clifton	26861	65	-	-	-	-	-	-	-	-	-
Below Second River	24500	23	47944	33	+78	45692	30	+69	43678	34	+62
- Newark	27010	67	-	-	-	-	-	-	-	-	-

NOTES:

1/ Percent reduction in peak flow compared with existing conditons. A plus (+) sign indicates a flow increase.
2/ Includes a channel along Pompton River and the Passaic River from Two Bridges to Little Falls.
3/ Flows are given for the first and second peaks occuring in the Lower Valley where they are distinguishable.

feet for existing conditions in the Great Piece Meadows, Table C-56. It is also noted that the effects of the tunnel outlet discharge at the Third River on flood stages in the Lower Valley downstream of Dundee Dam will require the same mitigation measures as indicated for the Little Falls to Third River Tunnel.

(c) Double Inlets. A modification to the Pompton River tunnel described above would include a second inlet at Little Falls. This double inlet concept would take advantage of the different timing of flood flow peaks in the Central Basin and Lower Valley and make more effective use of the tunnel in reducing flood flows in the Lower Valley. Flows would be introduced into the tunnel at Little Falls only when there was excess capacity before and after the maximum flow was diverted from the Pompton River.

The effects of this double inlet concept are shown in Table C-58. The Central Basin flows for the 40-foot tunnel (Building Block 23E) would be the same as those for the single tunnel inlet plan (Building Block 23C) described earlier. At Beatties Dam, the peak flows are reduced by 52 percent when compared with existing conditions flows. Above Dundee Dam, flows would be lowered almost to the zero damage stage for the 100-year event.

A second double inlet alternative consists of a tunnel that varies in size from 35 to 40 feet. This plan calls for a 35-foot tunnel from the Pompton River to Beatties Dam in Little Falls, and thence a 40-foot tunnel to the Third River (Building Block 23F). This configuration requires a channel modification in the Pompton River and along the Passaic River between Two Bridges and Beatties Dam to provide the 100 year level of protection. This plan, because of the larger diameter tunnel section below Little Falls, would seemingly have a larger carrying capacity than the single inlet 35-foot tunnel (Building Block 23D) as shown in Tables C-57 and C-58 and, therefore, have greater beneficial effects in the Central Basin.

Multiple tunnels were reviewed in the context of the double inlets at Beatties Dam and the Pompton River. The use of a separate 35-foot tunnel for the Pompton River diversion with a separate 25-foot tunnel for the Little Falls diversion, both with outlets at the Third River, would be an effective plan, particularly in the Lower Valley between Little Falls and Dundee Dam. However, channel improvements would be required along the Pompton River and the Passaic River between Two Bridges and Little Falls. A smaller tunnel, 21 feet in diameter, was tested for the Little Falls to Third River tunnel with the Pompton River 35-foot tunnel, but this plan would require local protection in the Lower Valley between Little Falls and Dundee Dam. The most effective combination would be a separate 40-foot diameter Pompton Inlet tunnel with a separate 21-foot diameter

TABLE C-58 DOUBLE INLET TUNNEL BUILDING BLOCK FLOW ANALYSIS
100 YEAR FLOOD EVENT

Existing Condition			Total Diversion 3/			Building Block 23E 40 Foot Dia. Tunnels (1)			Building Block 23F 35-40 Foot Dia. Tunnels w/channel (2)		
	Flow (cfs)	Hour	Flow (cfs)	Hour	% Red.	Flow (cfs)	Hour	% Red.	Flow (cfs)	Hour	% Red.
CENTRAL BASIN											
Pompton River	30875	33	30875	33	0	30875	33	0	30875	33	0
Tunnel Diversion	-	-	30875	33	-	26002	33	-	21372	33	-
Flow Downstream of Tunnel	30875	33	0	-	100	4873	33	84	9503	33	69
Below Packanack Brook	30189	40	4624	20	85	6395	20	79	10608	34	65
Mouth of Pompton R.	27795	49	4012	22	86	6323	40	77	10908	36	61
Passaic River Downstream of Two Bridges	25407	55	9688	93	62	12004	86	53	13214	36	48
Lower Valley 5/											
Beatties Dam	8100	21	8020	26	-	12441	85	52	14878	36	43
- Little Falls	26111	85	10048	92	62	-	-	-	12420	77	-
Tunnel Diversion - Little Falls	-	-	10048	92	-	- 4/	-	-	- 4/	-	-
Flow Downstream of Tunnel	8100	21	0	-	-	8279 4/	32	68	14576 4/	36	44
- Little Falls	26111	58	-	-	-	-	-	-	-	-	-
Below Peckman R.	8100	21	3610	18	86	4214	18	-	4214	18	-
- West Paterson	26146	58	0	-	-	8581	34	67	14842	36	43

TABLE C-58 (CONT.) DOUBLE INLET TUNNEL BUILDING BLOCK FLOW ANALYSIS
100 YEAR FLOOD EVENT

	Existing Condition		Total Diversion 3/			Building Block 23E 40 Foot Dia. Tunnels (1)			Building Block 23F 35-40 Foot Dia. Tunnels w/channel (2)		
	Flow (cfs)	Hour	Flow (cfs)	Hour	% Red.	Flow (cfs)	Hour	% Red.	Flow (cfs)	Hour	% Red.
Below Great Falls	11540	21	7620	18	71	8224	18	-	8224	18	-
- Paterson	26212	60	0	-	-	9011	37	66	15183	37	42
Below Dundee Dam	14501	22	11836	21	55	12856	20	51	12856	20	-
- Garfield	26281	63	0	-	-	9718	37	-	15894	38	40
Below Saddle River	20500	22	18006	21	33	18999	21	29	18999	21	-
- Wallington	26846	63	0	-	-	15733	37	-	21881	-	18
Below Third River	22500	23	46973	32	+75	44947	26	-	49802	23	+85
(includes tunnel discharge) - Nutley,	26861	65	-	-	-	45206	42	+68	45508	43	-
- Clifton											
Below Second River	24500	23	47944	33	+78	46273	26	+71	50559	24	+87
- Newark	27010	67	-	-	-	45712	43	-	45956	44	-

NOTES:

1/ Tunnel inlets at both the upper Pompton River and at Beatties Dam in Little Falls.

2/ Same as 1/ but tunnel diameter is 35 feet from Pompton inlet to Little Falls then 40 feet to Third River. Also includes channel modification to 100 year protection on entire Pompton River and Passaic River between Two Bridges and Beatties Dam.

3/ Total diversion is shown at both the Pompton River and Little Falls inlets.

4/ At the time of peak bypass flow downstream of Little Falls, no diversion is possible due to the complete utilization of the tunnel at the Pompton Inlet. Diversions at other times is limited only by difference between the flow diverted at the Pompton River and the design capacity of the tunnel, which is over 30,000 cfs with no Pompton diverison. This capacity at Little Falls is thus often more than adequate to prevent damaging flood flows.

5/ Flow are given for the first and second peaks occurring in the Lower Valley where they are distinguishable.

Little Falls tunnel which would provide for beneficial effects similar to those of the 40-foot diameter double inlet tunnel previously described and shown on Table C-58. However, with separate tunnels, local protection would not be necessary on the Pompton River nor in the Lower Valley between Beatties and Dundee Dam. Both of these tunnel combinations would be very costly with a total cost of about $800 million for the tunnels alone without mitigation for the tunnel discharge areas in the Lower Valley. These plans were not considered further because of the high cost.

(d) Two Bridges Inlet. The Two Bridges inlet is an intermediate inlet location proposed as an alternative to the Pompton River and the Little Falls tunnel inlets. The Two Bridges tunnel with levees and channel modification that provide a 100-year level of protection along the Pompton River allows a comparison of measures that fall between these two plans in terms of tunnel and channel modification measures. For the Two Bridges inlet there would be no channel improvements required in the large damage reach between Little Falls and Two Bridges on the Passaic River. Such channel modification is required with the Little Falls tunnel. The testing of different sized tunnels and operating rules revealed that the Two Bridges tunnel must be approximately 40 feet in diameter to fully eliminate improvements to Beatties Dam and the Passaic River channel downstream of Two Bridges to Little Falls. A tunnel smaller than 40 feet at Two Bridges would allow flows to rise above zero damage stages between Two Bridges and Little Falls and thus would require local protection to provide the 100-year level of protection in this reach. To alter Beatties Dam and provide a channel to alleviate this condition would defeat the purpose of this scheme. At the 40-foot diameter, this plan is very effective in both the Central Basin and the Lower Valley in terms of flood damage reduction. Lower Valley flows would be similar to these shown in Table C-55 for the 40-foot diameter Little Falls tunnel. As with the other tunnel schemes, mitigation measures in the form of local protection would be required in the Lower Valley in the vicinity of the tunnel outlet location. This scheme is developed as a "Building Block".

(e) Other alternatives. Modifications to the Pompton tunnel schemes were considered in an effort to reduce the tunnel size and to increase capacity in order to reduce overall costs. The first modification considered the effects of the Darlington Reservoir site, described in Building Block 18, on the Pompton River Tunnel. The effects were tested on the 35-foot tunnel from the Pompton River inlet to the Third River and on the double inlet configuration with the second inlet at Beatties Dam. The primary effect of Darlington Reservoir is to reduce the peak from 30,875 to 25,119 cfs at the Pompton River inlet and extend the duration of the peak over a much longer period of time. The single inlet tunnel would be very effective in

reducing flows to under 6000 cfs along the Pompton River. However, in the Lower Valley, flows would be similar to those indicated for the 40-foot diameter single inlet tunnel (Building block 23C) in Table C-57. With a double inlet, the effectiveness of the tunnel in the Lower Valley is not improved significantly because the extended peak flow on the Pompton River keeps the tunnel operating at its full capacity over a much longer period of time at the Pompton River inlet. Therefore it does not have available capacity to be useful for diversions at Little Falls. Supplemental local protection would be necessary to provide a 100 year level of protection throughout the areas affected by the scheme. The costs associated with the construction of Darlington Reservoir (about $200 million October 1985 price level) and the cost of supplemental local protection in the Lower Valley are not offset by the cost reduction associated with use of the smaller tunnel when compared to the 40-foot diameter double inlet scheme.

The second modification considered moving the Pompton inlet up the Ramapo River to Pompton Lake with a smaller branch tunnel to the Wanaque River. By moving the tunnel further upstream, it was hoped that the greater elevation (200 feet as compared to 180 feet NGVD) would permit a smaller tunnel and still allow for the same effectiveness in reducing flows in the Central Basin and Lower Valley. The results, however, indicated that a 40-foot diameter was still required and that this combination was not hydrologically effective because the flows of the Pequannock River would not be captured by the system. This condition would require supplemental protection along the Pompton River as well as in the Lower Valley and would be more costly in terms of an additional 9000 foot length of 40-foot diameter tunnel to Pompton Lake and 4000 feet of 20-foot diameter tunnel to Lake Inez on the Wanaque River. Both of these schemes did not accomplish the desired results in terms of lowering costs and increasing effectiveness and, therefore, are no longer considered as viable alternatives.

(f) Summary. The plans selected for development include the 35 and 40-foot diameter tunnels with Little Falls inlets, the 35 and 40-foot diameter tunnels with Pompton River inlets, the 40-foot and the 35/40-foot double inlet tunnels, and the 40-foot Two Bridges inlet tunnel. The other schemes considered in the formulation process were deemed not effective and too costly to warrant further consideration.

The preceding discussion is summarized in Table C-59. This table summarizes only those plans that were discussed and were significant to the formulation process while being important in the selection of tunnel components for development as "Building Blocks", as discussed below.

TABLE C-59
FORMULATION OF TUNNEL BUILDING BLOCKS

Tunnel Inlet	Tunnel Diameter	LOCAL PROTECTION			Developed as Building Block	Remarks
		Lower Valley 1/	Pompton River 2/	Passaic River 2/		
LITTLE FALLS	32'	Levee/Floodwall	100 Yr. CM 3/	100 Yr. CM	No	Plan is not effective in Lower Valley and requires extensive local protection.
	35'	Levee/Floodwall	100 Yr. CM	100 Yr. CM	23A	Plan is moderately effective and is good balance of tunnel and local protection.
	40'	Levee/floodwall	100 Yr. CM	100 Yr. CM	23B	Plan is very effective in some reaches of Lower Valley, but may be over designed.
POMPTON RIVER	35'	Levee/Floodwall	CM 4/	CM	23D	Plan is not effective in Lower Valley and needs some protection along Pomton River
	40'	Levee/Floodwall	None	CM	23C	Plan is moderately effective in Lower Valley and very effective in the Central Basin.
DOUBLE INLET 5/	40'	Levee/Floodwall	None	CM	23E	Effective in both Lower Valley and Central Basin.
	35'/40'	Levee/Floodwall	CM	CM	23F	Requires supplemental local protection in all reaches and Little Falls inlet is ineffective.
MULTIPLE TUNNELS 6/	35'/25'	Levee/Floodwall	CM	CM	No	Plan is not feasible with tunnels and local protection.
	40'/21'	Levee/Floodwall	None	CM	No	Cost of two tunnels is high and not feasible.
POMPTON/DARLINGTON	35'	Levee/Floodwall	None	CM	No	Combination w/Darlington is very expensive.
POMPTON LAKES	40'	Levee/Floodwall	CM	CM	No	Additional gains in capacity is offset by additional tunnel costs, and loss of effectiveness by not capturing Pequannock.
TWO BRIDGES	35'	Levee/Floodwall	100 Yr. CM	CM	No	Cost of channel and modifications makes Little Falls tunnels more economical.
	40'	Levee/Floodwall	100 Yr. CM	None	23G	Plan is effective in Lower Valley.

NOTES:
1 Refers to reach between Little Falls and Dundee Dam. Local protection is levees and floodwalls.
2 Passaic River between Little Falls and Two Bridges.
3 100-Year Channel modification plan includes levees and floodwalls along the Pompton River.
4 Channel modification smaller than 100-Year CM and no levees along the Pompton River.
5 Inlets at Pompton River and Little Falls.
6 Two tunnels, first number is size of Pompton River to Third River tunnel, second is Little Falls to Third River tunnel.
7 Levee/Floodwalls are included in each plan at the same scale, however, the residual damages in this reach would vary for each plan.

"Building Blocks". Based on the technical considerations previously described, and the hydrologic/flood damage reduction tests presented above, Tunnel "Building Blocks" were assembled. These plans consider tunnels from 35 to 40 feet in diameter, and consider the Little Falls, Pompton, Two Bridges and double inlet design. All "Building Blocks" include an outlet at the Passaic River at its confluence with the Third River and all are designed as inverted siphons with TBM construction. In addition, channel modifications and levees and floodwalls are included along the Pequannock, Wanaque and Ramapo Rivers to direct enough flows to the tunnel inlets to cause them to function at capacity. The extent of these surface works required for varying tunnel sizes was later refined in the Detailed Planning Stage. These plans are designated as "Building Blocks" 23A through G, and are presented below.

Building Block 23A. The function of this "Building Block" is to divert flood flows from the Passaic River at Little Falls at the upper reach of the Lower Valley and then reintroduce the flow to the estuarine portion of the Lower Valley through a 35-foot diameter single inlet tunnel which has its outlet along the Passaic River at its confluence with the Third River at Clifton and Nutley. Flood flows are directed to the tunnel from the major damage areas of the Pompton Valley and the Passaic River between Two Bridges and Little Falls by the channel modification and levee/floodwall plan elements of Building Block 15A located along those areas. In addition levees and floodwalls are located at the outlet in the Lower Valley to mitigate against the increased stages caused by the discharge of tunnel flows into that reach of the river. These "Building Block" elements are shown on Figure C-39.

At the peak of the 100-year design storm, 36,375 cfs will flow out of the Central Basin, of which about 23,635 cfs will be diverted into the tunnel and 12,740 cfs will continue downstream to the Lower Valley in the Passaic River's natural channel. At the confluence with the Third River, the tunnel will return the flow to the Passaic River which will produce a combined flow of 43,813 cfs. As discussed earlier, these effects are shown for the 35 foot-tunnel in Table C-55 which compares the flows resulting from the Central Basin channel and tunnel plan combination with those occurring under without project conditions. The plan allows for a design balance of first and second peak flows in the Lower Valley that leaves the second peak larger than the first peak. This "Building Block" would require some supplemental protection in the Lower Valley between Little Falls and Dundee Dam to provide uniform protection as a basin-wide plan, but provides a basis for comparing trade-offs of local protection against a larger tunnel as in Building Block 23B.

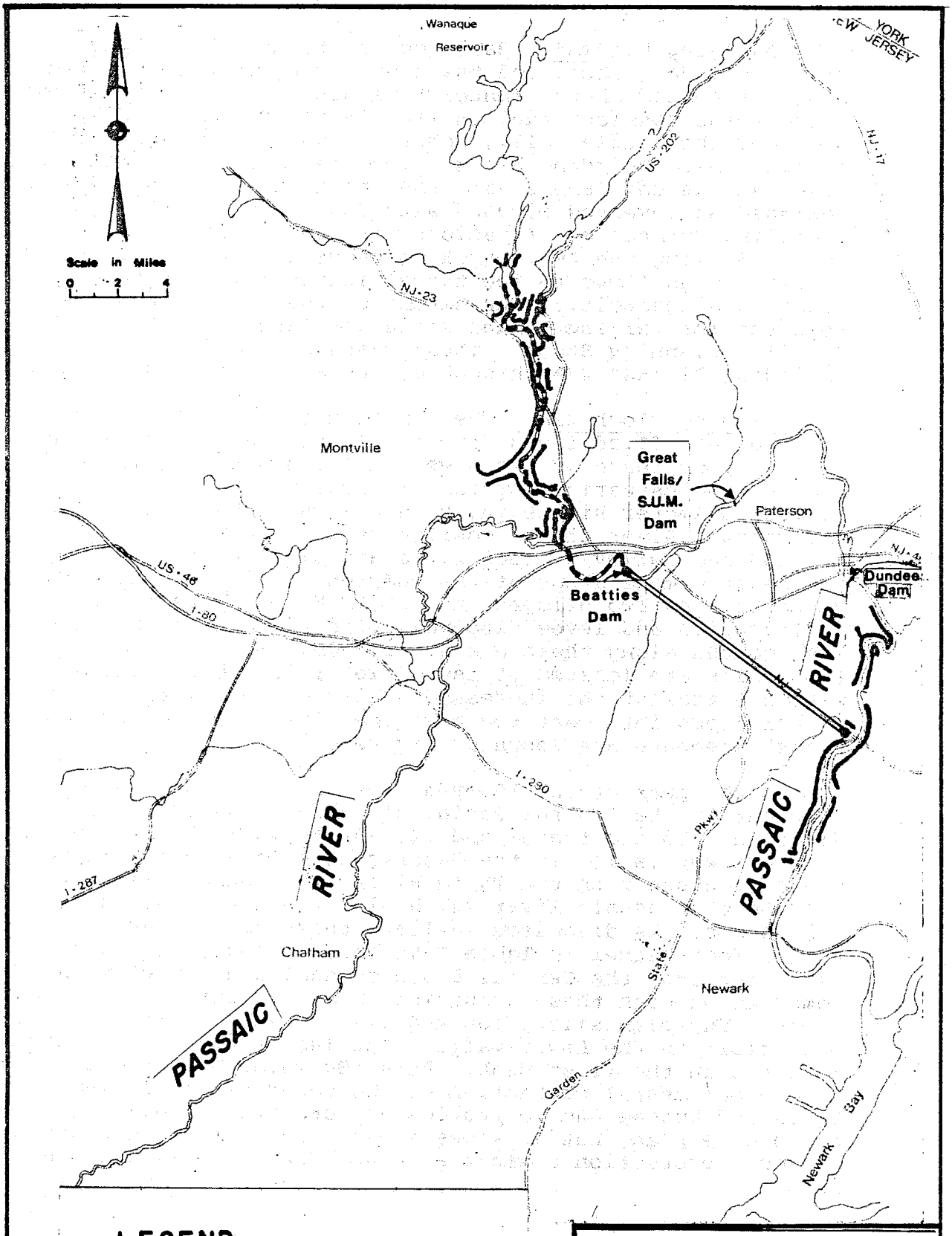

Wanaque
Reservoir
NEW YORK
NEW JERSEY
US-202
NJ-17
NJ-23
Scale in Miles
0 2 4
Montville
Great
Falls/
S.U.M.
Dam
Paterson
US-46
I-80
Beatties
Dam
Dundee
Dam
NJ-4
RIVER
PASSAIC
I-287
I-280
PKWY
RIVER
PASSAIC
Chatham
State
Newark
Garden
Bay
Newark
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
Passaic River Study N.J. & N.Y.
BUILDING BLOCK
23A & 23B

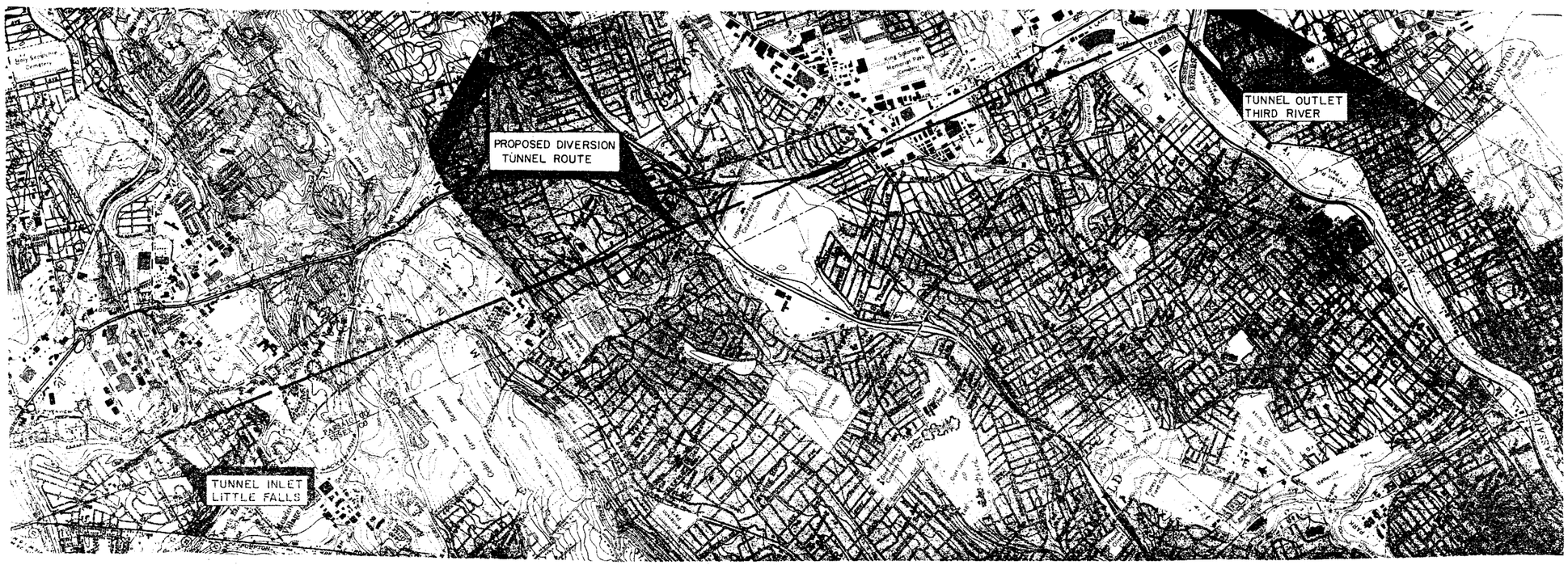
FIGURE C-39

The Central Basin 100 year channel modification plan (element of Plan 15A) protects the Pompton Valley and portions of the Passaic River in the Central Basin from flood damages to the 100 year level of protection and conveys the flows to the tunnel inlet. This plan consists of channels upstream from Little Falls to Two Bridges and then channels and levees up the entire length of the Pompton River with extensions on the Ramapo, Pequannock and Wanaque Rivers. Beatties Dam is replaced with a gated structure which opens during flood events. The tunnel element consists of inlet structures, the tunnel, and outlet structures. The proposed inlet portal is located in Little Falls near the bend in the Passaic River above Route 46 and just below the Union Street Bridge and Beatties Dam. A description of this inlet site was presented previously in this section under Hydrologic Considerations In Determining Inlet/ Outlet Locations.

The elements of the inlet include a morning glory tunnel inlet structure within the river and a river flow restrictor across the width of the river and located immediately downstream of the morning glory structure as shown in the accompanying Figures C-33 and C-40. The river flow restrictor would have a spillway crest about 23 feet high at elevation 142.0 feet NGVD (National Geodetic Vertical Datum) and three 8 ft. x 8 ft. openings to pass normal flows. The morning glory tunnel inlet would begin diverting flows into the tunnel when waters ponding behind the river flow restrictor rise to elevation 132.4 feet NGVD. When flood flows are larger than the tunnel capacity, the excess flows would continue downstream over the flow restrictor spillway.

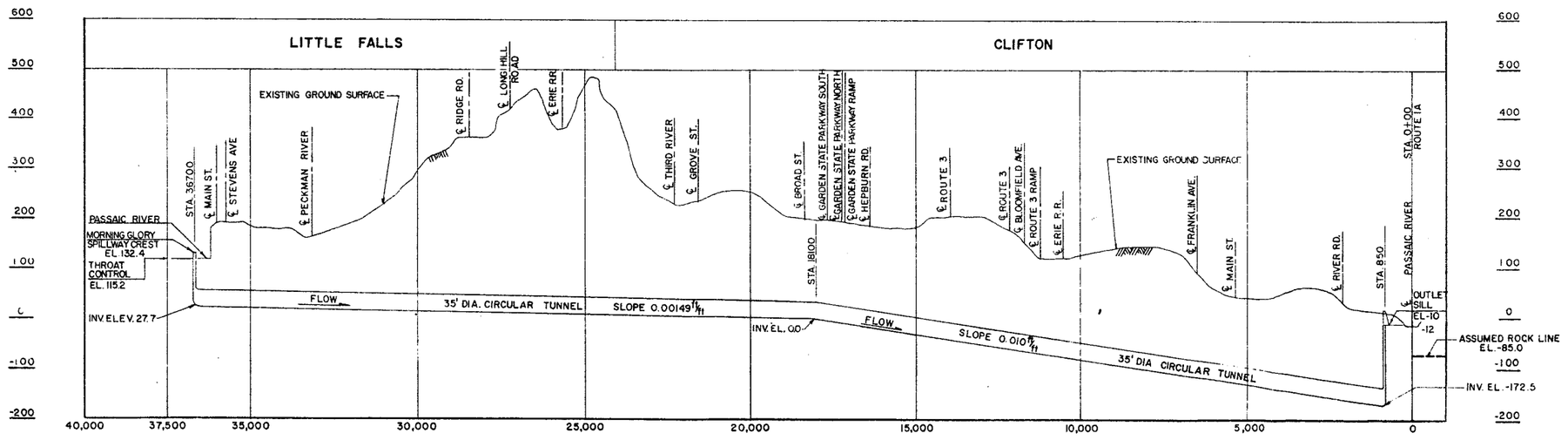
The tunnel is 36,400 feet long and has a circular shape with an inner diameter of 35 feet. The tunnel would be lined with a 2 foot thick layer of concrete for both tunnel support and for sealing the tunnel against groundwater infiltration and tunnel water exfiltration. For approximately half of its length, the invert of the tunnel would be above sea level starting at the upper end near Beatties Dam. To avoid the surface disruption of cut-and-cover construction toward the mouth of the tunnel, and to keep the tunnel alignment deep in bedrock, it would be necessary to construct about 18,000 feet of the tunnel well below sea level.

The outlet location is on the left bank of the Third River just upstream of its confluence with the Passaic River in a wide portion of the Third River and in a well defined valley of the stream. Flows exiting the tunnel would be directed into the Passaic River through the Route 21 bridge. The outlet site is well away from residential development and is currently used as an equipment and materials yard for a construction company. The Passaic Valley Sewage Commission (PVSC) Yantacaw pumping station is located downstream of the site.



PLAN

SCALE IN FEET
1500 0 1500 3000



PROFILE OF DIVERSION TUNNEL

SCALE IN FEET
HORIZ. 1500 0 1500 3000
VERT. 100 0 100 200

Passaic River Basin, N.J. & N.Y.

BUILDING BLOCK 23A
35 FOOT LITTLE FALLS
TO THIRD RIVER TUNNEL
PLAN & PROFILE

FIGURE C-40

The diverted flows would exit the tunnel vertically through an upshaft to the surface at sea level (greatly reducing water velocity) and then flow out the enlarged mouth of the Third River and under Route 21 into the Passaic River as shown in the sketches on Figure C-33. The Route 21 bridge would be enlarged to accommodate the increased flows. Levees and floodwalls would be constructed on both banks of the Third River to protect those nearby areas from increased river stages estimated to be 13.9 feet NGVD as compared to 10.5 feet that would occur under existing conditions for the 100 year design flows. These additional flows, however, would have very little or no effect on river stages downstream of the Rutgers Street bridge near the Second River because of the large flow capacity of the navigation channel below that location. Because the tunnel outlet is in the tidal reach of the Passaic River, levees and floodwalls are the only suitable local protection measure for mitigating these increased flood stages. Intermittent levees and floodwalls would be required for this purpose from the Second River to upstream of the Saddle River.

Under normal conditions, flows of up to 2,500 cfs would pass through the structure before diversion begins through the morning glory inlet into the tunnel. However, in the event of a floodwarning condition with accompanying river flows greater than 1,000 cfs, gates would close two of the three low flow outlets and partially close the third outlet. Downstream flows past the structure would be reduced to under 500 cfs as long as the design capacity of the tunnel was not exceeded. Flows in excess of tunnel capacity would flow over the flow restrictor spillway and proceed downstream. At the same time the gates were closing on the low flow outlets, the gates at the modified Beatties Dam immediately upstream would open to begin operation of the channel modification plan element. This act would open up the channel so that it would have the capacity to convey flood flows to the tunnel inlet and reduce flood stages in the Central Basin. It is important to note that under normal conditions, these gates would be closed to maintain the existing Beatties Dam pool elevation at 158.0 NGVD in order to preserve upstream wetlands and maintain the inlet to the Passaic Valley Water Commission water supply intake.

This "Building Block" provides a 100 year level of protection from the downstream limit of the mitigation measures near the Second River in the Lower Valley to upstream of the Saddle River. Between Dundee Dam and Little Falls, protection is variable but it reduces the the 100 year flood event to the level of less than a 10 year event. Upstream of the tunnel inlet, the channel modification with levees and floodwalls provides a 100 year level of protection to the major damage centers along the Passaic River and then up the entire length of the Pompton River. The Passaic River upstream of Two Bridges

21

receives benefits from the lowered flood stages at Two Bridges and the elimination of the flow reversal phenomena discussed earlier, although additional local protection would be required to provide a uniform 100 year level of protection to this area. Such measures are considered in Plans 28A, 30A and 33A.

Building Block 23B. This "Building Block" is similar to Building Block 23A with the major exception that the tunnel component is a 40-foot diameter single inlet tunnel, Figure C-39. While no detailed plan sketches are shown, the various elements of the tunnel component are modified accordingly. The 100 year channel modification in the Central Basin and the mitigation measures downstream of Rutherford are the same as for Building Block 23A.

At the peak of the 100 year flood event, 36,375 cfs would flow from the Central Basin to the tunnel inlet where 31,137 cfs would be diverted into the tunnel and 5,238 cfs would flow into the Lower Valley. At the mouth of the Third River, the combined peak flow would be about 43,000 cfs. These flows and flows at intermediate locations are shown on Table C-55. The flows between Little Falls and Dundee Dam are moderated to the point that most second peak flows are less than first peak flows which would mean that this tunnel may be slightly larger than necessary to protect this reach. The peak flows in the remaining areas of the basin upstream of Little Falls and downstream of Dundee Dam are essentially the same as Building Block 23A.

Operation of this plan is the same as for Building Block 23A with the exception that the larger tunnel capacity provides for a greater level of protection in the Lower Valley.

Protection afforded by this building block is the same as in Building Block 23A except for the reaches between Little Falls and Dundee Dam. There the 100 year flood event is reduced to an equivalent event under without project conditions ranging from less than the one year to less than a 10 year event.

Building Block 23C. This "Building Block" consists primarily of a 40-foot diameter single inlet tunnel which would divert flood flows from the Pompton River upstream of Pompton Plains Cross Road (Jackson Avenue) in Wayne Township to the Passaic River at the mouth of the Third River in Clifton and Nutley, New Jersey, Figure C-41. Profiles and tunnel component details are shown on Figures C-34, C-42 and C-43.

At the peak of the 100-year design storm, 30,875 cfs would flow into the Pompton River from the Wanaque, Ramapo, and Pequannock Rivers of which approximately 26,002 cfs would be diverted into the tunnel and 4,873 cfs would continue downstream. At the mouth of the Third River, the tunnel would

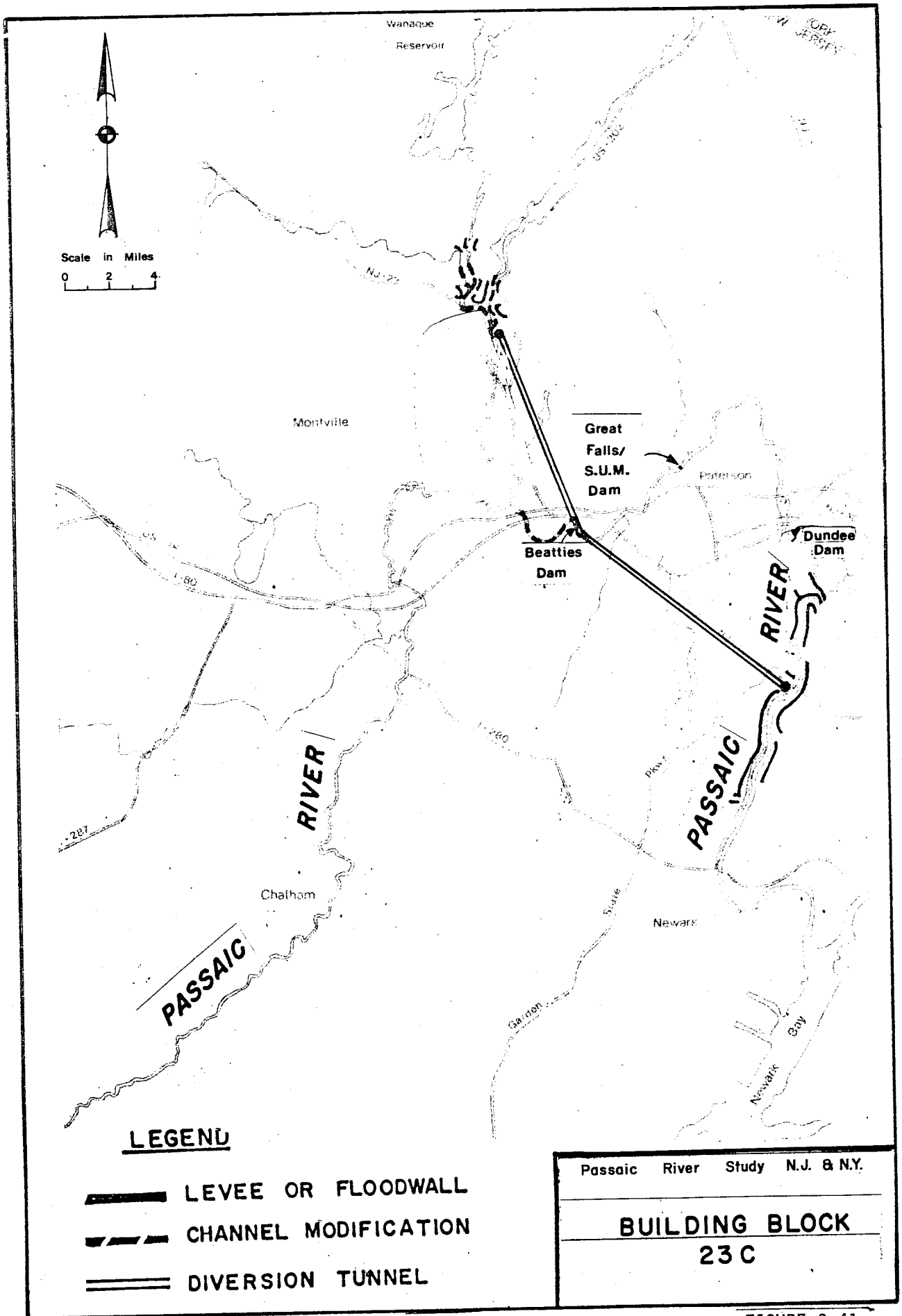


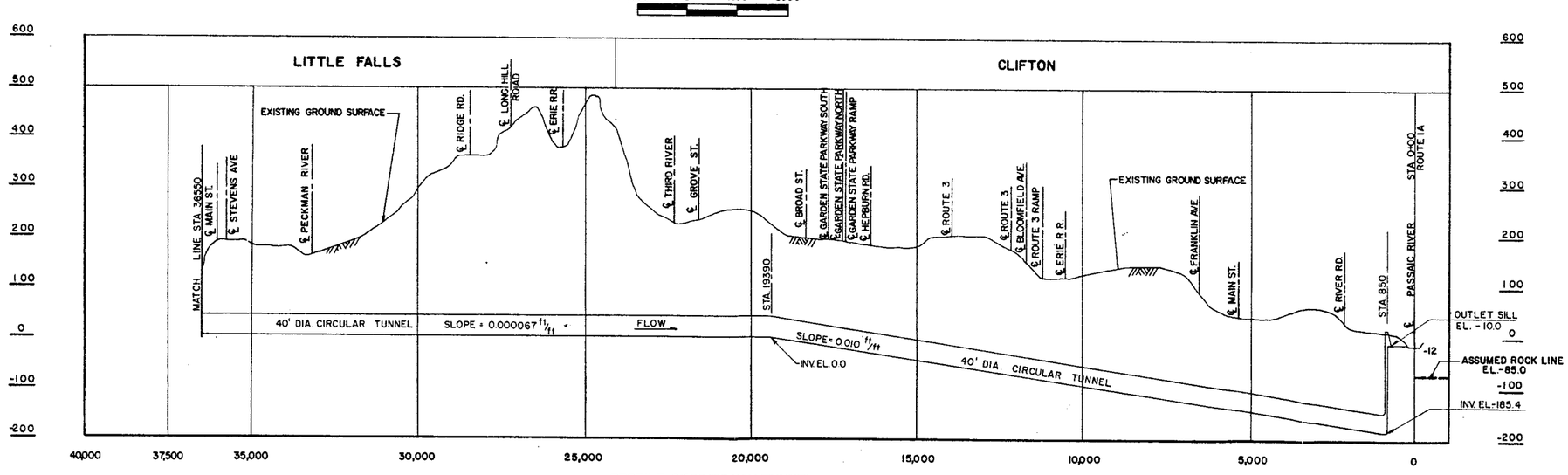
FIGURE C-41

317



PLAN

SCALE IN FEET
1500 0 1500 3000



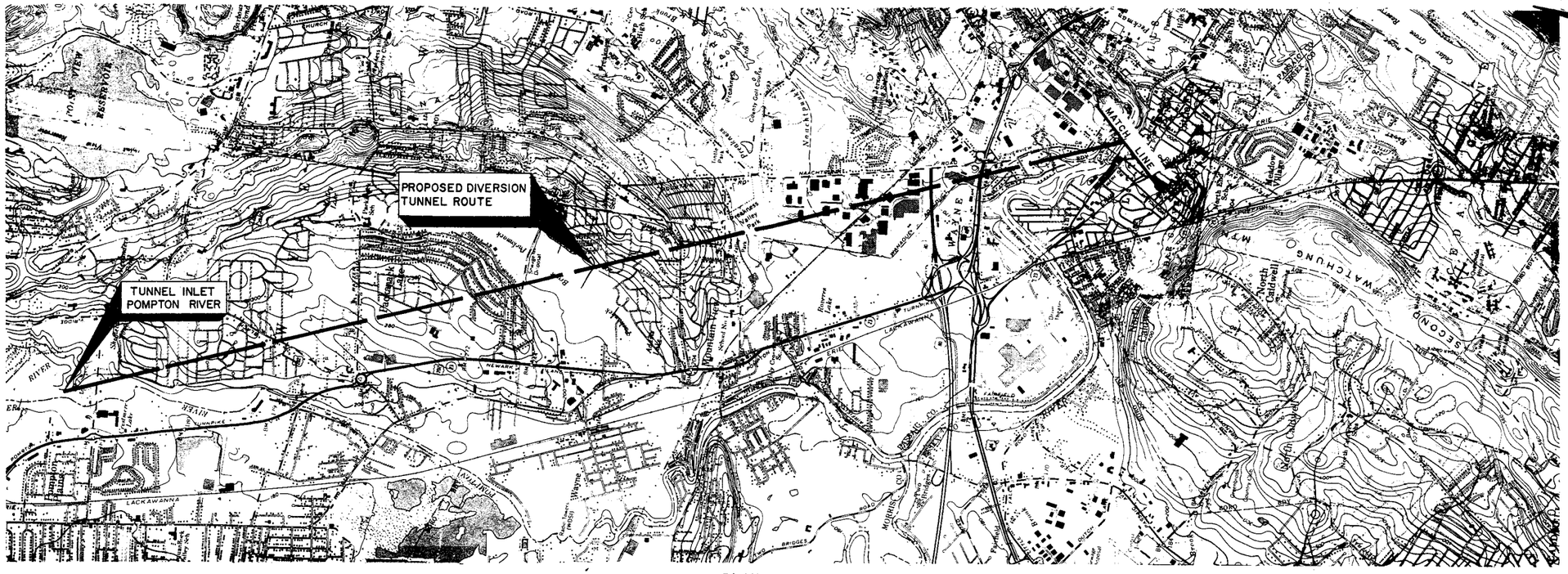
PROFILE OF DIVERSION TUNNEL

SCALE IN FEET
HORIZ. 1500 0 1500 3000
VERT. 100 0 100 200

Passaic River Basin, N.J. & N.Y.

BUILDING BLOCK 23C
40 FOOT POMPTON RIVER
TO THIRD RIVER TUNNEL
PLAN & PROFILE (1 OF 2)

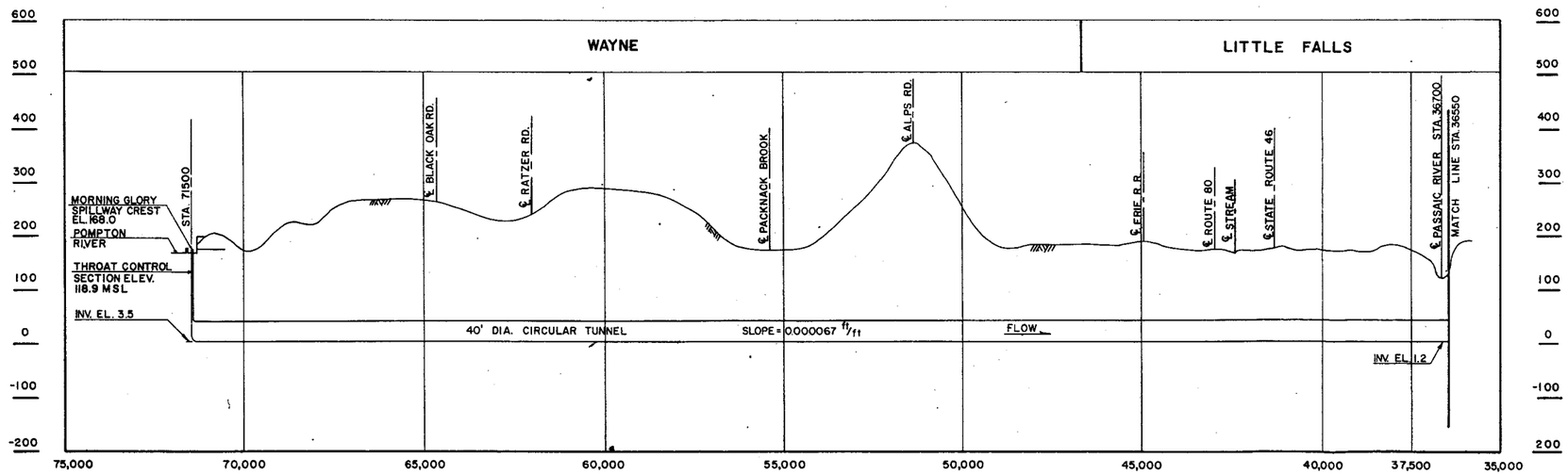
FIGURE C-42



PLAN

SCALE IN FEET

1500 0 1500 3000



PROFILE OF DIVERSION TUNNEL

SCALE IN FEET

HORIZ. 1500 0 1500 3000

VERT. 100 0 100 200

Passaic River Basin, N.J. & N.Y.

BUILDING BLOCK 23C
40 FOOT POMPTON RIVER
TO THIRD RIVER TUNNEL
PLAN & PROFILE (2 OF 2)

FIGURE C-43

return the flow to the Passaic River which would produce a combined flow of 42,620 cfs. The effect of the diversion is shown in Table C-57 which compares the flows resulting from this tunnel plan with those occurring under without project conditions. This tunnel would be very effective along the Pompton River giving flow reductions between 77 and 84 percent. The Passaic River between Two Bridges and Little Falls, however, would still suffer flood damages because the 100 year flow is reduced by only 53 percent. To convey these flows between Two Bridges and Little Falls, the channel would be modified by excavation and Beatties Dam would be replaced by a tainter gate structure. Lower Valley peaks between Little Falls and Dundee Dam are similar in magnitude to those resulting from Building Block 23A. No improvements are included downstream of Little Falls to Dundee Dam.

The tunnel portion of this plan consists of tunnel inlet structures, the 40-foot tunnel, and the outlet structures. The Pompton River remains in its natural state and no improvements are made downstream to Two Bridges. However, upstream of the Pompton Inlet, channel modifications, levees and floodwalls are required along the Pequannock, Wanaque and Ramapo Rivers to direct flood flows into the tunnel.

Downstream of Dundee Dam, flood stages would be increased due to the larger flows resulting from the tunnel discharges into the Passaic River and mitigation measures consisting of levees and floodwalls are required. Increases in flood stages due to these flows range up to 3.5 feet near the tunnel outlet.

The location of the inlet portal is upstream of Pompton Plains Cross Road (Jackson Avenue) in Wayne Township on the east bank of the Pompton River immediately downstream of the confluence of the Ramapo and Pequannock Rivers where they become the Pompton River. The site currently is part of a sand and gravel operation with these materials stockpiled on and adjacent to the site. The area around the site is generally undeveloped low-lying floodplain to the west and north, and agriculture lands to the east. Stream slopes in the area are very flat.

The inlet structures are shown in the sketches on Figure C-34. The structures consist of a river flow restrictor with roller gates, a gated diversion spillway, and a morning glory tunnel inlet. The river flow restrictor would be constructed across the Pompton River. Embankments would also be located on both banks of the river to assure that the tunnel will function at design flow levels. Average heights would range from 4.5 to 6.5 feet and lengths would be 795 feet on the east bank and 765 feet on the west bank. Also there would be a 7-foot high berm around the inlet basin perimeter (500 feet long).

23

The gated diversion spillway would be located on the east bank of the river and its function would be to open and allow floodwaters to enter the basin which contains the morning glory tunnel inlet. Seven 40-foot wide gates would be utilized to control these flows. These gates would be opened only when flooding conditions were being predicted. Otherwise, these gates would be kept closed at all times and no diversion of flows would occur.

The morning glory inlet would be contained in a basin lower in elevation than the river channel. This would allow the diversion of flows without increasing flood stages, and would, in fact, lower flood stages upstream of the inlet site. The basin would be 300 feet wide at its largest dimension and the floor would be 8 feet below the crest of the morning glory inlet to assure that flows would enter the inlet in a hydraulically efficient manner.

The tunnel would be 70,800 feet long and would have a circular shape with an inner diameter of 40 feet. The tunnel would be lined with a 2 foot thick layer of concrete for both tunnel support and for sealing the tunnel against groundwater infiltration and tunnel water exfiltration. The tunnel would follow a straight line route from the inlet to Little Falls and thence a straight line to the Third River outlet. To avoid surface disruption toward the mouth of the tunnel, and to keep the tunnel alignment deep in bedrock, it would be necessary to construct the tunnel well below sea level. For approximately 25 percent of its length, the invert of the tunnel would be below sea level starting at the lower end near the outlet.

The outlet location would be on the left bank of the Third River at its confluence with the Passaic River in a wide portion of the Third River and in a well defined valley of the stream. Flows exiting the tunnel would be directed into the Passaic River through the Route 21 bridge. The outlet site is well away from residential development and is currently used as an equipment and materials yard for a construction company. The Passaic Valley Sewage Commission (PVSC) Yantacaw pumping station is located downstream of the site.

The diverted flows would exit the tunnel through an upshaft to the surface at sea level (greatly reducing water velocity) and then flow out the enlarged mouth of the Third River and under Route 21 into the Passaic River as shown in the sketches on Figure C-34. The Route 21 bridge would be enlarged to accommodate the increased flows. Levees and floodwalls would be constructed on both banks of the Third River to protect those nearby areas from increased river stages estimated to be 13.9 feet NGVD as compared to 10.5 feet that would occur under

existing conditions for the 100-year design flows. Because the tunnel outlet would be in the tidal portion of the Passaic River, levees and floodwalls are the only suitable local protection measure for mitigating the increased flood stages. They would be required for this purpose from the Second River to upstream of the Saddle River. These additional flows, however, would have no effects on river stages downstream of the Rutgers Street Bridge because of the large flow capacity of the large navigation channel below that location.

In the Central Basin, channel improvements would be required along the Passaic River between Two Bridges and Beatties Dam. This improvement would be a trapezoidal channel 19,000 feet long, having a 180-foot bottom width, 1 on 2 side slopes, and an average excavation depth of 9 feet. In addition, Beatties Dam would also be replaced by a new structure consisting of 6 tainter gates which would be the same as shown in the sketch of the gates for the new Beatties Dam for the Double Inlet Building Block 23E on Figure C-49 presented later in this Section.

The operation of the tunnel would perform in the following manner. Under normal conditions, flows of up to approximately 5000 cfs (about the one year event) would pass through the river flow restrictor before diversion begins through the morning glory inlet into the tunnel. However, in the event of a floodwarning condition with accompanying river flows greater than 1000 cfs, the gates of the river diversion spillway to the morning glory inlet would be opened and a large portion (greater than 90%) of the flow would be diverted into the tunnel. Minimum flows would still pass downstream of the restrictor until the capacity of the tunnel is exceeded. At that point the gates in the flow restrictor structure would begin to open to allow flows exceeding design capacity to proceed downstream to prevent excessive flooding upstream. In the Central Basin, flood flows were targeted for reduction to the zero damage level along the Pompton River, however, this could not be accomplished in several low-lying areas. Under existing conditions, flows of 30,000 cfs or larger would occur for the 100 year frequency storm. With the tunnel improvement, flows would be reduced to about 5000 cfs.

The gates at the new Beatties Dam in Little Falls would normally be closed. However, during a flood event, they would be opened to enable the channel in the Passaic and Pompton Rivers to function to prevent flood damages. Flows in the Lower Valley would be significantly less than the flow that would occur under existing conditions.

The protection provided by this "Building Block" would approximate the 100 year level downstream from the tunnel inlet to Little Falls. Between Little Falls and Dundee Dam, the protection to these damage centers is variable but the 100 year event becomes equivalent to approximately less than a 10 year occurrence. Downstream of Dundee, a 100 year level of protection is provided by the mitigation measures extending from upstream of the Saddle River downstream to the vicinity of the Second River.

Building Block 23D. Building Block 23D is a 35-foot diameter single inlet tunnel from the Pompton River to the Third River, Figure C-44. This plan is based on the same concept as Building Block 23C. Because the size of the tunnel would be smaller, larger flows would be bypassed on the Pompton River and it would be necessary to provide a channel improvement on the Pompton River to contain these flows. This plan provides an opportunity to compare a smaller tunnel with a Pompton River channel against the larger tunnel without the Pompton channel in Building Block 23C. For this condition, the tunnel would divert 19,932 cfs of a total 100 year design flow of 30,875 cfs and bypass 10,943 cfs down the Pompton River channel. As in previous plans, the water would be returned to the Passaic River at the mouth of the Third River where the total flow would be 44,448 cfs. The flows are summarized in Table C-57.

Elements of the tunnel component are essentially the same as those in Building Block 23C except that the inlet and outlet structures would be scaled accordingly to adjust for bypass flows with the reduced tunnel size. This building block would also include a modified channel along the Passaic River from Beatties Dam at Little Falls to Two Bridges and along the Pompton River from Two Bridges to the Pompton River tunnel inlet, and a new Beatties Dam. The channel from Beatties Dam to Two Bridges, with the new Beatties Dam, would also be the same as described for Building Block 23C. But from that point, additional channel work along the Pompton River would be required. This channel would be 35,000 feet in length, with a bottom width ranging from 70 to 160 feet, and have 1 on 2 side slopes. The average depth of excavation would be 5 feet.

Operation of this plan would be basically the same as that described for Building Block 23C. The major difference is that there would be a larger bypass flow down the Pompton River. The gates at the new Beatties Dam would also be operated to open up the channel upstream along the Passaic and Pompton Rivers to reduce flood stages along those reaches.

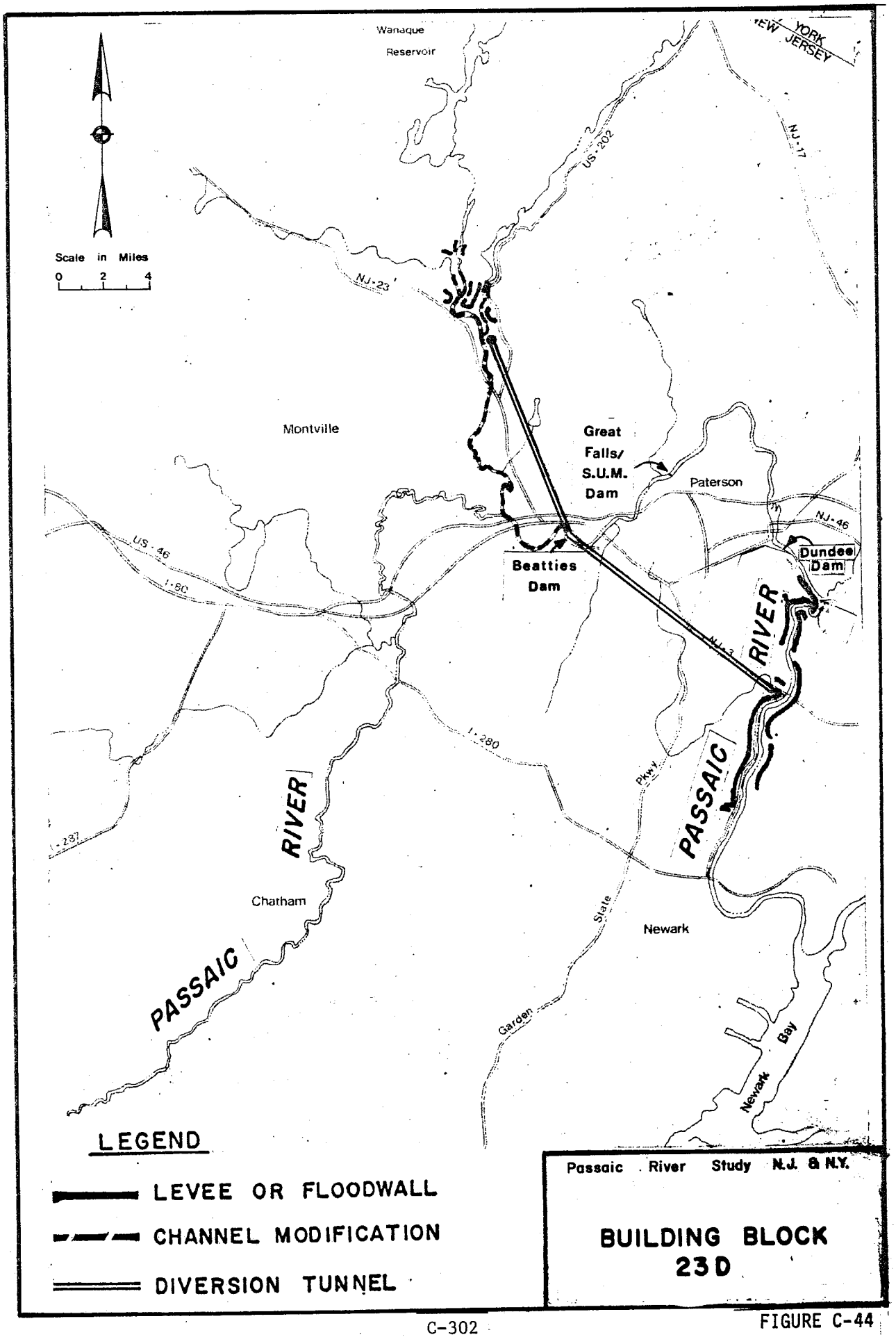

Wanaque
Reservoir
NEW YORK
NEW JERSEY
US-202
NJ-17
NJ-23
Scale in Miles
0 2 4
Montville
Great
Falls/
S.U.M.
Dam
Paterson
NJ-46
US-46
I-80
Beatties
Dam
Dundee
Dam
PASSAIC
RIVER
I-280
Pkwy
PASSAIC
RIVER
I-287
Chatham
State
Newark
Garden
Newark
Bay
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
BUILDING BLOCK
23D

FIGURE C-44

A 100 year level of protection would be provided along the channel improvement downstream of the tunnel inlet to Beatties Dam in Little Falls. Some benefits would also would be gained along the Passaic River upstream of Two Bridges. The Lower Valley between Little Falls and Dundee Dam would sustain some damage, but the 100 year flooding event would be reduced to approximately a 25 year event under existing conditions. Downstream of Dundee Dam, levee and floodwall, mitigation extending from the vicinity of Saddle River downstream to the Second River would provide a 100 year level of protection.

Building Block 23E. This "Building Block" is a double inlet tunnel plan consisting of a 40-foot diameter tunnel from the Pompton River to the Third River via Little Falls, Figure C-45. There would be two tunnel inlets, one at the upper Pompton River and the other at Little Falls as shown in Figures C-46 through C-49. This plan was developed to make more efficient use of the Pompton tunnel with the expectation that flows could be further reduced by a second inlet at Little Falls in the Lower Valley while operating the tunnel with a priority diversion at the Pompton River inlet. This "Building Block" is exactly the same as Building Block 23C, the 40-foot Pompton to Third River tunnel, with the exception of the second inlet at Little Falls. The double inlet takes advantage of the difference in timing of the flood flow peaks to make more effective use of the tunnel. The objective would be to divect as much flow as possible at the Pompton River inlet and then, if the tunnel flow were operating at a level less than capacity, allow additional flow to enter the tunnel at Little Falls by manipulating gates in the Little Falls river flow restrictor. If the inlets were both uncontrolled, the Little Falls inlet would hydraulically limit diversions at the Pompton River inlet and the effectiveness of this plan would be reduced. Therefore, the key to the functioning of this plan is the second inlet at Little Falls. The Little Falls inlet is basically the same as that developed for Building Block 23A but with four 8-foot high by 17.1-foot wide gated openings through the river flow restrictor structure as compared to the three 8-foot high by 8-foot wide openings in Building Block 23A. These larger culverts would allow large flows up to 7,525 cfs to be bypassed without diversion into the tunnel.

The effectiveness of this arrangement is illustrated by Table C-58 which shows that flows would be reduced an additional 13 to 16 percent in the Lower Valley to below Dundee Dam, when compared to the 40-foot Pompton River tunnel (Building Block 23C). This scheme would reduce the 100 year flood event to a 2-3 year event in the Lower Valley under existing conditions.

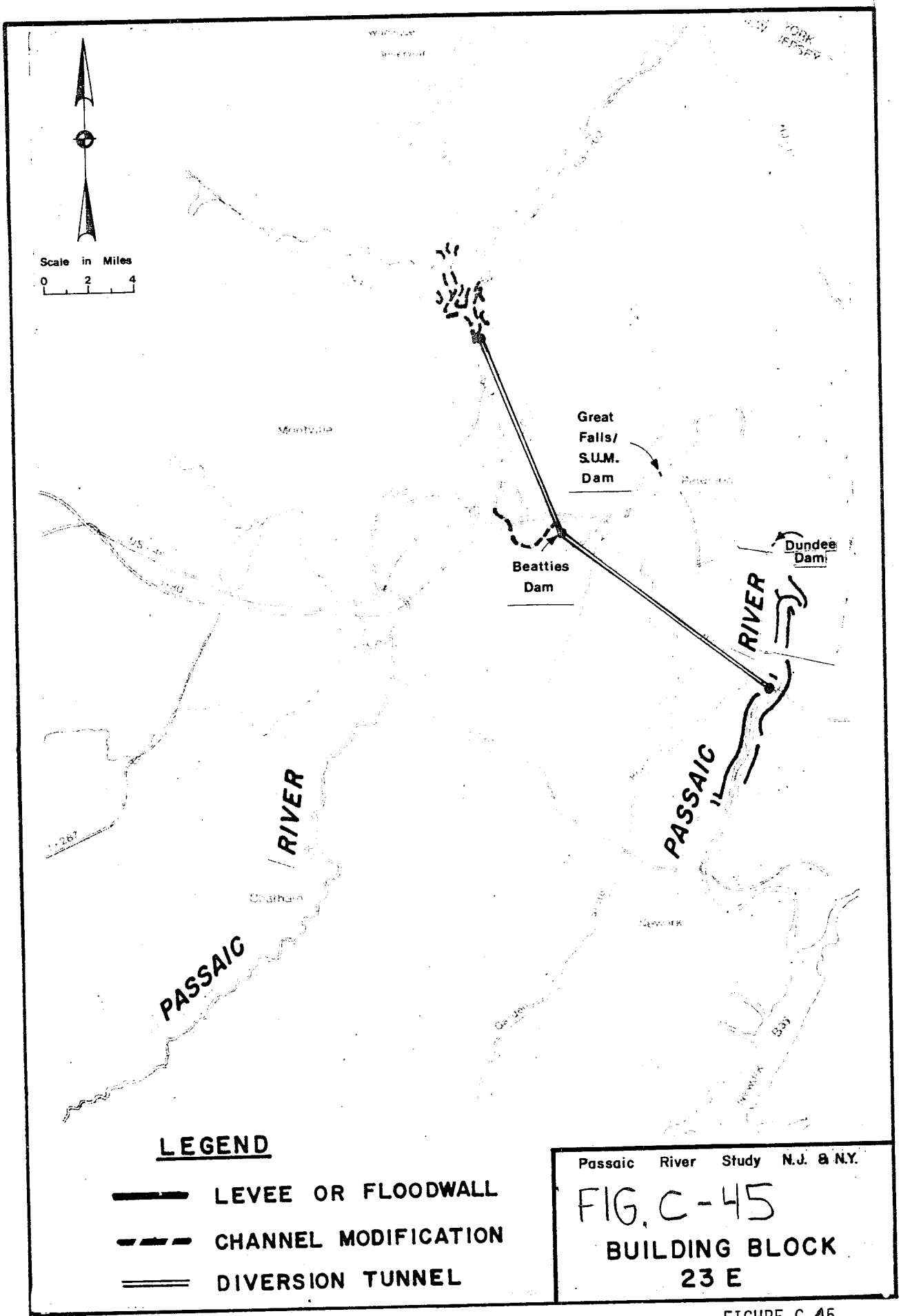
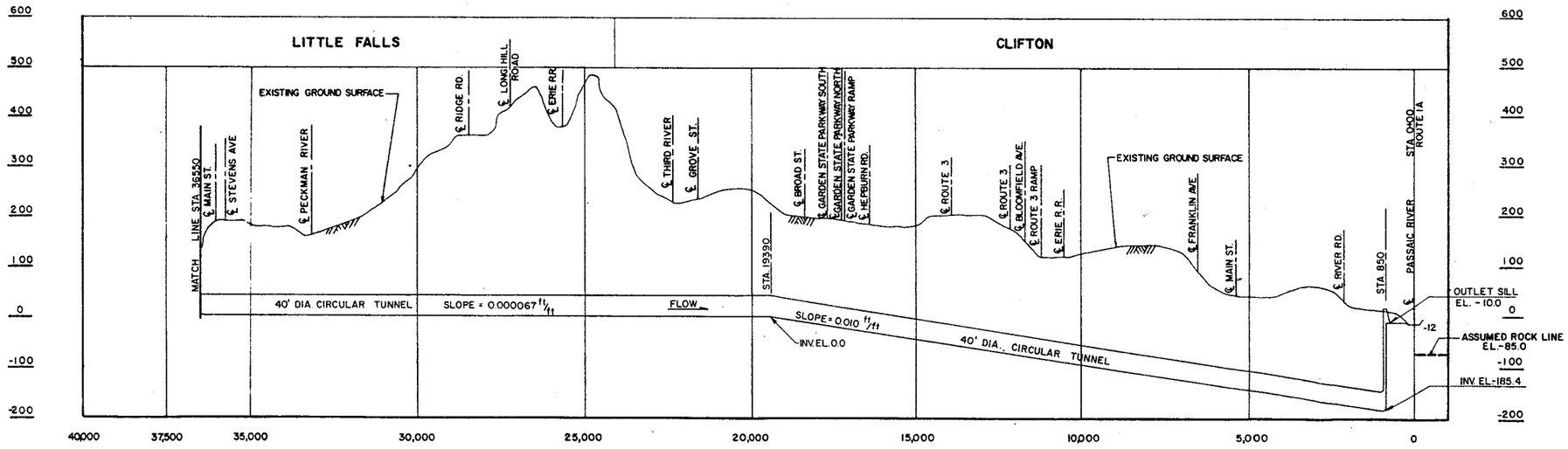

Scale in Miles
0 2 4
Great Falls/ S.U.M. Dam
Beatties Dam
Dundee Dam
PASSAIC RIVER
PASSAIC RIVER
Chatham
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
FIG. C-45
BUILDING BLOCK
23 E

FIGURE C-45



PLAN

SCALE IN FEET
1500 0 1500 3000



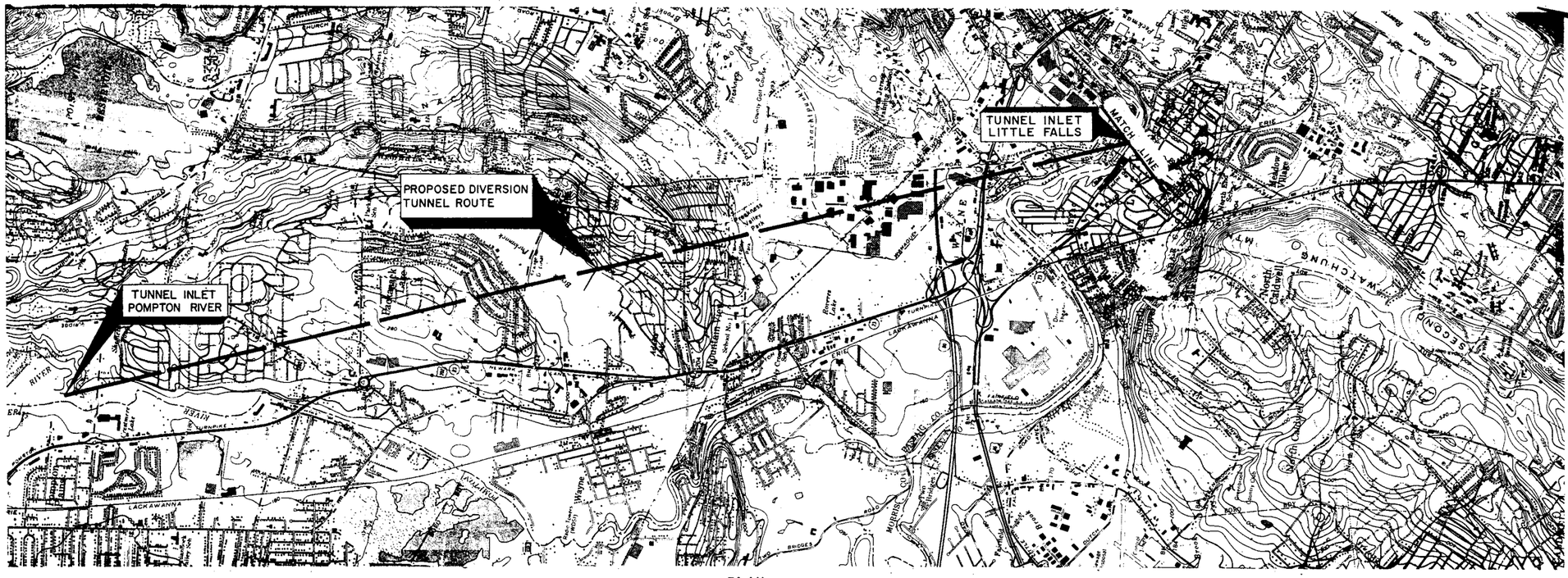
PROFILE OF DIVERSION TUNNEL

SCALE IN FEET
HORIZ. 1500 0 1500 3000
VERT. 100 0 100 200

Passaic River Basin, N.J. & N.Y.

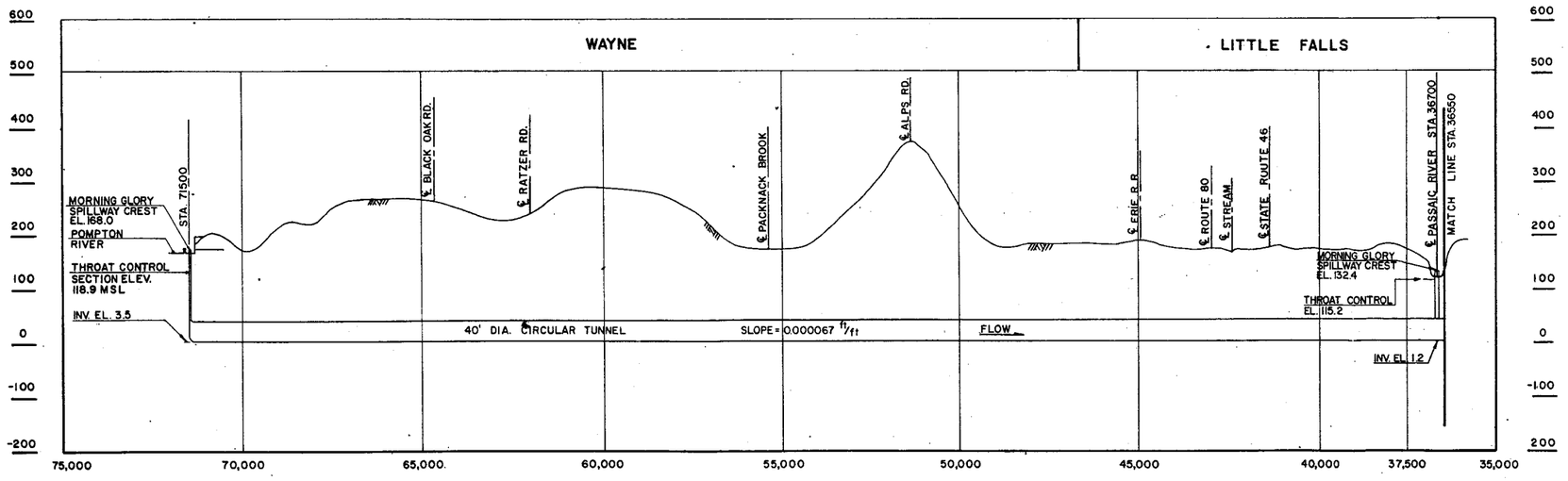
BUILDING BLOCK 23E
40 FOOT DOUBLE INLET TUNNEL
PLAN & PROFILE (1 OF 2)

FIGURE C-46



PLAN

SCALE IN FEET
1500 0 1500 3000



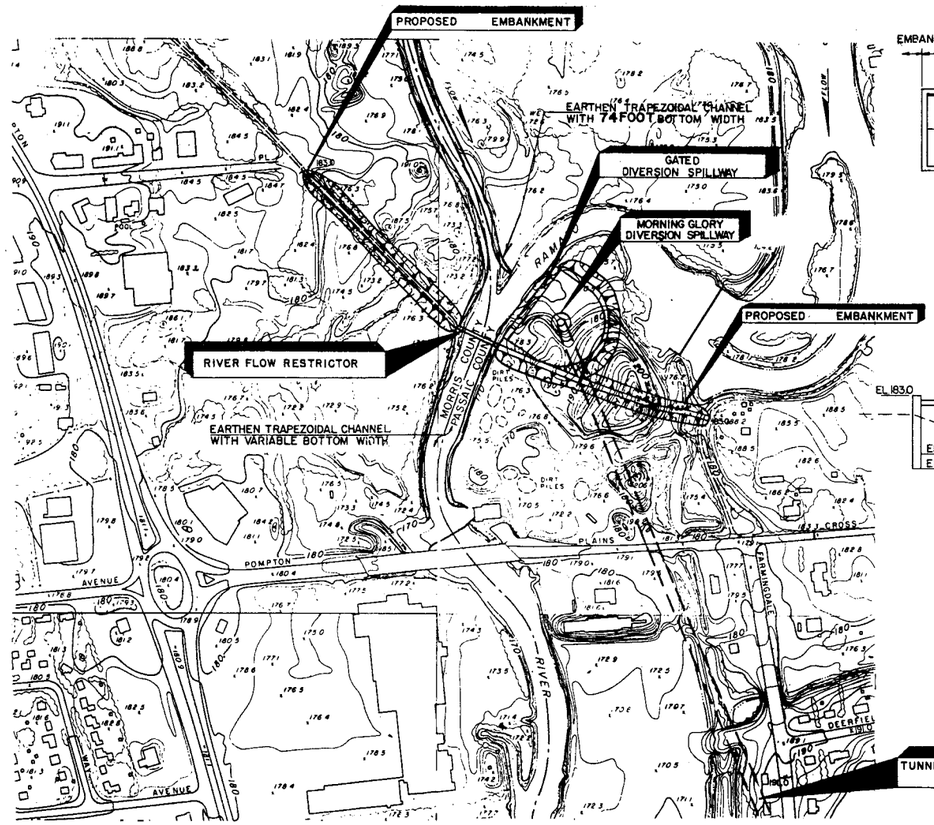
PROFILE OF DIVERSION TUNNEL

SCALE IN FEET
HORIZ, 1500 0 1500 3000
VERT. 100 0 100 200

Passaic River Basin, N.J. & N.Y.

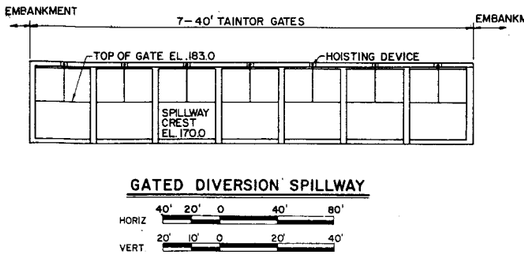
BUILDING BLOCK 23E
40 FOOT DOUBLE INLET TUNNEL
PLAN & PROFILE (2 OF 2)

FIGURE C-47



INLET LOCATION

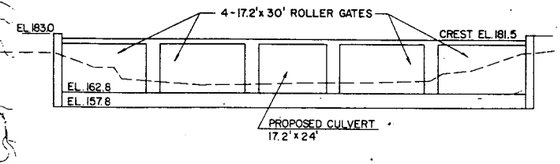
200' 100' 0 200' 400'



GATED DIVERSION SPILLWAY

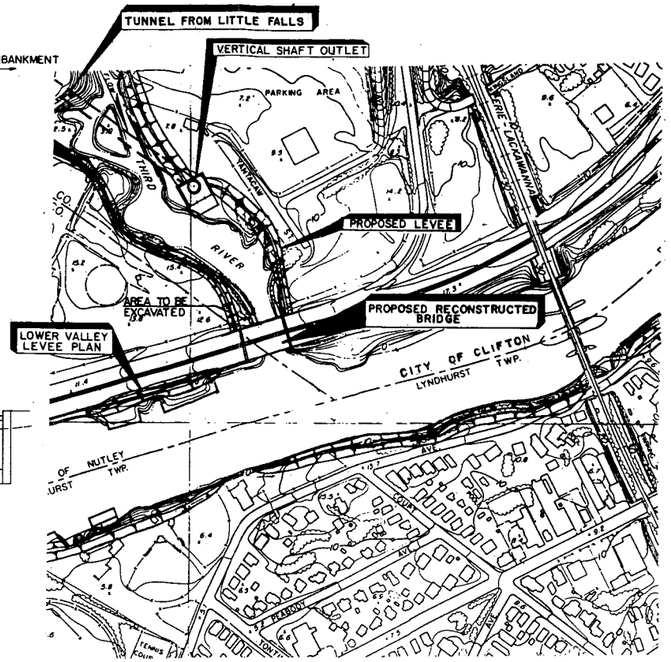
HORIZ 40' 20' 0 40' 80'

VERT 20' 10' 0 20' 40'



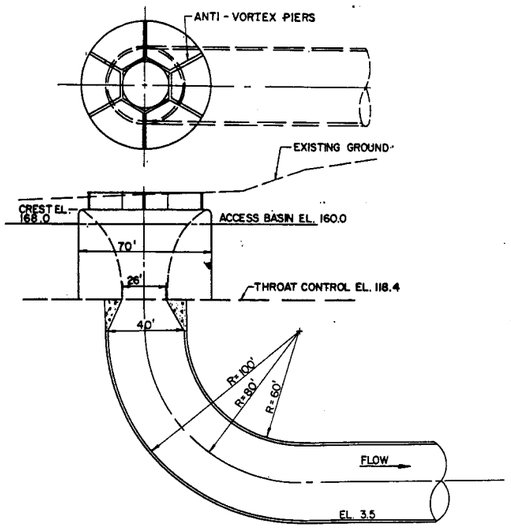
RIVER FLOW RESTRICTOR

20' 10' 0' 20' 40'



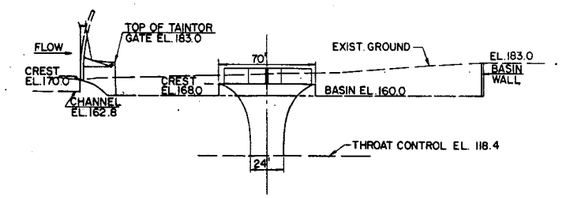
OUTLET LOCATION

200' 100' 0' 200' 400'



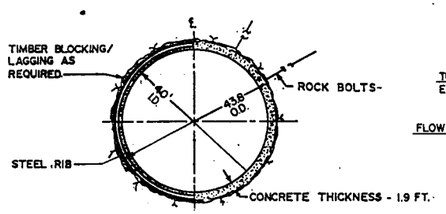
MORNING GLORY SPILLWAY

30' 20' 10' 0 30' 60'



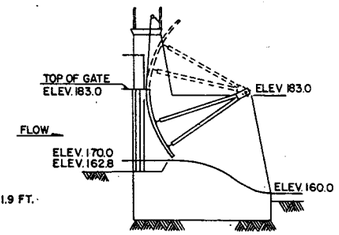
DIVERSION INLET SECTION VIEW

40' 20' 0 40' 80'



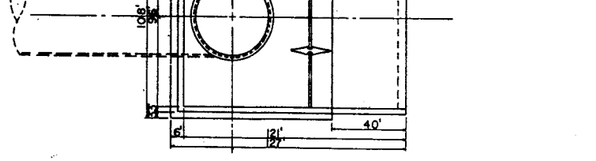
CIRCULAR TUNNEL SECTION

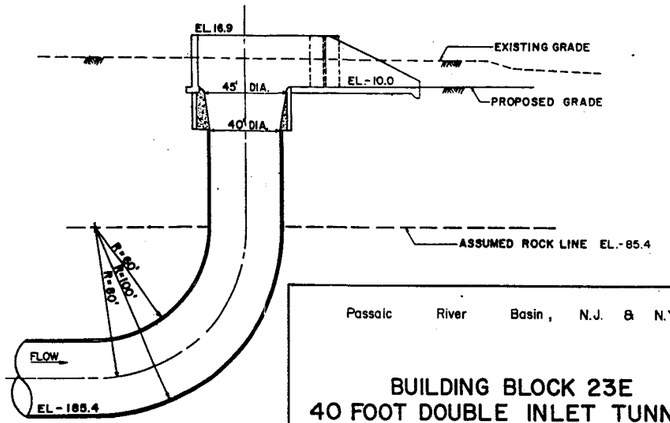
NOT TO SCALE



TAINTOR GATE SECTION

NOT TO SCALE





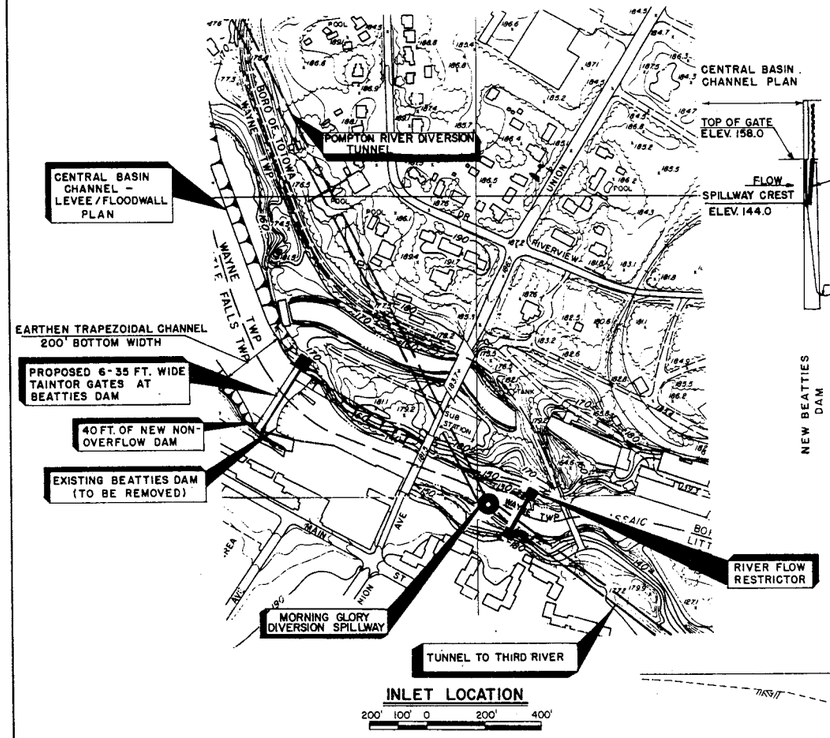
VERTICAL SHAFT OUTLET

30' 20' 10' 0 30' 60'

Passaic River Basin, N.J. & N.Y.

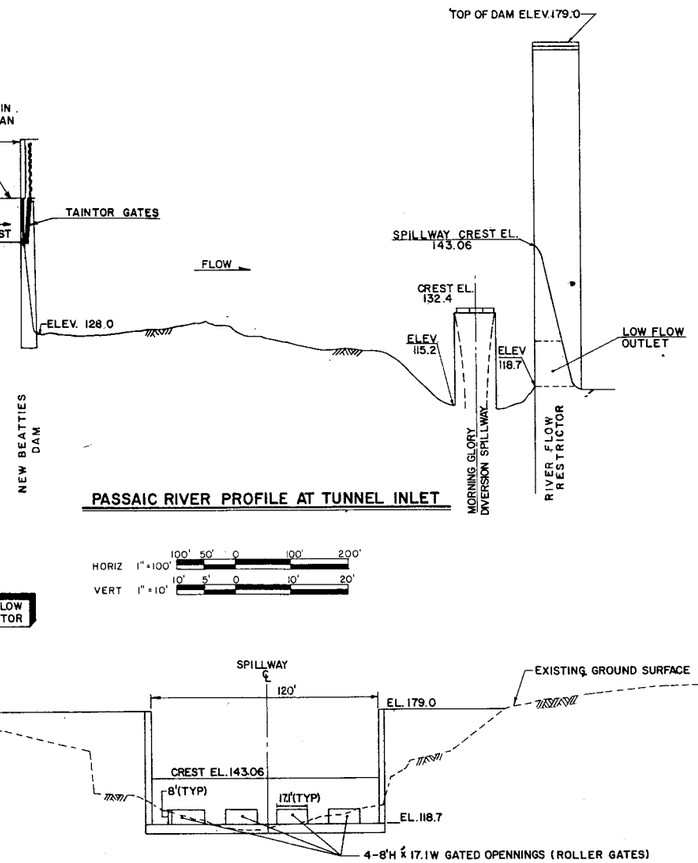
BUILDING BLOCK 23E
40 FOOT DOUBLE INLET TUNNEL
POMPTON RIVER
INLET & OUTLET SKETCHES

FIGURE C-48



INLET LOCATION

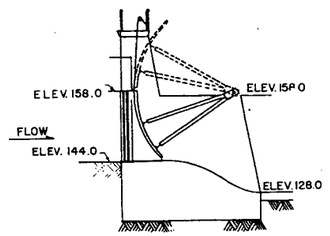
200' 100' 0 200' 400'



PASSAIC RIVER PROFILE AT TUNNEL INLET

HORIZ 1"=100' 100' 50' 0 100' 200'

VERT 1"=10' 10' 5' 0 10' 20'

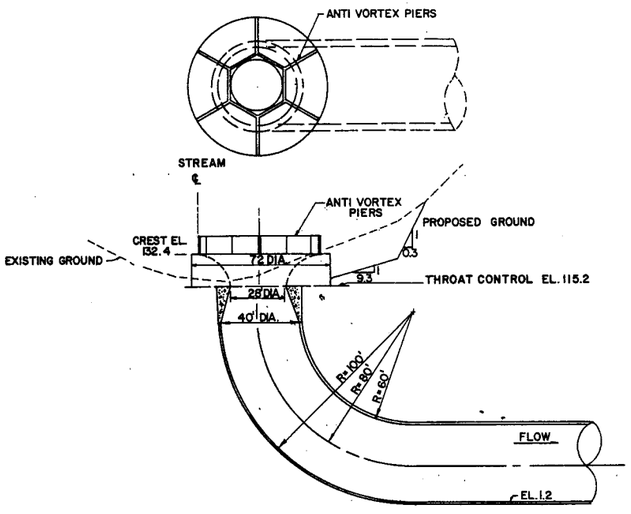


TAINTOR GATE SECTION

NOT TO SCALE

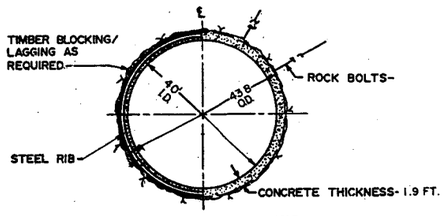
RIVER FLOW RESTRICTOR

30' 20' 10' 0 30' 60'



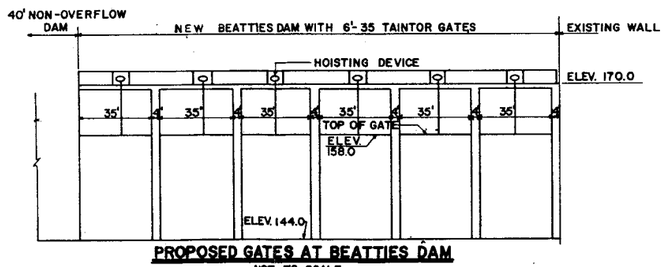
MORNING GLORY SPILLWAY

30' 20' 10' 0 30' 60'



CIRCULAR TUNNEL SECTION

NOT TO SCALE



PROPOSED GATES AT BEATTIES DAM

NOT TO SCALE

Passaic River Basin, N.J. & N.Y.

BUILDING BLOCK 23E
40 FOOT DOUBLE INLET TUNNEL
LITTLE FALLS
INLET & OUTLET SKETCHES

FIGURE C-49

This "Building Block" would require a monitoring system to assure efficient and effective operation. Until now, all previous plans required no elaborate control systems because, once the plans were put into operation, they would be uncontrolled and, in effect, control themselves. In this double inlet tunnel, the Pompton River inlet would be operated as described in Building Block 23C and once in operation, it would be uncontrolled. The inlet in this building block, however, would be closely monitored so that the available tunnel capacity would be known at Little Falls. This information, as well as data fed from various key locations in the basin, would aid in the decision making to determine how gates would be operated at Little Falls to maximize use of the tunnel.

The areas benefitting from this tunnel scheme are the same as those described in Building Block 23C. The only difference is in the Lower Valley between Little Falls and Dundee Dam where flows for the 100 year event would be reduced to the equivalent of less than a 5 year event as compared to less than a 10 year event for Building Block 23C.

Building Block 23F. This double inlet building block would utilize a 35-foot diameter tunnel from the Pompton River inlet to the Little Falls inlet where the tunnel section becomes is 40 feet in diameter as it continues to the Third River, Figure C-50. This scheme provides a comparison of the effectiveness of a smaller double inlet tunnel in order to reduce overall costs and maximize benefits. Like Building Block 23D (35-foot Pompton River tunnel), this scheme would also require channel modifications along the Passaic River from Beatties Dam, at Little Falls upstreamto Two Bridges, and along the Pompton River from Two Bridges to the Pompton River inlet. Channel modifications, levees and floodwalls would also be required upstream of the Pompton inlet along the Pequannock, Wanaque and Ramapo Rivers to divert flood flows to the tunnel. Although the physical features of this building block are exactly the same as the 35-foot Pompton River tunnel above Little Falls, the larger 40-foot tunnel below Little Falls allows the tunnel additional hydraulic capacity at the Pompton River inlet. In comparing the capacities of these two schemes downstream of Little Falls as given in Tables C-57 and C-58, the 35/40-foot double inlet tunnel reduces Lower Valley flows an additional 7 to 12 percent over the 35-foot single inlet Pompton River tunnel (Building Block 23D). These effects amount to reducing the 100 year event to the equivalent 20 year event.

This building block would utilize the same physical elements of the 40-foot double inlet tunnel at the Little Falls inlet and at the Third River outlet. The same monitoring and operating system would be required for this scheme. Benefits for this

25

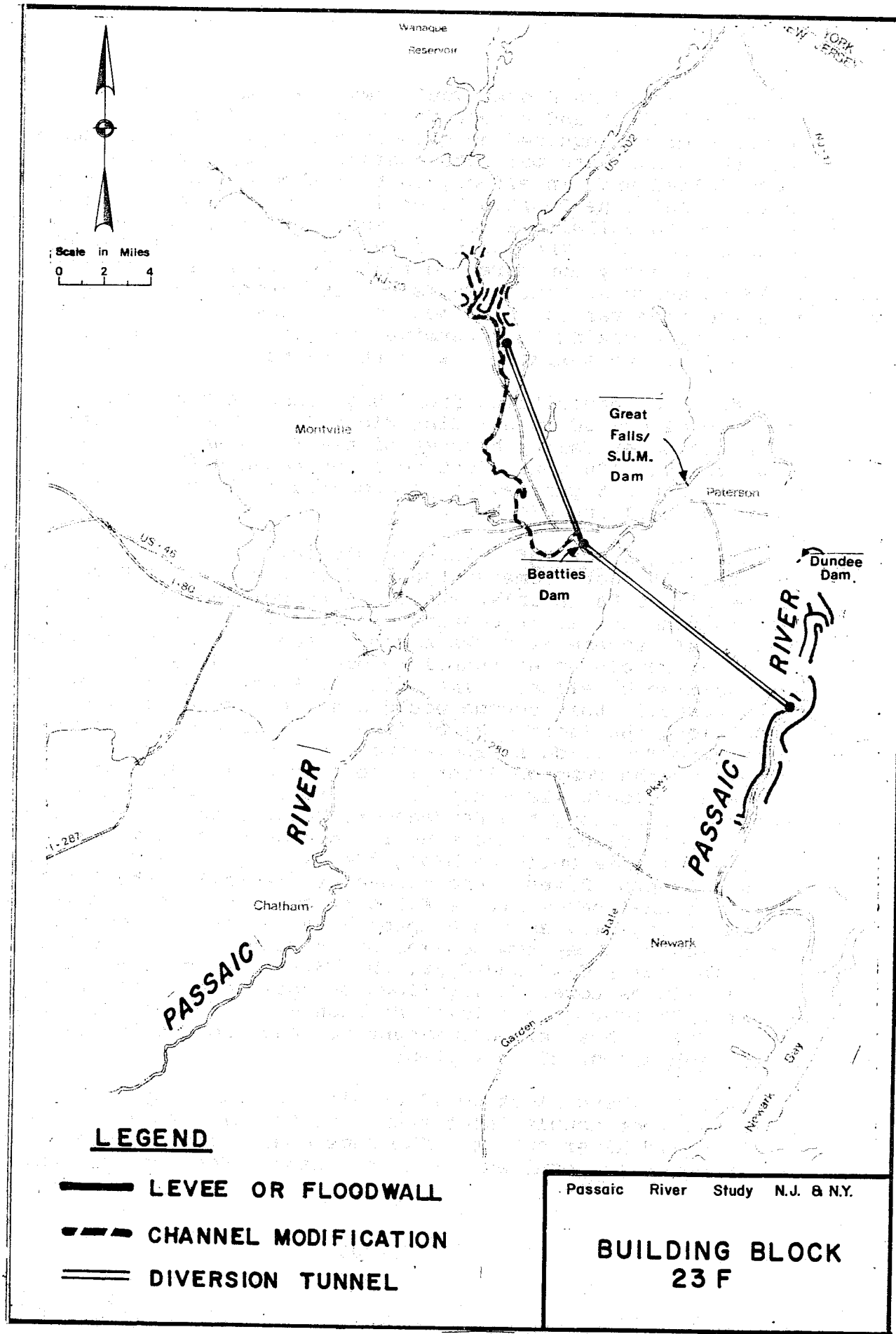

Wanaque
Reservoir
Scale in Miles
0 2 4
Montville
Great
Falls/
S.U.M.
Dam
Paterson
Beatties
Dam
Dundee
Dam
US-46
I-80
I-287
PASSAIC
RIVER
PASSAIC
RIVER
Chatham
Newark
Garden State Pkwy
Newark Bay
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
BUILDING BLOCK
23 F

FIGURE C-50

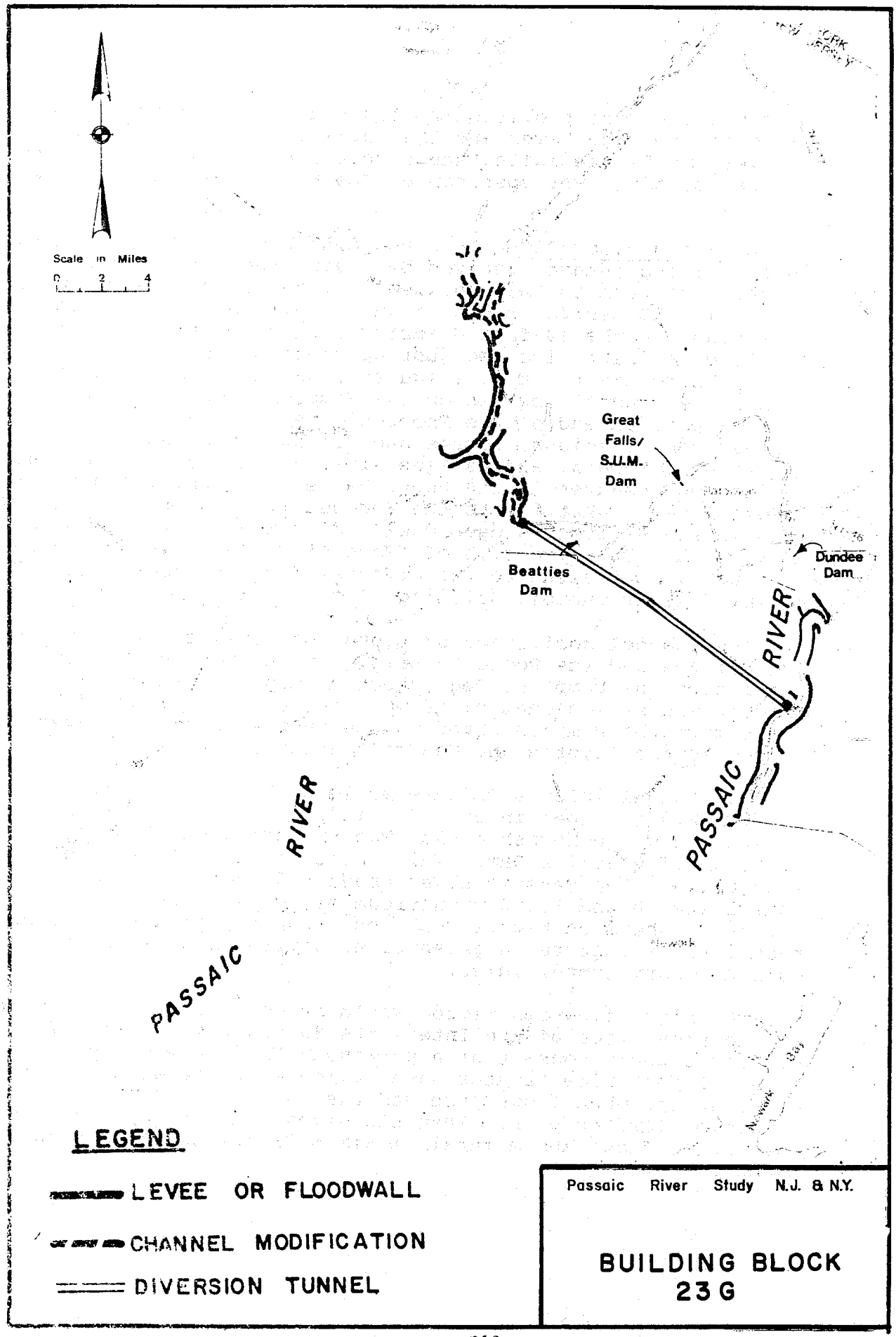
plan would be the provision of 100 year level of protection along the Pompton River and the Passaic River between Two Bridges and Little Falls, and significant flood stage reductions on the Passaic River upstream of Two Bridges and in the Lower Valley.

Building Block 23G. This building block offers a compromise in tunnel and channel lengths by moving the Little Falls inlet further upstream to the confluence of the Passaic and Pompton Rivers in the Central Basin, Figure C-51. Basic features of this plan are the 40-foot diameter single inlet tunnel from the Two Bridges inlet, located just upstream of the Route 80 Bridge, to the Third River outlet (Figures C-35 and C-52); a channel with levees and floodwalls on the Pompton River from Two Bridges to the upstream end of the Pompton River; extensions of the channel modifications, levees and floodwalls along the Pequannock, Ramapo, and Wanaque Rivers; and levee/ floodwall mitigation measures in the Lower Valley from the vicinity of the Saddle River downstream to the Second River to protect that area from increased flood stages due to discharge of tunnel flows in that reach. The diversion of flood flows for this scheme would be roughly equivalent to the effects of the 40-foot Little Falls to Third River tunnel, Building Block 23B.

The channel modifications along the Passaic River between Two Bridges and the Route 80 bridge in the Pompton Valley (including the Pompton, Pequannock, Ramapo and Wanque River) and a short transition channel segment function to direct flood flows down the Pompton River to the tunnel inlet and lower flood stages in the Pompton and Central Passaic River.

The tunnel inlet structure would be somewhat similar to the Pompton River tunnel inlet. The inlet structure would be located in Wayne Township near Two Bridges about 2 miles upstream of Beatties Dam. This inlet would be located on the east bank of the Passaic River about 500 feet upstream of Interstate 80 and 1,500 downstream of Two Bridges. The inlet structure shown on Figure C-35 would consist of a river flow restrictor structure, a gated river diversion spillway and a morning glory tunnel inlet.

The river flow restrictor would be constructed adjacent to the upstream face of the Interstate 80 highway bridge. The structure would consist of a permanent 55-foot wide opening and eight 32-foot wide tainter gates which would be closed at all times except when flows exceeded the 100 year design flow condition for the plan. Then the gates would be opened to pass the larger flows and maintain maximum diversion through the tunnel.



C-312

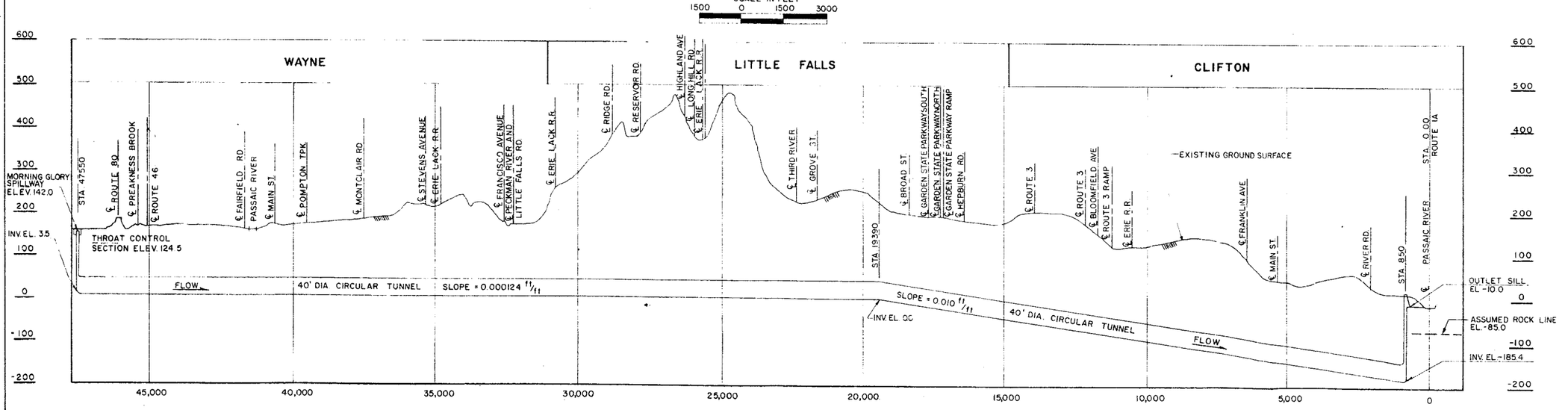
FIGURE C-51



PLAN

SCALE IN FEET

1500 0 1500 3000



PROFILE OF DIVERSION TUNNEL

SCALE IN FEET

HORIZ. 1500 0 1500 3000

VERT. 100 0 100 200

Passaic River Basin, N.J. & N.Y.

BUILDING BLOCK 23G
40 FOOT TWO BRIDGES TO THIRD RIVER TUNNEL
PLAN & PROFILE

FIGURE C-52

The gated diversion spillway would be located on the east bank of the river and its function would be to allow floodwaters to enter the basin which contains the morning glory inlet. Eight 40-foot wide gates would be utilized to control these flows. These gates would be opened only when flows exceeded 1,000 cfs and when flooding conditions were being predicted. These gates would otherwise be kept closed at all times and no diversion of flows would occur.

The morning glory inlet would be contained in a basin lower in elevation than the river channel. This would allow the diversion of flows without increasing flood stages upstream of the inlet site. They would in fact be lowered. The basin would be 300 feet wide at its largest dimension and the floor would be 8 feet below the crest of the morning glory inlet to assure that flows would enter the inlet in a hydraulically efficient manner.

The tunnel would be 46,700 feet long and would have a circular shape with an inner diameter of 40 feet. The tunnel would be lined with a 2-foot thick layer of concrete for tunnel support and for sealing the tunnel against groundwater infiltration and tunnel water exfiltration. The tunnel would follow a straight line route from the inlet to a work shaft site north of Cedar Grove Reservoir, then to the Third River outlet site. To avoid the surface disruption of cut and cover construction toward the mouth of the tunnel, and to keep the tunnel alignment deep in bedrock, it would be necessary to construct the tunnel below sea level. For approximately 40 percent of its length, the invert of the tunnel would be below sea level starting at the lower end near the outlet.

The function and design of the outlet structure for this building block are the same as that described for Building Block 23C and are shown on Figure C-35. Mitigation measures required because of the tunnel outlet discharges are the same as those described for Building Block 23A.

The operation of the tunnel, while similar to those procedures for the Pompton River tunnel inlet, has some minor variations. Beatties Dam and the river flow restrictor both serve to control and reduce the downstream momentum of flow so that the intake basin will receive flows efficiently. No flows would be diverted unless flooding conditions were predicted. However, in the event of a floodwarning condition with accompanying river flows greater than 1,000 cfs, the gates of the river diversion spillway to the morning glory inlet would be opened and a large portion (greater than 90%) of the flow would be diverted into the tunnel. Minimum flows would still pass downstream of the restrictor until the capacity of the tunnel is exceeded. At that point the gates in the river flow restrictor structure would begin to open to allow flows exceeding design

capacity to proceed downstream to prevent excessive flooding upstream. In the Central Basin, flood flows would be reduced to the zero damage level along the Pompton River. Under existing conditions flows of 26,000 cfs or larger would occur for the 100-year frequency storm. With the tunnel improvement, flows would be reduced to about 5,000 cfs in the upper reaches of the Lower Valley.

The Pompton River and the Passaic River between Little Falls and Two Bridges would be protected to the 100 year level while the Passaic River upstream of Two Bridges would have flood stages significantly reduced. In the Lower Valley, protection would be variable but would approximate Building Block 23B by reducing the 100 year event to between less than a 1 to 10 year event under current conditions. Downstream, between Dundee Dam and the Second River, the levee/floodwall mitigation measures would provide a 100 year level of protection from the effects of the tunnel discharges at the Passaic River's confluence with the Third River.

BUILDING BLOCK 27 - TIDAL BARRIER

Building Block 27 is a tidal barrier plan designed to protect the lower reaches of the Passaic River from tidal flooding. The expected 2040 conditions 100 year tide elevation of 10.0 NGVD controls flooding along the Passaic River and its tributaries from the mouth upstream to N.J. Route 3 in the City of Passaic. At this point the flooding is caused by both tidal and fluvial flooding. Fluvial flows control the hydraulic system upstream of this point, with the tidal influence gradually diminishing upstream to Dundee Dam.

The purpose of the tidal barrier is to prevent unusually high tides, caused by storm surges, from entering the lower Passaic River Basin. The facility would also have the capability to pump normal and flood flows through the closed barrier to prevent ponding. The tidal barrier would have sector gates that remain open under normal conditions and would be closed only when storm influenced tides are predicted to exceed 5.0 feet NGVD, which is less than the 1 year tidal elevation of 5.5 ft. NGVD under expected 2040 conditions.

The design of the tidal barrier is based upon the parameters of location, navigational concerns of the channel, velocity of tidal currents and cost of the barrier and appurtenant structures.

The Passaic River is a navigable river. The Federal navigation channel extends from the mouth up to the Eighth Street Bridge in Wallington, a distance of approximately 15 miles. The deep draft navigation channel within Newark Bay extends upstream in the Passaic River to the railroad swing

bridge, which is located downstream of the New Jersey Turnpike in Kearny. Along the Passaic River, the first 2.5 miles is maintained at a depth of 30 feet (elevation -32.4) with a channel width of 300 feet. Upstream from the 30-foot deep channel for the next 4.5 miles, the channel is 20 feet deep and 300 feet wide. Navigation access would be maintained by an opening through the tidal barrier which would be closed by two sector gates during extremely high floods. In determining the width of the navigational structure, investigation of types of vessels that use the Passaic River waterway was made. It was determined that a 100 foot wide navigational structure would provide enough maneuverability for the largest vessels that use this waterway.

For flood protection purposes, the closer the barrier is to the mouth of the river, the greater is the flood damage reduction potential. This is true since the tidal barrier would offer protection to a greater portion of the river which would otherwise need levees and floodwalls to protect it from high storm tides. If, however, the barrier could be located further upstream in the shallow draft channel, a smaller and less expensive barrier could be constructed. An upstream tidal barrier would result in less interference with river traffic. Therefore, two potential sites for a tidal barrier were investigated and evaluated. The first site is located immediately upstream of the New Jersey Turnpike Bridge, in the extreme lower reaches of the shallow draft 20-foot navigation channel. In this location, the natural channel width is 800 feet from bank to bank. However, from its easterly direction, the Passaic River turns to the south just downstream of the site after passing through the N.J. Turnpike and railroad bridges which hinders navigational movement. The second site is located near the mouth of the Passaic River in the vicinity of the abandoned Central Railroad of New Jersey river crossing within the 30-foot navigation channel. The natural channel width is 700 feet wide at this location but expands to 1,100 feet immediately downstream.

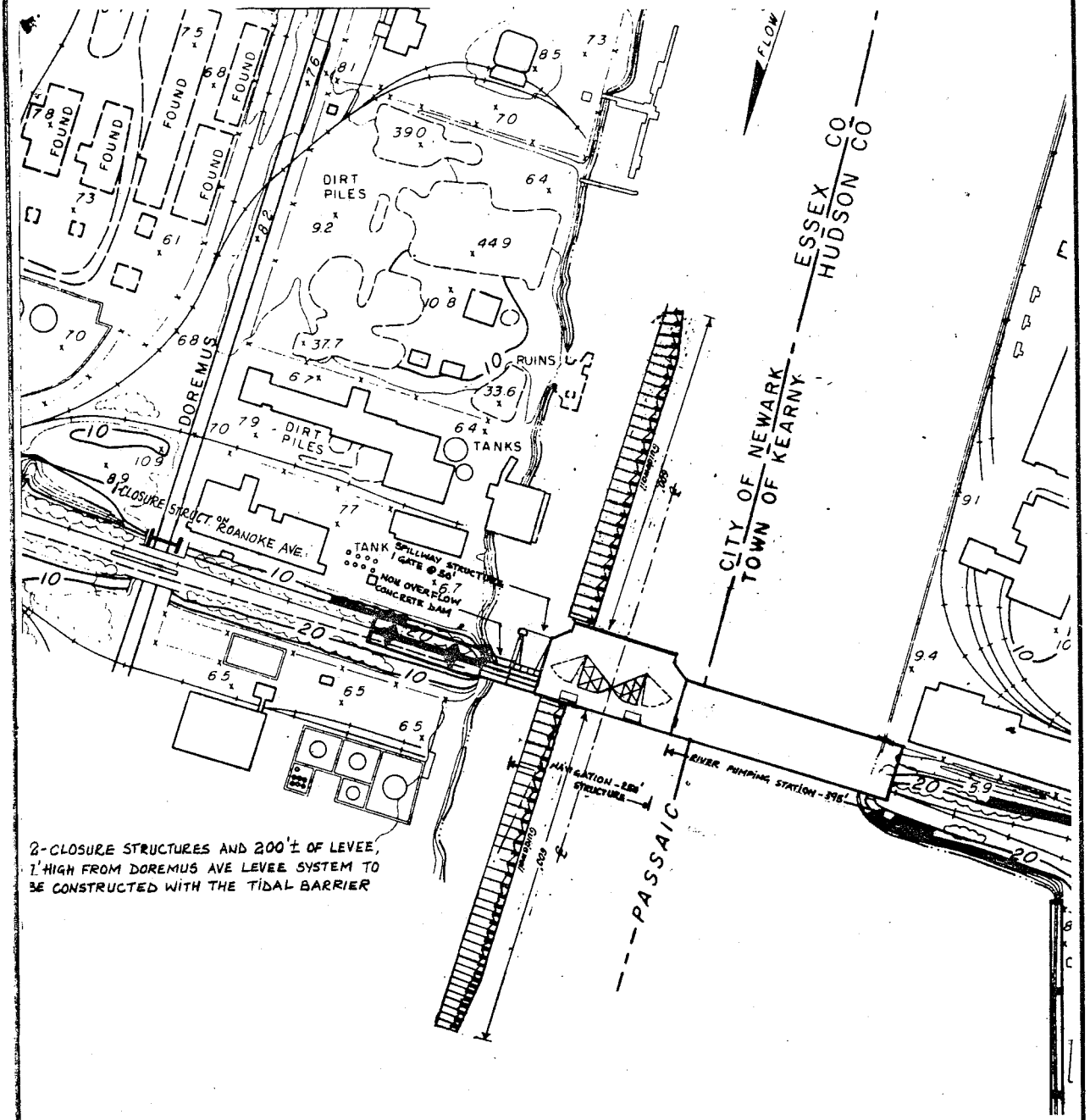
An evaluation of the navigational aspects of the two sites indicated that navigation conditions at the first (upper) site would be unacceptable due to the two bridges located immediately downstream. In addition, the narrow channel would limit turning and mooring of ships during periods when the barrier was closed, and the 90 degree bend in the river would be a hindrance to safe navigation with the barrier in this location. These constraints do not exist at the lower site. The wider channel downstream at the head of Newark Bay provides space for mooring and maneuvering, and the straight channel alignment minimizes navigational problems. In addition, approximately 5,000 feet of levee and 6,000 feet of floodwall can be eliminated if the tidal barrier is located at the lower site.

As shown in Figure C-53, the proposed barrier consists of a 100 foot wide navigation opening with two sector gates for closure during extreme tides, a short non-overflow concrete dam, a 50-foot wide spillway gate and a low head river pumping plant. Velocity calculations indicated that a maximum tidal flow of 12,000 cfs during spring tides would give rise to a velocity of 1.5 to 2 fps. It was determined that in addition to the navigation structure opening, a 50-foot wide spillway gate would be constructed to pass the normal tidal flows. The top of the barrier would be 15 feet NGVD. This alternative provides protection against the 100 year tide plus five feet of freeboard under expected 2040 conditions. Preliminary analysis indicates that the pumping station would be required to handle 20,000 cfs during the occurrence of a 100 year event, while the barrier is closed. The design and cost of the pumping station used for the Passaic River Study were based on the design presented for the Hackensack River barrier study.

To complete the closure necessary to protect the tidal influenced damage areas, approximately 100 feet of levee and 12,600 feet of floodwall are required with the tidal barrier. The major portion of this local protection is located in Kearny downstream of the barrier and around Kearny Point to closure upstream at the major railroad bridges on the Hackensack River. This local protection is similar to the local protection system presented in Building Block 13A discussed earlier in this section. To provide comparable protection with levees and floodwalls, 35,000 feet of levees and 30,000 feet of floodwall would be required for the corresponding reaches in Plan 13A.

The total project cost of the tidal barrier and all necessary levee/floodwalls to protect the lower reaches of the Passaic River is $152 million (October 1985 price levels). The total annual cost is $18.6 million. Included in the annual costs were: annual capital costs; operation and maintenance costs which include electric power costs; energy capacity charge; and interim replacement costs.

The tidal barrier was designed to be operated under existing condition hydraulics. The economic analysis indicated that the tidal barrier is not economically feasible, therefore, this alternative has been dropped from consideration as a component of a basin-wide plan. If combined with tunnel alternatives, the existing tidal barrier design would have required revision to accommodate the increase in flow. The resulting scheme would also be economically infeasible.



Passaic River Study N.J. & N.Y.

TIDAL BARRIER

BUILDING BLOCK 27

FIGURE C-53 340

III - INTERMEDIATE STAGE PLANS

INTRODUCTION

The "Building Blocks" discussed in the previous section which were found to warrant further study were utilized in various combinations to formulate more than 150 Intermediate Stage alternatives. This array was screened to a somewhat more manageable number (approximately 80 plans and "Building Blocks"), as summarized in Table C-60, and as presented below. As presented in Table C-33, 12 "Building Blocks" and 36 plans were found to be economically feasible. Tunnel diversion measures are central elements to approximately 80% of the plans found feasible. In each case, only those benefit categories needed to determine economic feasibility were included.

It is noted that a number of the plans presented below involve combinations of nonstructural and structural local protection measures. The plans developed were limited to the uniform application of measures for major plan formulation reaches. Such a limit was placed on the formulation in order to keep the level of detail and number of alternatives to a reasonable array; the actual number of combinations within each reach is extremely large and the resulting development of plans well beyond the scope of this study, while serving no useful purpose at this time. Coordination of the plans presented below with municipal and local interests, and coordination through the public involvement program guided the refinement of plans within major reaches while focusing nonstructural/structural trade-offs in a meaningful direction during subsequent iterations of the plan formulation process.

PLAN 5 - PERMANENT EVACUATION, FLOODPROOF/RAISING, DAM AND BRIDGE MODIFICATION

An analysis was made of combining Building Block 3 with Building Block 4 in order to determine if levels of protection could be increased. It was concluded that the raising of bridges would require substantial road modifications and was not economically justified. The three existing dams were also analyzed and it was determined that to have significant reductions in stages upstream of each dam, channel modifications, in addition to the dam modification, would be required. This plan, Plan 5, was not economically justified and was eliminated from further consideration.

TABLE C-60 - SUMMARY OF INTERMEDIATE PLAN FORMULATION

PLAN	LEVEL OF PROTEC-TION	PLAN ECONOMI-CALLY FEASIBLE	MEASURES NOT EFFIC &/OR COMPL	PLAN NOT ECONOMICALLY FEASIBLE	PLAN FORMULATION REACHES 1 TIDAL (DS RT 3)	2 FLUVIAL RT 3-BEATTIES	TUNNEL ELEMENTS	3 BEATTIES TO TWO BRIDGES	TUNNEL ELEMENTS	4 POMPTON RIVER	5 TWO BRIDGES TO CHATHAM
5-PE/FP/R/ D&B MOD (BBS 3&4)	-		X	X	NS	NS	-	NS	-	NS[3]	NS
7A-CM (BLDG BLK)	100 YR	X			-	100 YR CM	-	-	-	-	-
7B-CM (BLDG BLK)	50 YR	X			-[1]	50 YR CM		-[1]	-	-[1,3]	-[1]
8-CM/PE (BBS 7A+1E)	10-100 YR	X	X		PE	100 YR CM	-	PE	-	PE	PE
9-CM/FP/R (BBS 7+2)	-		X	X			-		-		
10A-CM/NS (BBS 7A+3C)	100 YR			X	NS	100 YR CM	-	NS	-	NS[3]	NS
10B-CM/NS (BBS 7B+3C)	100 YR			X	NS	50 YR CM+NS	-	NS	-	NS[3]	NS
12-PE/LEV (BBS 1+11)	-		X								
13A-LEV (BLDG BLK)	100 YR	X			LEV	LEV	-	-	-	-	LEV
13B-LEV (BLDG BLK)	SPF			X	LEV	LEV	-	-[1]	-	-[3,1]	LEV[1]
14A-LEV/NS (BBS 3A+13A)	10-100 YR	X			LEV	LEV	-	NS	-	NS[3]	LEV+NS
14B-LEV/PE (BBS 1E+13A)	10-100 YR	X			LEV	LEV	-	PE	-	PE[3]	LEV
15A-CM/LEV (BBS 7+13A)	100 YR	X			LEV	100 YR CM+LEV	-	CM	-	CM+LEV[3]	LEV
15B-CM/LEV (BBS 7+13A)	100 YR	X			LEV	50 YR CM+LEV	-	-[1]	-	-[3,1]	-[1]
16A-CM/LEV/NS (7A+14A)	100 YR	X			LEV	100 YR CM	-	NS	-	NS[3]	LEV+NS
16B-CM/LEV/NS (3+15A)	100 YR	X			LEV	100 YR CM+LEV	-	CM	-	CM+LEV[3]	NS
16C-CM/LEV/NS (3+15B)	100 YR			X	LEV	50 YR CM+LEV	-	NS	-	NS[3]	NS
19-RESERVOIRS	-		X								
22-AQUIF RECH/OTH MEAS	-		X	X							
23A-TUN (BLDG BLK)	VARIABLE	X			-	-	3RD R OUT;LEV	CM	LT FLS IN;35'	CM+LEV[2]	-
23B-TUN (BLDG BLK)	VARIABLE	X			-	-	3RD R OUT;LEV	CM	LT FLS IN;40'	CM+LEV[2]	-
23C-TUN (BLDG BLK)	VARIABLE	X			-	-	3RD R OUT;LEV	CM	POMPT. IN;40'	-[2]	-
23D-TUN (BLDG BLK)	VARIABLE	X			-	-	3RD R OUT;LEV	CM	POMPT. IN;35'	CM[2]	-
23E-TUN (BLDG BLK)	VARIABLE	X			-	-	3RD R OUT;LEV	CM	DUAL IN;40'	-[2]	-
23F-TUN (BLDG BLK)	VARIABLE	X			-	-	3RD R OUT;LEV	CM	DUAL IN;35/40'	CM[2]	-
23G-TUN (BLDG BLK)	VARIABLE	X			-	-	3RD R OUT;LEV	-	TWO BR. IN;40'	CM+LEV[2]	-
24-RES/TUN (BBS 19+23)	-		X								
28A-TUN/NS (BBS 23+3)	100 YR	X			NS	-	23A	CM	23A	CM+LEV[2]	NS
28B-TUN/NS (BBS 23+3)	100 YR	X			NS	-	23B	CM	23B	CM+LEV[2]	NS
28C1-TUN/NS (BBS 23+3)	100 YR	X			NS	-	23C	CM	23C	NS[2]	NS
28C2-TUN/NS (BBS 23+3)	100 YR	X			NS	-	23C	NS	23C	NS[2]	NS

TABLE C-60 - SUMMARY OF INTERMEDIATE PLAN FORMULATION (CONT)

PLAN	LEVEL OF PROTEC-TION	PLAN ECONOMI-CALLY FEASIBLE	MEASURES NOT EFFIC &/OR COMPL	PLAN NOT ECONOMICALLY FEASIBLE	PLAN FORMULATION REACHES 1 TIDAL (DS RT 3)	2 FLUVIAL RT 3-BEATTIES	3 BEATTIES TO TUNNEL ELEMENTS	3 TWO BRIDGES	4 TUNNEL ELEMENTS	4 POMPTON RIVER	5 TWO BRIDGES TO CHATHAM
28C3-TUN/NS (BBS 23+3)	100 YR	X			NS	-	23C	PE	23C	PE+NS[2]	NS
28D-TUN/NS (BBS 23+3)	100 YR	X			NS	-	23D	CM	23D	CM+NS[2]	NS
28E1-TUN/NS (BBS 23+3)	100 YR	X			NS	-	23E	CM	23E	NS[2]	NS
28E2-TUN/NS (BBS 23+3)	100 YR	X			NS	-	23E	NS	23E	NS[2]	NS
28E3-TUN/NS (BBS 23+3)	100 YR	X			NS	-	23E	PE	23E	PE+NS[2]	NS
28F-TUN/NS (BBS 23+3)	100 YR	X			NS	-	23F	CM	23F	CM+NS[2]	NS
28G-TUN/NS (BBS 23+3)	100 YR	X			NS	-	23G	-	23G	CM+LEV[2]	NS
29A-G-TUN/CM (BBS 23+7)	-		X								
30A-TUN/LEV (BBS 23+13)	100 YR	X			LEV	LEV	23A	CM	23A	CM+LEV[2]	LEV
30B-TUN/LEV (BBS 23+13)	100 YR	X			LEV	LEV	23B	CM	23B	CM+LEV[2]	LEV
30C-TUN/LEV (BBS 23+13)	100 YR	X			LEV	LEV	23C	CM	23C	-[2]	LEV
30D-TUN/LEV (BBS 23+13)	100 YR	X			LEV	LEV	23D	CM	23D	CM[2]	LEV
30E-TUN/LEV (BBS 23+13)	100 YR	X			LEV	LEV	23E	CM	23E	-[2]	LEV
30F-TUN/LEV (BBS 23+13)	100 YR	X			LEV	LEV	23F	CM	23F	CM[2]	LEV
30G-TUN/LEV (BBS 23+13)	100 YR	X			LEV	LEV	23G	-	23G	CM+LEV[2]	LEV
31A-G-TUN/LEV/CM (23+15)	-		X								
32A-G-TUN/CM/NS (23+10)	-		X	X							
33A-TUN/LEV/NS (23+14)	100 YR	X			LEV	LEV	23A	CM	23A	CM+LEV[2]	LEV+NS
33B-TUN/LEV/NS (23+14)	100 YR	X			LEV	LEV	23B	CM	23B	CM+LEV[2]	LEV+NS
33C1-TUN/LEV/NS (23+14)	100 YR	X			LEV	LEV	23C	CM	23C	NS[2]	LEV+NS
33C2-TUN/LEV/NS (23+14)	100 YR	X			LEV	LEV	23C	NS	23C	NS[2]	LEV+NS
33C3-TUN/LEV/NS (23+14)	100 YR	X			LEV	LEV	23C	PE	23C	PE+NS[2]	LEV+NS
33D-TUN/LEV/NS (23+14)	100 YR	X			LEV	LEV	23D	CM	23D	CM+NS[2]	LEV+NS
33E1-TUN/LEV/NS (23+14)	100 YR	X			LEV	LEV	23E	CM	23E	NS[2]	LEV+NS
33E2-TUN/LEV/NS (23+14)	100 YR	X			LEV	LEV	23E	NS	23E	NS[2]	LEV+NS
33E3-TUN/LEV/NS (23+14)	100 YR	X			LEV	LEV	23E	PE	23E	PE+NS[2]	LEV+NS
33F-TUN/LEV/NS (23+14)	100 YR	X			LEV	LEV	23F	CM	23F	CM+NS[2]	LEV+NS
33G-TUN/LEV/NS (23+14)	100 YR	X			LEV	LEV	23G	-	23G	CM+LEV[2]	LEV+NS
34A-G-TUN/LEV/CM/NS (23+16)	-		X								

LEGEND: BBS = BUILDING BLOCKS
PE = PERMANENT EVACUATION
D&B = DAM & BRIDGE MODIFICATION
CM = CHANNEL MODIFICATION
FP = FLOODPROOFING
R = RAISING
LEV = LEVEE/FLOODWALL
TUN = TUNNEL
NS = NON-STRUCTURAL (FP, R, PE)

1 NS = 10 YEAR LEVEL OF PROTECTION
2 TUNNEL INLETS INCLUDE ASSOCIATED SURFACE WORKS ON THE LOWER RAMAPO, PEQUANNOCK, AND WANAQUE RIVERS
3 ALSO INCLUDES THESE MEASURES ALONG THE LOWER RAMAPO, PEQUANNOCK AND WANAQUE RIVERS

PLAN 8 - CHANNEL MODIFICATION, PERMANENT EVACUATION

This plan was a combination of channel modification and permanent evacuation. As described in Building Block 1, permanent evacuation of floodprone structures was feasible in only a minimal number of reaches, and only for 10 year flooding under existing conditions. Therefore, this plan combined the permanent evacuation in Building Block 1E with the channel modification described in Building Block 7A. Although this plan was economically feasible, it was eliminated from further consideration since it would provide highly variable and localized protection, ranging from a 10 year level in the permanent evacuation reaches to a 100 year level in the channel modification reaches. As such, it was considered an incomplete plan.

PLAN 9 - CHANNEL MODIFICATION, FLOODPROOF/RAISING

This alternative combined floodproofing and raising (Building Block 2) with channel modification (Building Block 7). Evaluation of this plan determined that combining nonstructural measures with channel modification would not be economically feasible. Therefore, this plan was eliminated from further consideration.

PLAN 10A - CHANNEL MODIFICATION, FLOODPROOF/RAISING, PERMANENT EVACUATION

This alternative combined Building Block 3C (raising, floodproofing, and permanent evacuation) in the Central Basin area and tidal reach of the Lower Valley with the channel modification in the Lower Valley described in Building Block 7A to provide a continuous 100 year level of protection throughout the Basin. This plan was not economically justified and was screened from further consideration.

PLAN 10B

This alternative combined the structural improvements discussed in Building Block 7B with raising, floodproofing, and permanent evacuation measures. The Central Basin and tidal reach of the Lower Valley would be provided with a 100 year level of protection by measures identical to those discussed in Building Block 3C, since no structural improvements would be implemented in these areas. This plan would raise the level of protection in the Lower Valley from the 50 year (Building Block 7B) to the 100 year level. As with Plan 10A, this alternative was found not to be economically justified and was eliminated from further consideration.

PLAN 12 - PERMANENT EVACUATION, LEVEE/FLOODWALL

Analysis of Building Block 1 indicated that, except for a few frequently flooded areas, permanent evacuation as a comprehensive solution was not justified. As a result, this plan, Plan 12, was essentially a levee/floodwall plan with permanent evacuation in selected areas. However, as in Building Block 11 this plan required bridge and/or dam modification. Therefore, Plan 12 was identical to Plan 14B and was no longer considered.

PLAN 14A - LEVEE/FLOODWALL, NONSTRUCTURAL, DAM AND BRIDGE MODIFICATION

This plan consisted of a combination of levees, floodwalls, floodproofing, raising and removal of structures from flood prone areas. The Lower Valley and the Central Basin above the upstream reach of Deepavaal Brook would be protected against a 100 year flood by the levee/floodwall systems described in Building Block 13A.

In the Pompton Valley and along the Passaic River between Beatties Dam and the upstream limit of Deepavaal Brook, the use of levees and floodwalls to contain the flood flows within the river's banks would constrict the water and increase flood stages to the point where such works are not economically feasible. They would also increase flooding both upstream and downstream. Therefore, levees and floodwalls by themselves cannot function in these reaches. The only economical measures which would not impact on the features of the rest of the plan were nonstructural. In this case, this was the floodproofing, raising and evacuation of structures from the area inundated by the 10 year flood (Building Block 3A) along the Pompton, Pequannock, Ramapo and Wanaque Rivers and the Passaic River between Beatties Dam and the upstream limit of Deepavaal Brook. Plan 14A, which was determined to be economically justified, is illustrated in Figure C-54.

PLAN 14B

This plan consisted of combining the 100 year levee/ floodwall plan (Building Block 13A) with permanent evacuation in order to further reduce flood damages. However, permanent evacuation was feasible for only a limited number of structures in the 10 year floodplain (Building Block 1E). Therefore, although Plan 14B was economically justified, it was not considered to be much more effective than Building Block 13A and was screened from further evaluations.

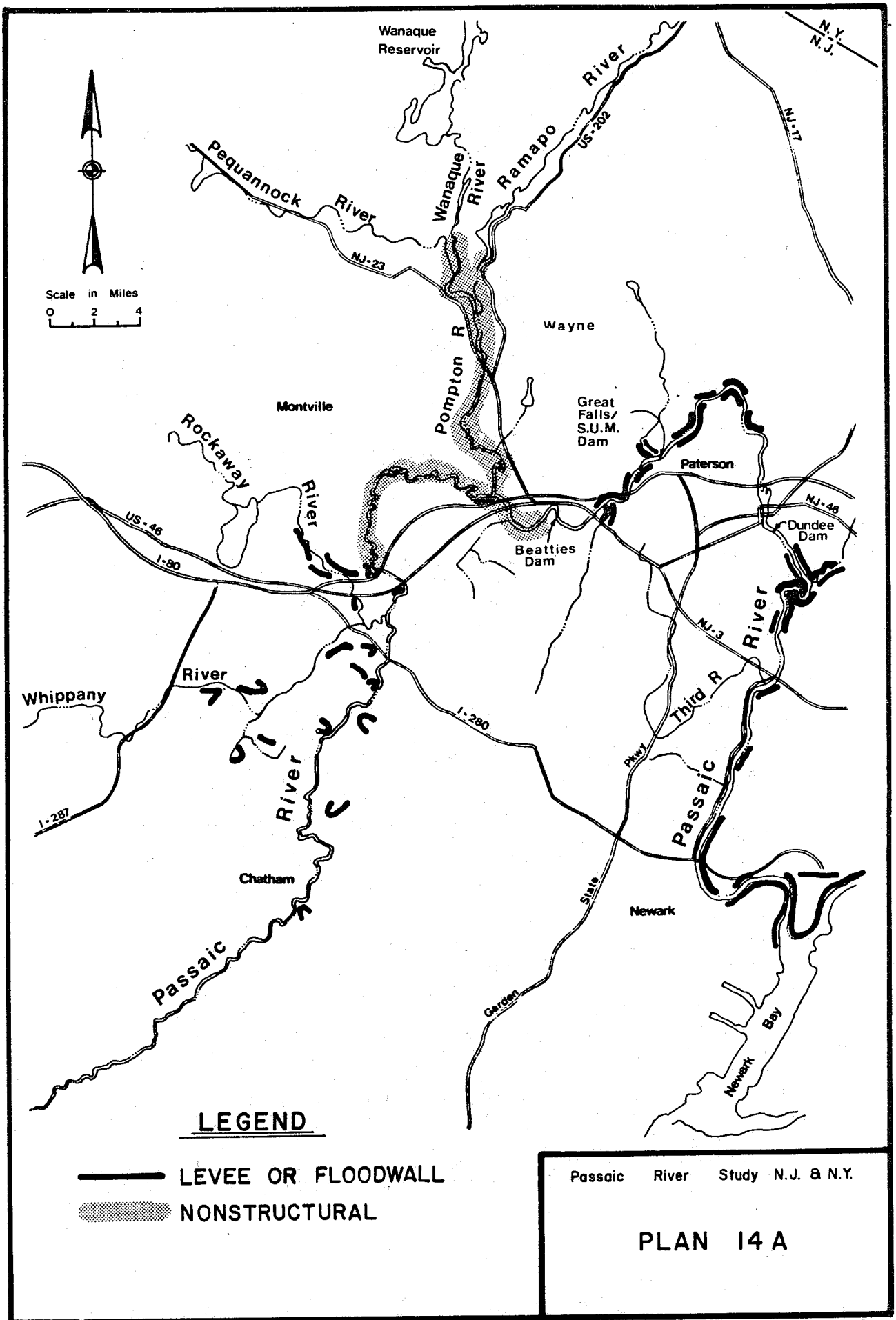

Wanaque Reservoir
Pequannock River
Wanaque River
Ramapo River
N.Y.
N.J.
NJ-17
US-202
NJ-23
Scale in Miles
0 2 4
Wayne
Pompton R
Montville
Great Falls/ S.U.M. Dam
Rockaway River
Paterson
NJ-46
US-46
I-80
Dundee Dam
Beatties Dam
NJ-3
Third R
Passaic River
Whippany River
I-280
Pkwy
I-287
Passaic River
Chatham
State
Newark
Garden
Bay
Newark
LEGEND
LEVEE OR FLOODWALL
NONSTRUCTURAL
Passaic River Study N.J. & N.Y.
PLAN 14 A

FIGURE C-54

PLAN 15 - CHANNEL MODIFICATION, LEVEE/FLOODWALL

These alternatives were combination plans, consisting of channel modifications, levees and floodwalls, designed to protect against the 100 year storm along the Passaic, Rockaway, Whippany, Pompton, Pequannock, Ramapo and Wanaque Rivers.

The intent of these alternatives was to improve and increase the flood flow carrying capacity of the channel, particularly at damage areas. Where the channel did not provide protection to the 100 year level, levees or floodwalls were required. Various types of channels including earthen trapezoidal, and concrete rectangular configurations were investigated. Their viability was contingent upon effectiveness, cost, and environmental considerations.

The channel modification, levee/floodwall plans are described below and are illustrated in Figure C-55 and C-56. The physical features of the plans are summarized in Table C-61.

PLAN 15A

Plan 15A was developed to provide a 100 year level of protection for the Passaic main stem. It encompassed the reaches from the mouth at Newark Bay upstream to Beatties Dam in Little Falls, from Beatties Dam to Chatham and along the Rockaway, Whippany, Pompton, Pequannock, Ramapo and Wanaque Rivers.

The Lower Valley reaches would be protected by a series of intermittent levees and floodwalls on the Passaic River (a variation of the levee/floodwall systems as shown in Building Block 13A) combined with the channel modifications described in Building Block 7A which would extend from downstream of Route 3 upstream to Beatties Dam. This Lower Valley portion included approximately 87,300 feet of levees, ranging in height from 3.5 to 10.0 feet and approximately 93,600 feet of floodwalls, ranging from 4.0 to 10.0 feet in height.

Before describing the Central Basin reaches, certain key technical data should be reiterated. As discussed previously in Section 4, flooding in the Central Basin is due to the backwater effect caused by the mild gradients of the Passaic and Pompton Rivers in combination with the naturally constrictive channel between Two Bridges and Beatties Dam and the tailwater elevations caused by Beatties Dam. This alternative would eliminate all flow reversal on the Passaic River at Two Bridges that occurs as a result of the downstream channel constriction, aid movement of flood flows to Beatties Dam and, subsequently, reduce ponding and flood stages in the Central Basin. The elimination of flood storage in the Central Basin would, however, significantly increase downstream flood flows.

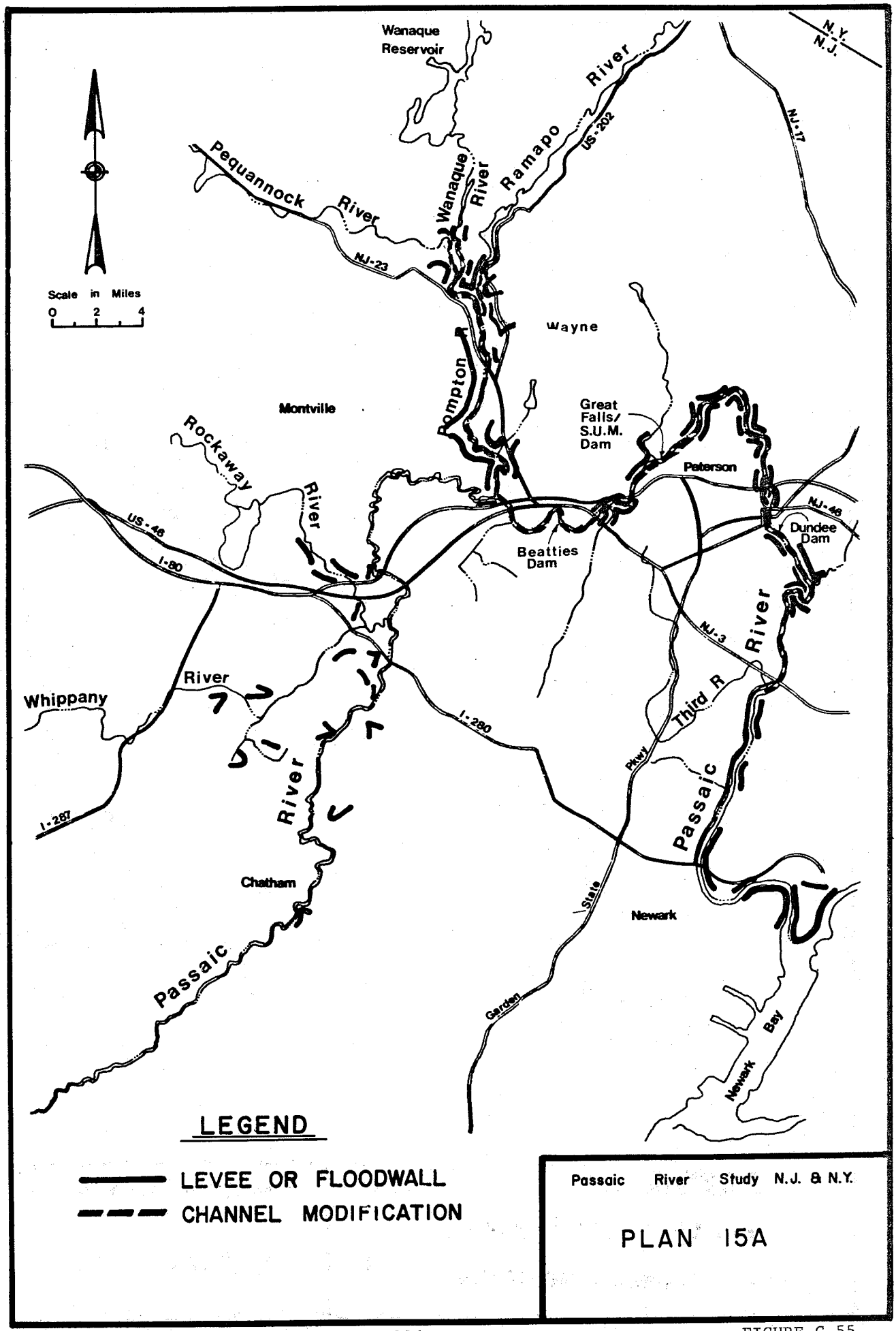

Wanaque Reservoir
Pequannock River
Wanaque River
Ramapo River
N.Y.
N.J.
US-202
NJ-17
NJ-23
Scale in Miles
0 2 4
Wayne
Rockaway River
Montville
Pompton
Great Falls/ S.U.M. Dam
Paterson
NJ-46
Dundee Dam
US-46
I-80
Beatties Dam
NJ-3
Third R
Whippany River
I-280
Pkwy
Passaic River
I-287
Chatham
State
Newark
Passaic River
Garden
Bay
Newark
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
Passaic River Study N.J. & N.Y.
PLAN 15A

FIGURE C-55

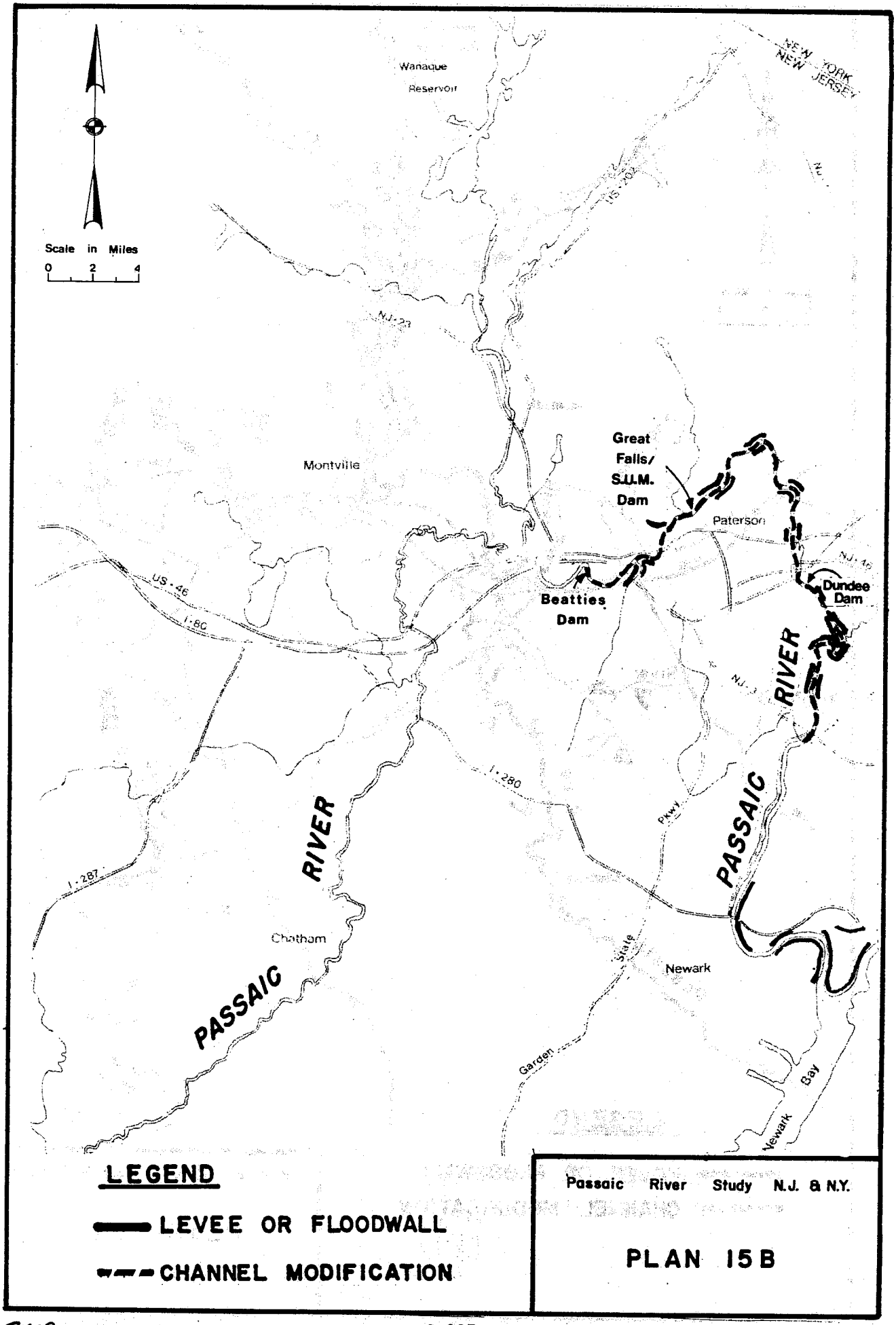

Scale in Miles
0 2 4
Wanaque Reservoir
NEW YORK
NEW JERSEY
NJ-23
Montville
Great Falls/ S.U.M. Dam
Paterson
NJ-19
Dundee Dam
Beatties Dam
US-46
I-80
NJ-3
PASSAIC RIVER
I-280
Pkwy
PASSAIC RIVER
I-287
Chatham
State
Newark
Garden
Bay
Newark
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
Passaic River Study N.J. & N.Y.
PLAN 15B

FIGURE C-56

TABLE C-61 PLANS 15A AND 15B

CHANNEL MODIFICATION, LEVEE/FLOODWALL PHYSICAL FEATURES

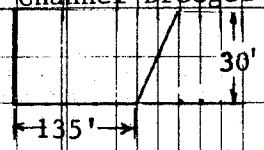
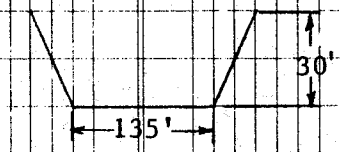
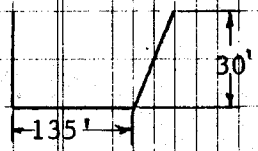
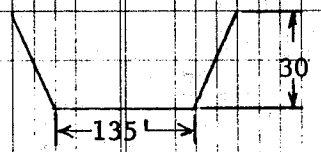
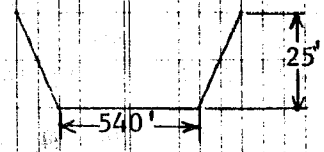
PLAN	LOCATION	STATION	LENGTH	CHANNEL	LEVEE/FLOODWALL
15A	Mouth to Route 3	0+00 to 599+00	61,900	Existing Channel	Levees - 47,345 ft Floodwalls - 32,820 ft
		599+00 to 619+00	2,000	Channel Dredged	
	Route 3 to Dundee Dam	619+00 to 645+00	2,600	Vertical Wall 	Levees - 4,150 ft Floodwalls - 2,250 ft
		645+00 to 773+50	12,850		Levees - 5,000 ft Floodwalls - 3,200 ft
		773+50 to 790+84	1,734	Vertical Wall 	Levees - 1,950 ft Floodwalls - 2,150 ft
		790+84 to 870+00	7,916		Levees - 5,500 ft Floodwalls - 10,350 ft
		870+00 to 890+00	2,000	Channel Dredged	Levees - 1,850 ft Floodwalls - 7,550 ft
	Dundee Dam to Great Falls	917+85 to 963+00	4,515		Levees - 500 ft Floodwalls - 1,050 ft

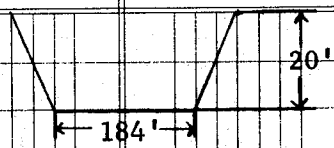
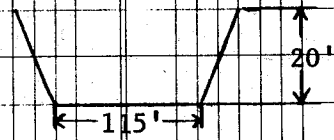
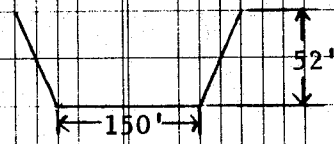
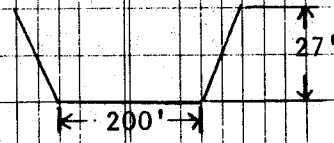
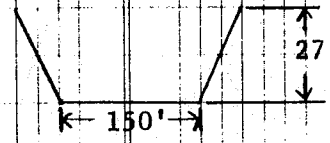
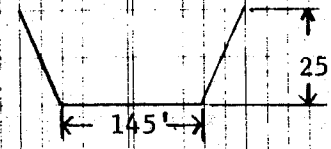
TABLE C-61 (CONT.) PLANS 15A AND 15B

CHANNEL MODIFICATION, LEVEE/FLOODWALL PHYSICAL FEATURES

10 LOCATION	12 STATION	13 LENGTH	14 CHANNEL	15	16 LEVEE/FLOODWALL	17
	963+00 to 987+50	2,450	340'	25'	Levees Floodwalls	1,700 ft 1,300 ft
	987+50 to 1011+00	2,350	280'	25'	Floodwalls	2,000 ft
	1011+00 to 1093+00	8,200	270'	25'	Levees Floodwalls	350 ft 1,050 ft
	1093+00 to 1225+00	13,200	210'	25'	Levees Floodwalls	6,250 ft 3,200 ft
	1225+00 to 1260+00	3,500	115'	25'	Floodwalls	2,000 ft
	1260+00 to 1304+00	4,400	95'	25'	Levees Floodwalls	4,400 ft 2,400 ft

TABLE C-61 (CONT.) PLA 15A and 15B

CHANNEL MODIFICATION, LEVEE/FLOODWALL PHYSICAL FEATURES

1 LOCATION	3 STATION	4 LENGTH	5 CHANNEL	6	7 LEVEE/FLOODWALL	8
Great Falls to Beatties Dam	1338+60 to 1443+20	10,460			Levees - Floodwalls -	7,400 ft 19,600 ft
	1443+20 to 1536+00	9,280			Levees - Floodwalls -	900 ft 2,700 ft
Beatties Dam to Two Bridges (Passaic River)	1564+50 to 1568+65	415				
	1568+65 to 1620+00	5,135				
	1620+00 to 1663+50	4,350				
	1663+50 to 1686+75	2,325				

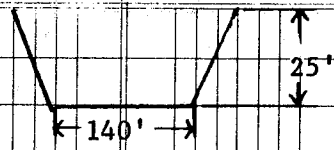
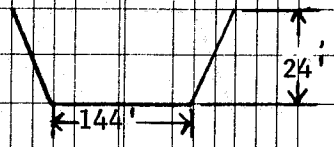
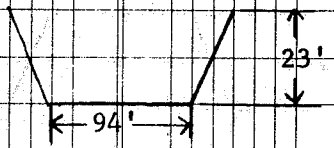
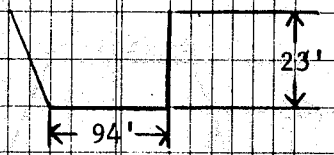
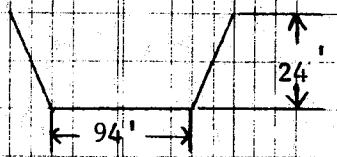
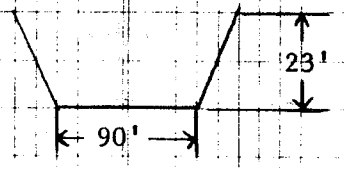
C-330

352

3 of 10

TABLE C-61 (CONT.) PLANS 15A AND 15B

CHANNEL MODIFICATION, LEVEE/FLOODWALL PHYSICAL FEATURES

LOCATION	STATION	LENGTH	CHANNEL	LEVEE/FLOODWALL
	1686+75 to 1746+30	5,955		
Two Bridges to Pompton Plains (Pompton River)	0+00 to 73+20	7,320		Levees - 11,600 ft Floodwalls - 7,300 ft
	73+20 to 80+50	730		Levees - 4,100 ft Floodwalls - 400 ft
	80+50 to 92+90	1,240		Levees - 400 ft Floodwalls - 1,300 ft
	92+90 to 104+00	1,110		Levees - 3,200 ft Floodwalls - 1,300 ft
	104+00 to 135+00	3,100		Levees - 3,200 ft Floodwalls - 1,900 ft

CHANNEL MODIFICATION, LEVEE/FLOODWALL PHYSICAL FEATURES

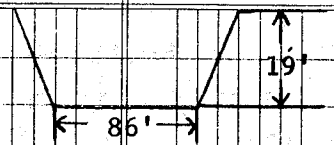
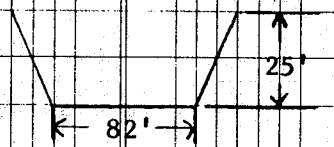
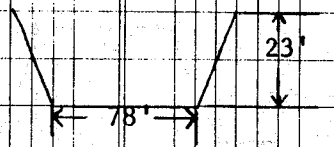
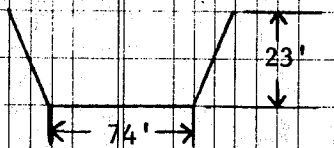
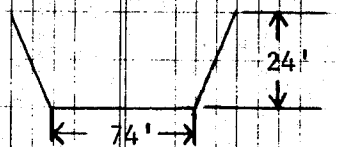
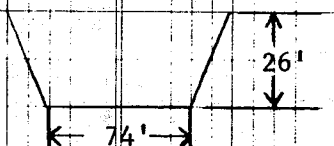
LOCATION	STATION	LENGTH	CHANNEL	LEVEE/FLOODWALL	
C-332	135+00 to 150+00	1,500		Levees	1,800 ft
	150+00 to 240+00	9,000		Levees Floodwalls	34,600 ft 2,400 ft
	240+00 to 280+50	4,050		Levees	5,500 ft 2,200 ft
	280+50 to 322+76	4,276		Levees Floodwalls	4,400 ft
	322+76 to 357+35	3,459		Levees	3,500 ft
Pequannock River	0+00 to 30+00	3,000		Levees	3,000 ft

TABLE C-61 (CONT.) PLANS 15A AND 15B

CHANNEL MODIFICATION, LEVEE/FLOODWALL PHYSICAL FEATURES

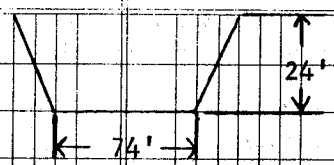
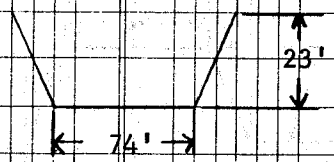
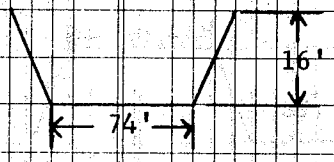
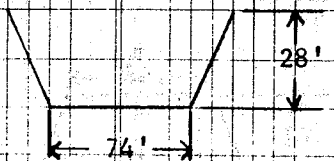
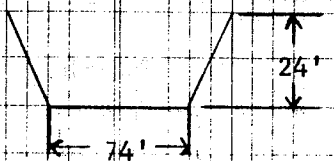
10 LOCATION	12 STATION	13 LENGTH	14 / 15 CHANNEL	16 / 17 LEVEE/FLOODWALL
C-333	30+00 to 79+30	4,930		Levees - 3,000 ft
	79+30 to 116+00	3,670		Levees - 5,600 ft
	116+00 to 135+00	1,900		Levees - 2,400 ft
Ramapo River	0+00 to 35+30	3,530	Relocate Channel	Levees - 2,800 ft
	35+30 to 36+55	125		Levees - 200 ft
	36+55 to 70+10			Levees - 3,500 ft Floodwalls - 600 ft

TABLE C-61 (CONT.) PLANS 15A AND 15B

CHANNEL MODIFICATION, LEVEE/FLOODWALL PHYSICAL FEATURES

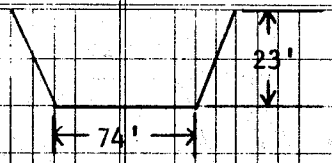
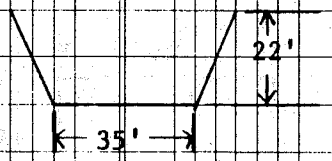
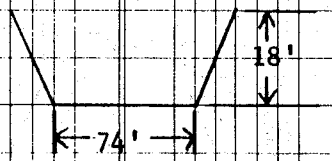
1 LOCATION	3 STATION	4 LENGTH	5 CHANNEL	6	7 LEVEE/FLOODWALL	8
	70+10 to 72+30	220			Levees	990 ft
	72+30 to 101+75	2,945			Levees Floodwalls	5,200 ft 950 ft
Wanaque River	0+00 to 51+35	5,135			Levees	5,500 ft
Passaic River Two Bridges to Chatham					Levees Floodwalls	61,930 ft 1,280 ft

TABLE C-61 (CONT.) PLANS 15A AND 15B

CHANNEL MODIFICATION, LEVEE/FLOODWALL PHYSICAL FEATURES

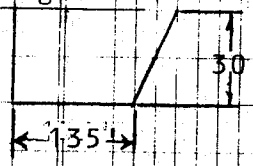
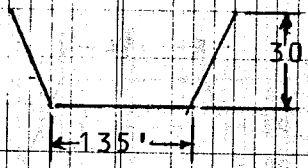
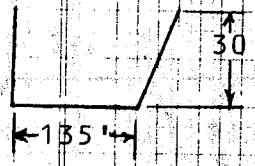
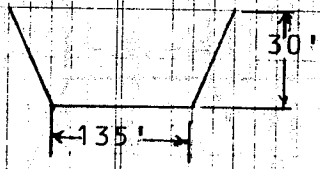
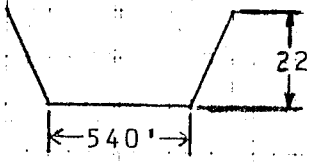
1 LOCATION	2 STATION	3 LENGTH	4 CHANNEL	5 LEVEE/FLOODWALL
15B Mouth to Route 3	0+00 to 599+00	61,900	Existing Channel	Levees - 30,775 ft Floodwalls - 30,420 ft
	599+00 to 619+00	2,000	Channel Dredged	
Route 3 to Dundee Dam	619+00 to 645+00	2,600	Vertical wall 	
	645+00 to 773+50	12,850		Levees - 5,410 ft Floodwalls - 5,000 ft
	773+50 to 790+84	1,734	Vertical wall 	Levees - 830 ft Floodwalls - 2,650 ft
	790+84 to 870+00	7,916		Levees - 2,000 ft Floodwalls - 9,770 ft
	870+00 to 890+00	2,000	CHANNEL DREDGED	Levees - 490 ft Floodwalls - 2,670 ft
Dundee Dam to Great Falls	917+85 to 963+00	4,515		

TABLE C-61 (CONT.) PLANS 15A AND 15B

CHANNEL MODIFICATION, LEVEE/FLOODWALL PHYSICAL FEATURES

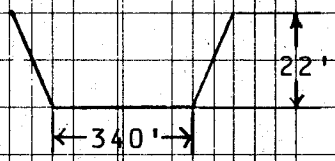
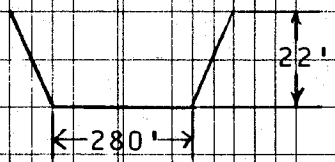
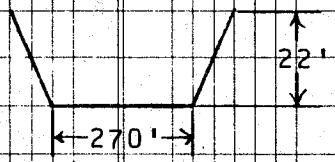
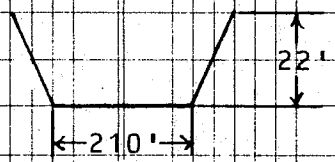
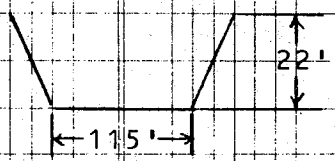
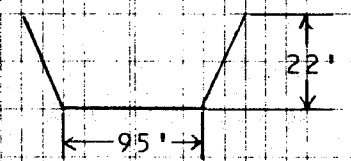
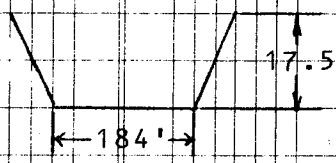
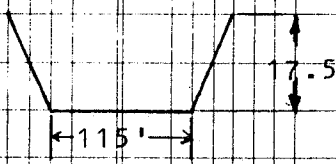
LOCATION	STATION	LENGTH	CHANNEL	LEVEE/FLOODWALL
	963+00 to 987+50	2,450		
	987+50 to 1011+00	2,350		
	1011+00 to 1093+00	8,200		LEVEES - 1250 ft. FLOODWALLS - 1550 ft.
	1093+00 to 1225+00	13,200		LEVEES - 5950 ft. FLOODWALLS - 9020 ft.
	1225+00 to 1260+00	3,500		LEVEES - 900 ft. FLOODWALLS - 3500 ft.
	1260+00 to 1304+00	4,400		LEVEES - 700 ft. FLOODWALLS - 8100 ft.

TABLE C-61 (CONT.) PLANS 15A AND 15B

CHANNEL MODIFICATION, LEVEE/FLOODWALL PHYSICAL FEATURES

LOCATION	STATION	LENGTH	CHANNEL	LEVEE/FLOODWALL
Great Falls to Beatties Dam	1338+60 to 1443+20	10,460		LEVEES - 1800 ft. FLOODWALLS - 2150 ft.
	1443+20 to 1536+00	9,280		LEVEES - 6850 ft. FLOODWALLS - 8350 ft.

Due to the close proximity of structures along the existing banks of the Passaic River between Beatties Dam and Two Bridges it was decided to generally hold the modified channel for this reach to within the existing banks in order to avoid the acquisition of any structures. The channel modification would extend from 415 ft. downstream of Beatties Dam to 1,330 ft. upstream of Two Bridges, for a total distance of approximately 3.6 miles.

The modified earthen channel on the Passaic River would have 1 on 2.5 side slopes and a bottom width that would range in size from 200 ft. at Beatties Dam to 140 ft at Two Bridges. In order to contain the 100 year flow on the Passaic River in this reach it would be necessary to lower the channel bottom an average of 15 ft. In addition, it would be necessary to remove and replace Beatties Dam by a new structure containing six 35 ft. wide tainter gates. Details of the new structure would be the same as shown in Figure C-33 for the Little Falls Tunnel Inlet. The spillway crest would be set at elevation 136.0 ft. (MSL) while the top of gate would be set at 158.0 ft. (MSL) which is approximately the same elevation as the existing dam. The gates would normally be closed so as to maintain a pool elevation of 158 ft. As the discharge increases during a storm, the gates would open so that the pool elevation for a 100 year discharge would be approximately 157.1 ft. (MSL). Operated in this manner, the pool upstream of Beatties Dam would be maintained at or near existing levels under normal conditions. This would minimize effects on water tables, wetlands, the Passaic Water Supply Commission intake, hydropower plans for Beatties Dam, and other purposes. During flooding conditions, the pool would be maintained below the damaging flood stages for storms up to the 100 year event.

Due to the significantly lower modified channel thalweg, a relatively steep transition (on the order of 0.5%) would be required at Two Bridges on the Passaic in order to meet the existing channel bottom. Because of the steep transition, it would be necessary to provide riprap in this area.

Channel modifications on the Pompton River would extend from the mouth upstream to the confluence with the Ramapo and Pequannock Rivers, a distance of approximately 6.8 miles. The modified earthen channel would have 1 on 2 side slopes and a bottom width that would range in size from 144 ft. at the mouth to 74 ft. at the upstream limit of the improvement. Accordingly, it would be necessary to buyout 14 structures located on an existing island in the channel. The depth of the modified channel on the Pompton River would be dictated by the elevation of the proposed invert on the Passaic River at the confluence.

Channel modifications would extend along the Pequannock, Ramapo and Wanaque Rivers. The channel bottom widths would be restricted to 74 feet wide, the size of the upstream Pompton River modified channel. The modified earthen channels would have 1 on 2 side slopes.

The channel modifications along the Pequannock River would extend from the Pompton River confluence upstream for approximately 2.6 miles. The modified channel bottom would be lowered by an average of 14 feet.

The confluence of the Ramapo and Pequannock Rivers would be relocated approximately 1,800 feet upstream from its present location. Channel modifications along the Ramapo River would extend from its relocated confluence with the Pequannock upstream to the Pompton Lakes Dam, a distance of approximately 1.3 miles. Due to restrictions in top width, the bottom width for the proposed channel would be reduced from 74 to 35 feet from Dawes Highway to the upstream limit of the modification. The channel bottom would be lowered an average of 12 feet.

Along the Wanaque River the channel modifications would extend from its confluence with the Pequannock River upstream to the Paterson-Hamburg Turnpike Bridge, a distance of approximately 1.0 mile. The modified channel bottom would be lowered by an average of 6 feet.

The resulting channel plan, however, would not be able to completely contain the 100 year flow. Therefore, to provide protection against the design flow, 13.7 miles of levees and 3.2 miles of floodwalls would be required along the Pompton River, Packanack Brook and Beaver Dam Brook to supplement the channel. The levees would be set back from the stream, where possible, to preserve the natural flood detention areas. The levees, which would have 1 on 3 side slopes and a top width of 10 ft., would have an average height of 9.5 ft. and an average base width of 67 ft. Levees and floodwalls would also be required along the Pequannock, Ramapo and Wanaque Rivers. A total of 6.1 miles of levees and 0.3 miles of floodwalls having an average height of 8.0 feet would be required. These levees would have an average base width of 58 feet. Ponding areas, pumping stations and associated interior flood control facilities would be provided behind the levees and floodwalls to carry surface runoff from the protected areas into the rivers.

The elimination of all flow reversal for the 100 year storm on the Passaic River at Two Bridges would reduce the flood stages of the 100 year storm and would contain the design flow within the banks in this reach. The reduction in stages would be approximately 13 ft. at Beatties Dam and 7 ft. at Two Bridges. The effect of the Passaic River channel modification

would diminish progressively upstream on the Passaic River. Downstream of the confluence with the Rockaway River, the 100 year stage on the Passaic River would only be reduced by approximately 3 ft. The modification would have no effect on stages on the Upper Passaic River. The backwater stages of the 100 year flow would be reduced by approximately 1 foot on the lower Whippany River and 1.5 ft. on the lower Rockaway River. Along the Pompton River, the reduction in flood stages obtained by this alternative would be an average of 7.5 ft. along the length of the modified channel. In addition to the reduction of backwater effects achieved with the Passaic River channel modification, the Central Basin setback levee elements of Building Block 13A, located upstream of Deepavaal Brook, were incorporated into this plan; however, the heights were reduced in accordance with the 100 year stage reduction achieved by the channel.

Evaluation of this plan determined that it would be economically justified. It was noted that the elements of plan 15A located upstream of Beatties Dam could be utilized with tunnel diversion plans.

PLAN 15B

Plan 15B is designed to provide protection against the 100 year storm along the Passaic River's Lower Valley, from its mouth at Newark Bay, upstream to Beatties Dam in Little Falls. This 100 year level of protection assumed that no improvements are implemented in the Central Basin. This alternative involved a series of intermittent levees and floodwalls on the Lower Passaic River combined with the features and alignments of the channel modifications in Building Block 7B. This plan called for approximately 57,000 feet of levees, ranging in height from 3.5 to 10.0 feet and approximately 87,000 feet of floodwalls, ranging from 5.0 to 10.5 feet in height. The Central Basin setback levee elements of Building Block 13A could also be utilized in conjunction with this plan. Plan 15B was determined to be economically justified.

PLAN 16A - LEVEE/FLOODWALL, NONSTRUCTURAL, CHANNEL MODIFICATION

This alternative is a combination of levees, floodwalls, channel modifications and nonstructural measures. The central feature of the plan was the channel modification described as Building Block 7A which extended along the Passaic River from Route 3 upstream to Beatties Dam, a distance of approximately 16.1 miles, and would protect against a 100 year event. The remaining elements in this alternative were identical to Plan 14A, with levees and floodwalls along the lower Passaic River

downstream of Route 3, and in the Central Basin above the upstream limit of Deepavaal Brook; however, no levee/floodwall systems would be located between Route 3 and Beatties Dam along the lower Passaic River, the location of the channel improvement. These levees would again protect against a 100 year flood. The Pompton Valley and Passaic River between Beatties Dam and the upper limit of Deepavaal Brook would be protected against a 10 year flood through the floodproofing, raising and evacuation of structures. Plan 16A, which is illustrated in Figure C-57, was determined to be economically feasible.

PLAN 16B

Plan 16B is essentially a variation of Plan 15A. Plan 16B replaced the intermittent levee/floodwall systems included in Plan 15A in the Central Basin above the upstream limit of Deepavaal Brook with comprehensive nonstructural measures. Nonstructural measures were not considered for the Pompton Valley nor Lower Valley, since the continuous levee/floodwall and channel modifications would provide for the 100 year level of protection in the Pompton Valley, and since nonstructural measures were not economically justified in the Lower Valley. Plan 16B, which would provide a 100 year level of protection, was determined to be economically justified. Plan 16B is illustrated in Figure C-58.

PLAN 16C

This alternative combined Plan 15B with raising, floodproofing, and permanent evacuation measures in the Central Basin. The nonstructural components of this plan were identical to the Central Basin component of Building Block 3C. This plan would provide a 100 year level of protection. However, it was determined to be economically infeasible and was, therefore, screened from further evaluation.

PLAN 19 - EXISTING AND NEW RESERVOIRS

An analysis was performed to consider the utilization of the existing reservoir systems within the Basin in combination with potential new reservoir sites. A key constraint of this analysis was based upon the use of existing reservoirs primarily for water supply purposes. The constraint was that the safe yield of the existing reservoir systems would be maintained when new reservoirs were added to these systems. This implied a flood control-water supply trade-off. The results of this analysis indicated that there were no effective flood damage reduction reservoirs - either new or existing. Consequently this plan was not analyzed further.

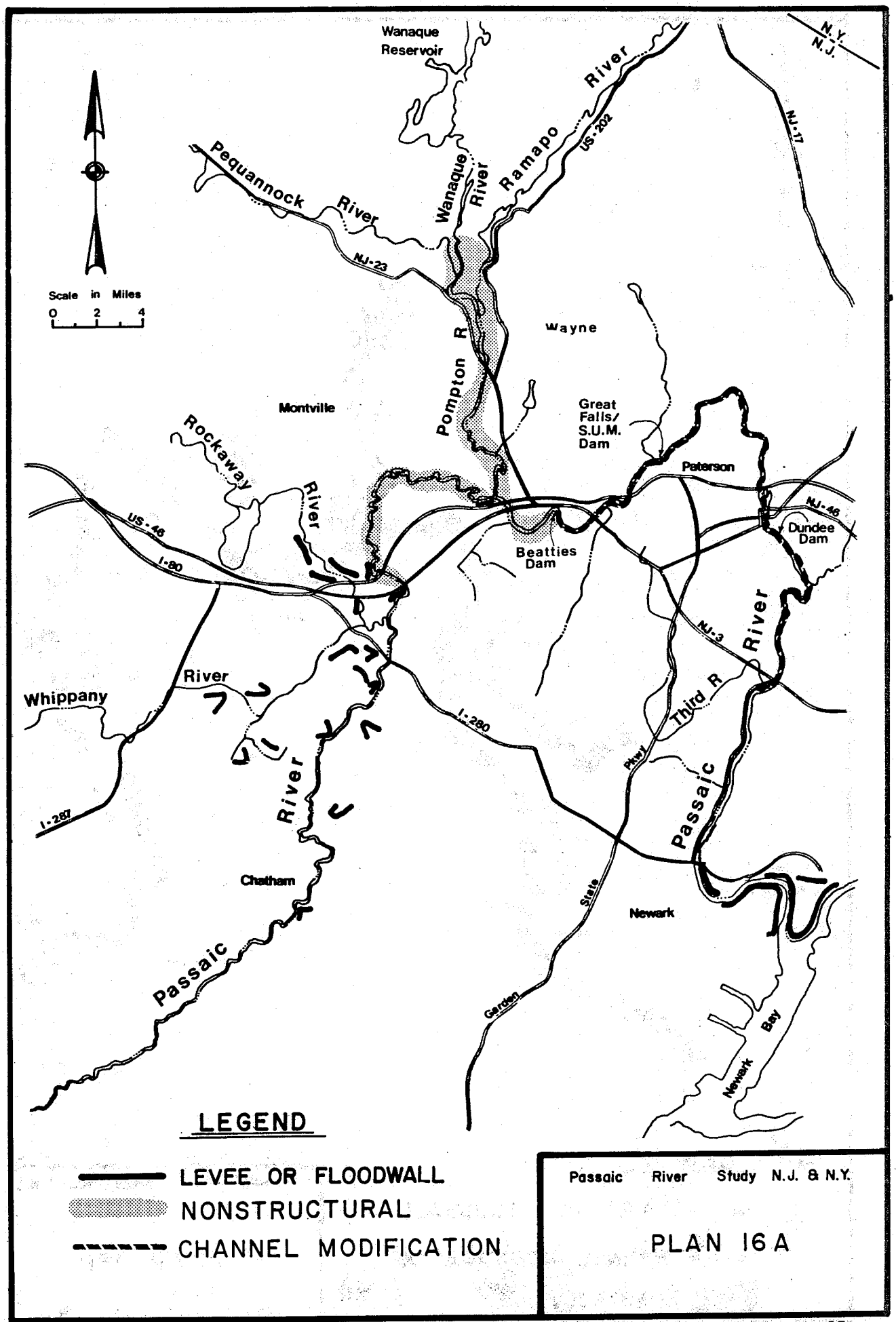

Wanaque Reservoir
Pequannock River
Wanaque River
Ramapo River
US-202
N.Y.
N.J.
NJ-17
Scale in Miles
0 2 4
NJ-23
Wayne
Pompton R
Montville
Great Falls/ S.U.M. Dam
Rockaway River
Paterson
US-46
I-80
Beatties Dam
NJ-46
Dundee Dam
NJ-3
Third R
Whippany River
I-280
Pkwy
Passaic River
I-287
Chatham
State
Newark
Passaic River
Garden
Newark Bay
LEGEND
LEVEE OR FLOODWALL
NONSTRUCTURAL
CHANNEL MODIFICATION
Passaic River Study N.J. & N.Y.
PLAN 16A

FIGURE C-57

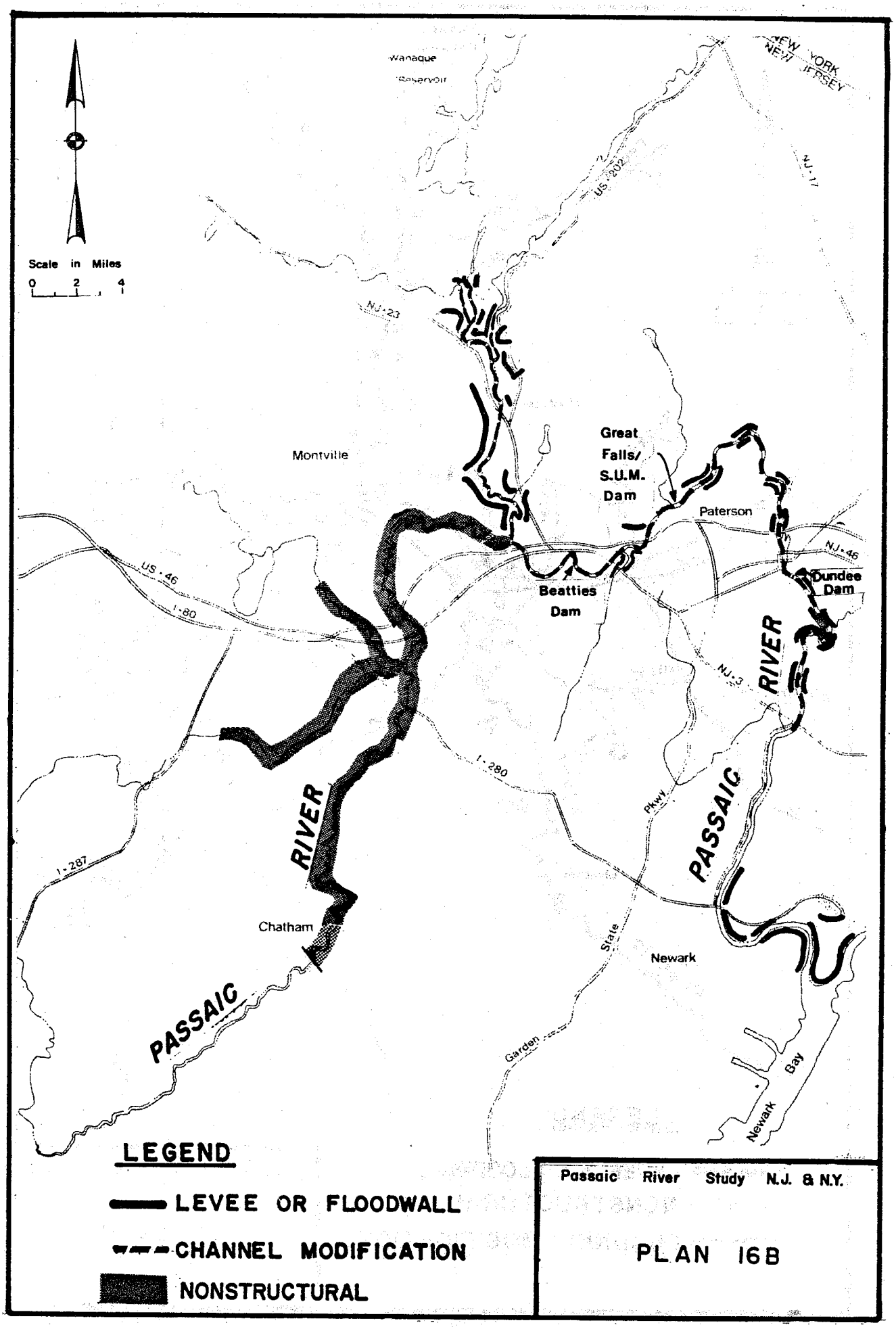

Scale in Miles
0 2 4
Wanaque Reservoir
NEW YORK
NEW JERSEY
US-202
NJ-17
NJ-23
Montville
Great Falls/ S.U.M. Dam
Paterson
NJ-46
US-46
I-80
Beatties Dam
Dundee Dam
NJ-3
PASSAIC RIVER
I-280
Pkwy.
I-287
Chatham
PASSAIC
State
Newark
Garden
Newark Bay
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
NONSTRUCTURAL
Passaic River Study N.J. & N.Y.
PLAN 16B

FIGURE C-58

PLAN 24 - RESERVOIRS, TUNNELS

The only new reservoir with any potential to affect the cost and/or level of protection provided by tunnel plans was Darlington Reservoir (see Results under BUILDING BLOCKS, 17 and 18 - EXISTING AND NEW RESERVOIRS for a description of the analysis resulting in this conclusion). Hydrologic studies indicated that for the design levels of the tunnel plans considered, the Darlington Reservoir would not reduce the overall cost of the combined reservoir and tunnel nor increase the level of protection associated with the tunnel element. (See Other Alternatives under BUILDING BLOCK 23 - TUNNEL DIVERSIONS for a description of this analysis.) Consequently Plan 24 was not considered further.

PLAN 22, PLAN 25 AND PLAN 26 - AQUIFER RECHARGE PLANS

Since the central component of these plans, aquifer recharge, was not a feasible alternative, these plans were not considered in the development of alternative solutions.

PLAN 28 - TUNNELS, PERMANENT EVACUATION, FLOODPROOFING/RAISING

This alternative would combine nonstructural measures (raising, floodproofing, and permanent evacuation) discussed in Building Block 3 with the various tunnel plans described in Building Block 23. The purpose of combining the two types of measures was to eliminate the residual damages which would occur at the 100 year flood event in order to provide a uniform 100 year level of protection in the Central Basin and in the Lower Valley tidal reaches. Since various tunnel alternatives were developed, (Building Blocks 23A through G), an appropriate range of complementary nonstructural alternatives was developed, as described below.

PLAN 28A

This would be a combination of nonstructural measures with the 35-foot diameter Little Falls inlet tunnel. Since the tunnel component would also require continuous channel modification along the Passaic River between Little Falls and Two Bridges, and along the Pompton River and tributaries, along with levees and floodwalls in the Pompton Valley, nonstructural measures were only considered along the Central Passaic River upstream of Two Bridges and along the Lower Valley tidal area.

PLAN 28B

This plan is similar to Plan 28A as discussed above, except that the nonstructural measures would be combined with the 40-foot diameter Little Falls inlet tunnel. Plans 28A and B are illustrated in Figure C-59.

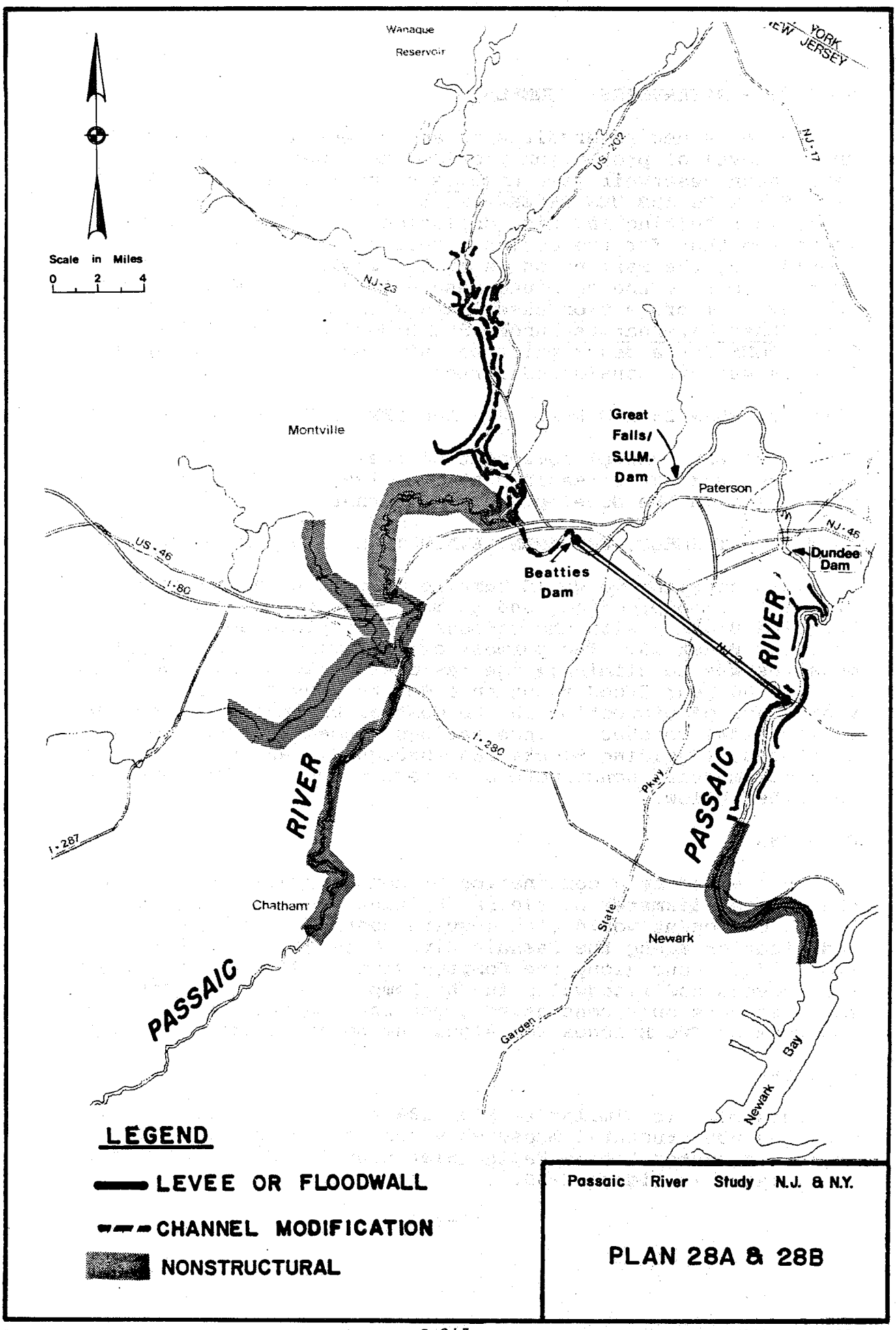

Wanaque
Reservoir
NEW YORK
NEW JERSEY
US-202
NJ-17
NJ-23
Scale in Miles
0 2 4
Montville
Great
Falls/
S.U.M.
Dam
Paterson
NJ-46
US-46
I-80
Beatties
Dam
Dundee
Dam
PASSAIC
RIVER
I-280
Pkwy
PASSAIC
RIVER
I-287
Chatham
State
Garden
Newark
Bay
Newark
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
NONSTRUCTURAL
Passaic River Study N.J. & N.Y.
PLAN 28A & 28B

FIGURE C-59

Plan 28C1

This plan would combine nonstructural measures with the 40-foot diameter Pompton River inlet tunnel. The incorporation of nonstructural measures was considered for the Lower Valley tidal area, the Central Passaic River upstream of Two Bridges, and the Pompton River in order to eliminate 100 year residual damages which would occur even with the necessary channel modification (described in Building Block 23C).

PLAN 28C2

This plan would be similar to Plan 28C1, as raising floodproofing, and permanent evacuation would be combined with the 40-foot diameter Pompton inlet tunnel. For this plan, however, the channel modification located between Little Falls and Two Bridges along the Passaic River would not be included and Beatties Dam would not be modified. This would result in flooding conditions in this reach as well as some backwater flooding upstream along the Pompton River despite the reduced Pompton River flows. Instead of the channel modification, nonstructural measures would be used along this reach to reduce damages in this reach as well as those indicated in Plan 28C1.

Plan 28C3

This plan would be identical to Plan 28C2, however, permanent evacuation would substitute for the combination of nonstructural measures for the lower Pompton River reaches and the Passaic River between Two Bridges and Little Falls. Figure C-60 illustrates Plan 28C1, C2 and C3.

PLAN 28D

This plan would be a combination of raising, floodproofing, and evacuation with the 35-foot diameter Pompton River inlet tunnel. Nonstructural alternatives were considered along the Lower Valley tidal area, Central Passaic River upstream of Two Bridges, and the Pompton River as illustrated in Figure C-61.

PLANS 28E1, 28E2, and 28E3

These plans would combine the 40-foot diameter Double Inlet tunnel plan with nonstructural measures along the Lower Valley tidal area, the Central Passaic River and Pompton River. The channel modification feature on the Passaic River between Little Falls and Two Bridges along with the modified Beatties Dam (as described in Building Block 23E) would be included as part of

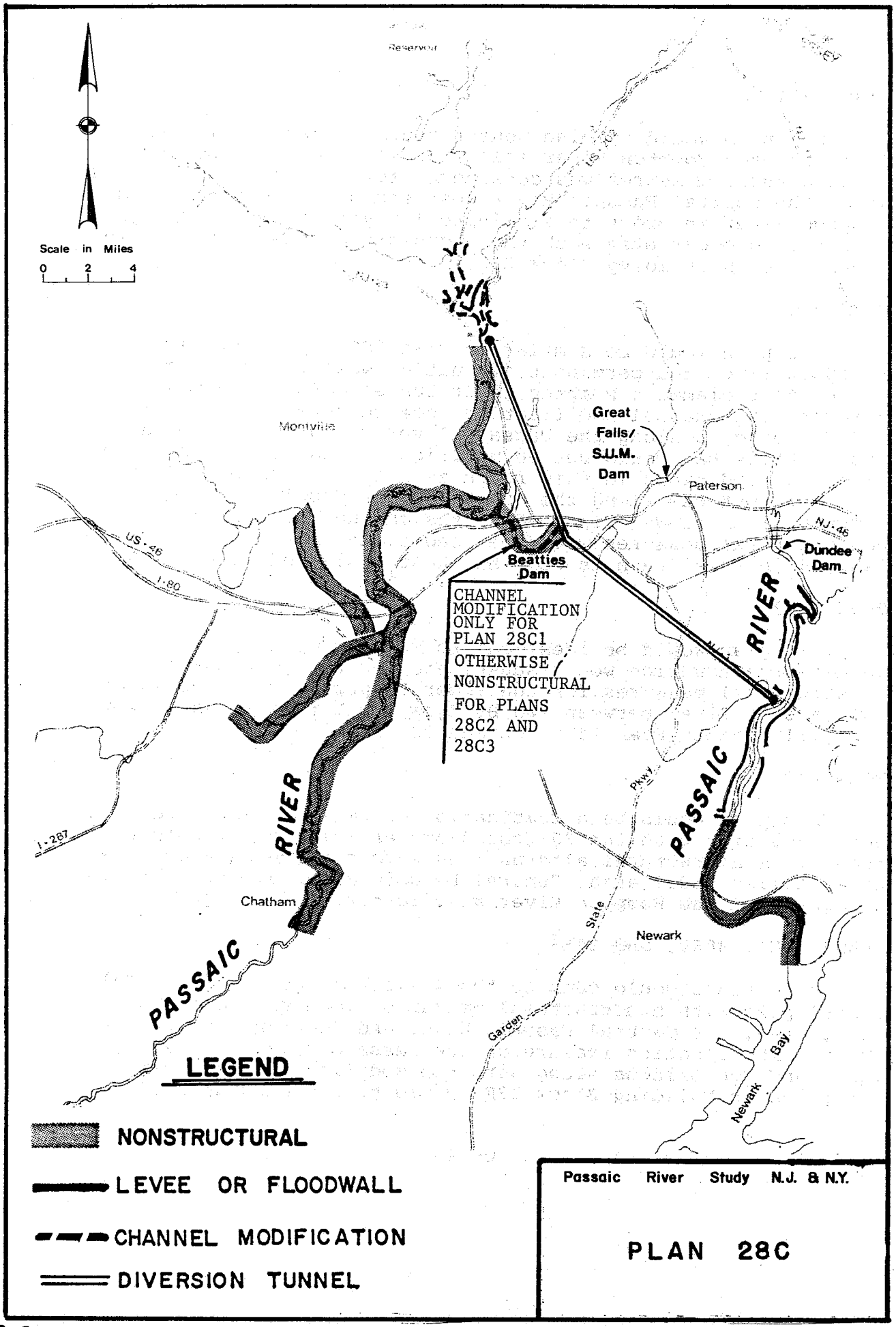

Scale in Miles
0 2 4
Great Falls/ S.U.M. Dam
Paterson
Montville
Beatties Dam
Dundee Dam
NJ-46
US-46
I-80
I-287
PASSAIC RIVER
PASSAIC RIVER
Chatham
Newark
State
Garden
Bay
Newark
Pkwy
CHANNEL MODIFICATION ONLY FOR PLAN 28C1
OTHERWISE NONSTRUCTURAL FOR PLANS 28C2 AND 28C3
LEGEND
NONSTRUCTURAL
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
PLAN 28C

FIGURE C-60

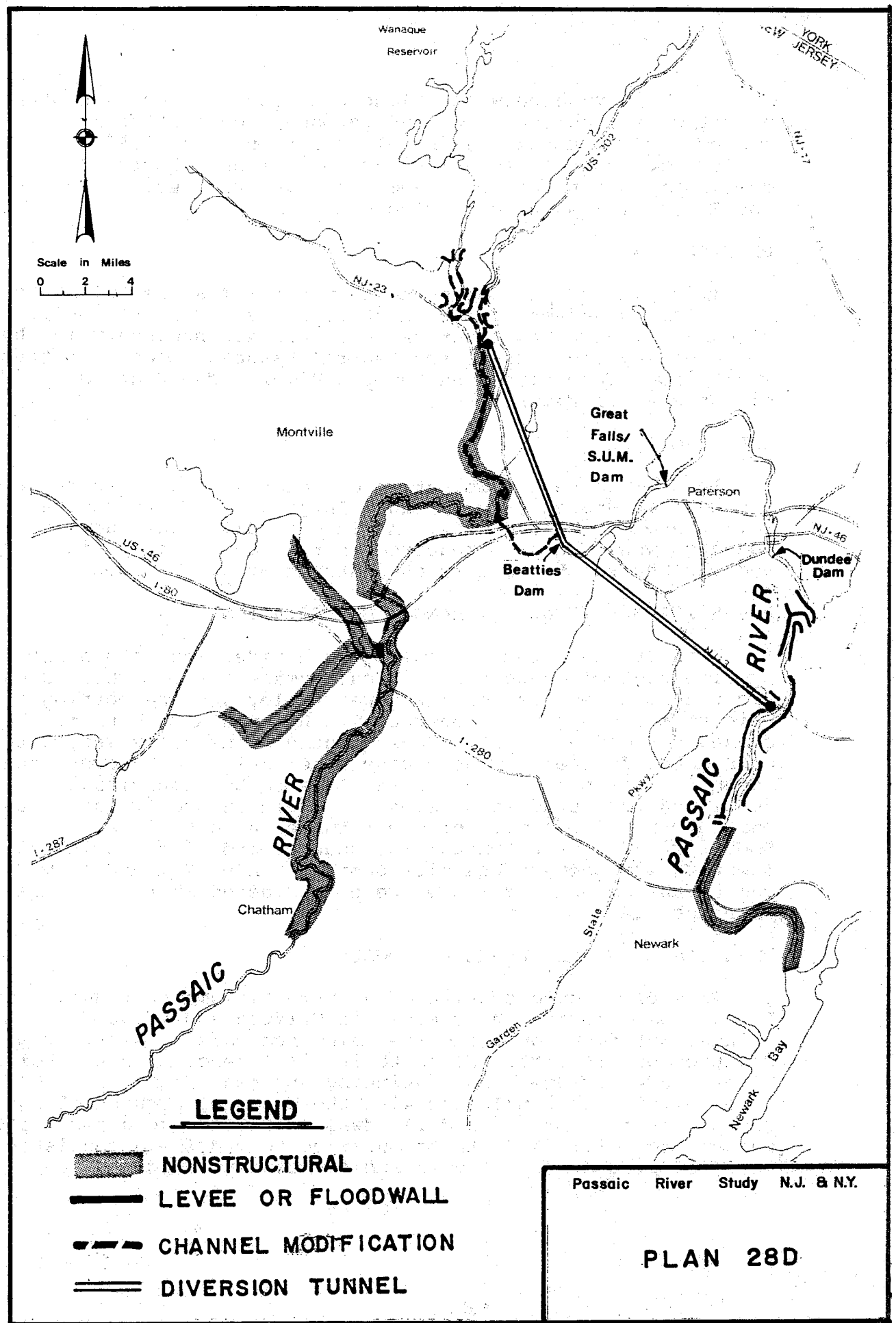

Wanaque
Reservoir
YORK
JERSEY
US-202
NJ-23
Scale in Miles
0 2 4
Montville
Great
Falls/
S.U.M.
Dam
Paterson
NJ-46
US-46
I-80
Beatties
Dam
Dundee
Dam
PASSAIC
RIVER
I-280
I-287
Chatham
PASSAIC
RIVER
Parkway
State
Garden
Newark
Newark
Bay
LEGEND
NONSTRUCTURAL
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
PLAN 28D

FIGURE C-61

Plan 28E1 only; otherwise, Plans 28E2 and 28E3 would contain nonstructural combinations and permanent evacuation, respectively, in this reach. In addition, Plan 28E3 would include permanent evacuation (instead of nonstructural combinations) in the lower Pompton River reaches. Plan 28E1, E2 and E3 are illustrated in Figure C-62.

PLAN 28F

This plan would combine nonstructural measures with the 35/40-foot diameter Double Inlet tunnel alternative (Building Block 23F). The nonstructural elements are necessary in the Lower Valley tidal area, the Central Passaic reaches upstream of Two Bridges, and along the Pompton River. The plan is illustrated in Figure C-63.

PLAN 28G

This would be a combination of nonstructural measures and the 40-foot diameter Two Bridges Inlet tunnel alternative, as illustrated in Figure C-64. As in Plan 28A, nonstructural measures would only be required in the Lower Valley tidal area and the Central Passaic reach upstream of Two Bridges.

PLANS 29A-G - TUNNELS, CHANNEL MODIFICATION

Plan 29, as a comprehensive basin-wide plan, could not provide protection to two critical damage areas. These areas are the tidal portion of the Lower Valley and the portion of the main stem Passaic River between Two Bridges and Chatham, where channels would not work. Consequently Plans 29A-G were not considered further as basin-wide alternatives. However, the potential for portions of these plans to be economically justified were studied as separate elements and evaluated as part of the formulation of other tunnel alternatives. Specifically, the potential for channel modification in the Lower Valley between Beatties Dam and Dundee Dam and from Dundee Dam to the Second River area were considered in the formulation of Plans 31A-G.

PLAN 30A - TUNNEL, LEVEE/FLOODWALL

This plan would consist of a 35-foot diameter tunnel from Little Falls to the Third River in Clifton and a 100 year channel modification along the main stem Passaic River from Beatties Dam in Little Falls to its confluence with the Pompton River at Two Bridges and continuing upstream along the Pompton River beyond its confluence with the Wanaque, Pequannock and the Ramapo Rivers. Levees and floodwalls would be required along the Pompton River and its tributaries to provide a consistent level of protection. Levees and floodwalls would also be

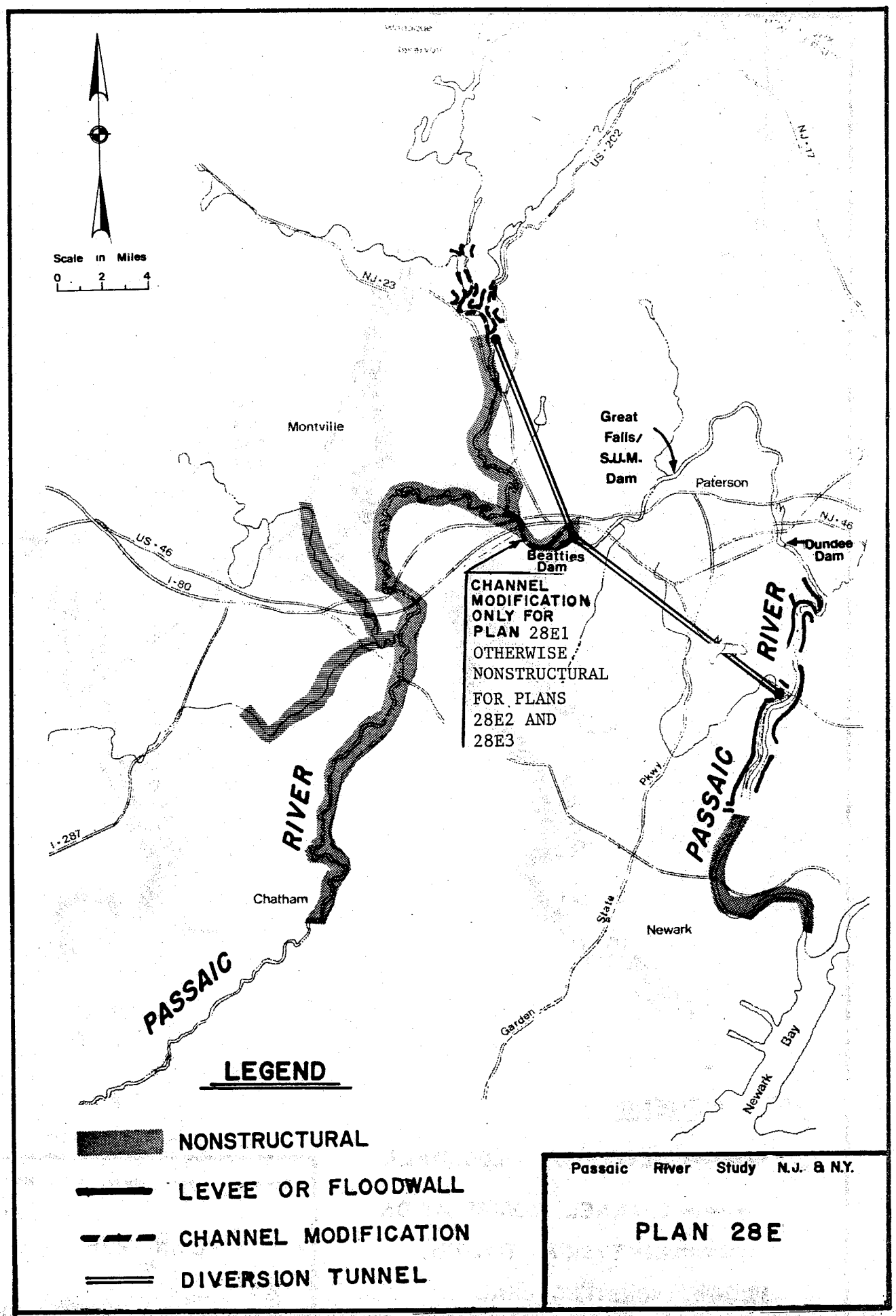

Scale in Miles
0 2 4
US-202
NJ-17
NJ-23
Montville
Great Falls/ S.J.I.M. Dam
Paterson
NJ-46
Dundee Dam
Beatties Dam
US-46
I-80
CHANNEL MODIFICATION ONLY FOR PLAN 28E1 OTHERWISE NONSTRUCTURAL FOR PLANS 28E2 AND 28E3
PASSAIC RIVER
PASSAIC RIVER
I-287
Chatham
Pkwy
State
Newark
Garden
Newark Bay
LEGEND
NONSTRUCTURAL
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
PLAN 28E

FIGURE C-62

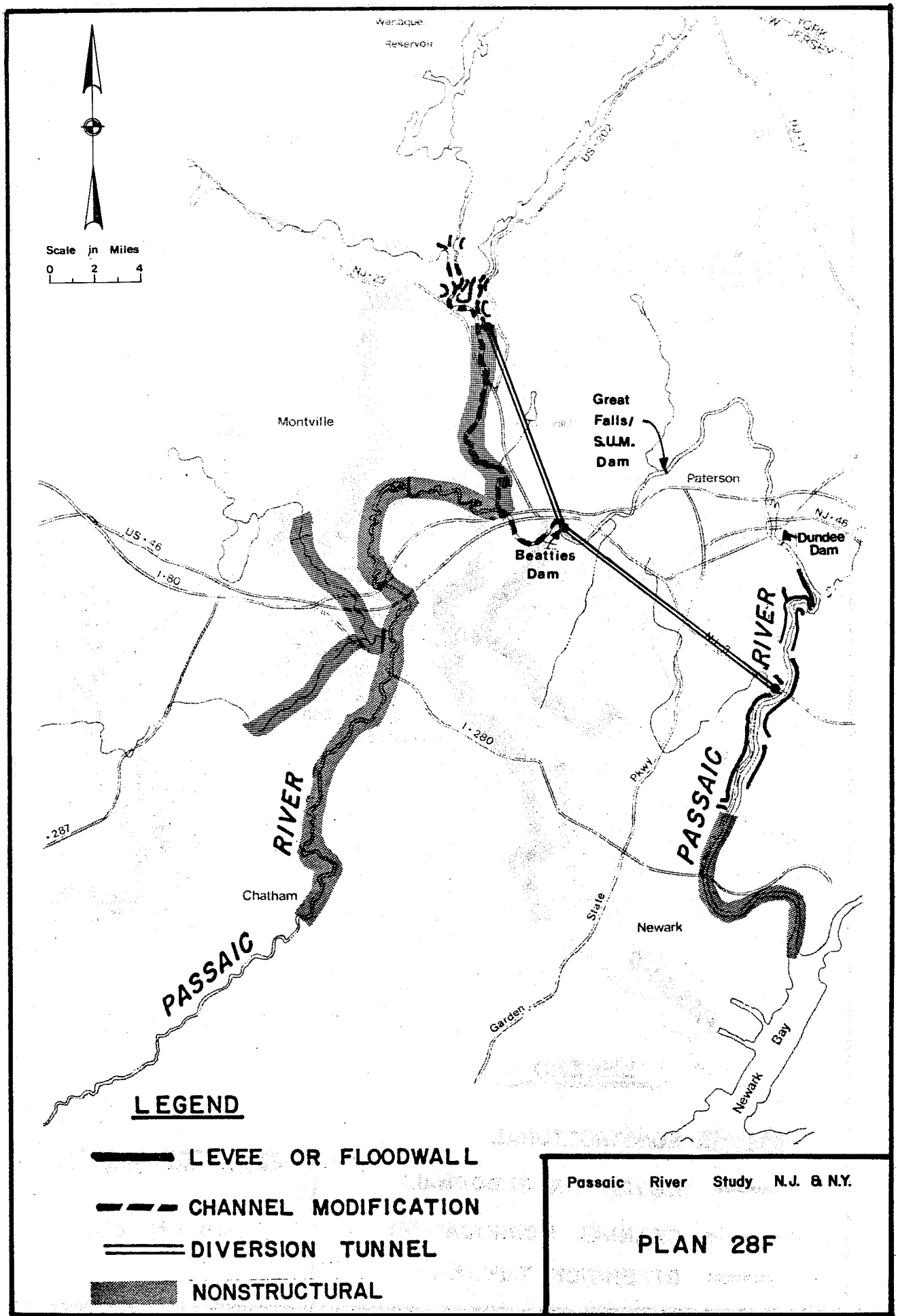

Scale in Miles
0 2 4
Montville
Great Falls/ S.U.M. Dam
Paterson
Beatties Dam
Dundee Dam
PASSAIC RIVER
PASSAIC RIVER
Chatham
Newark
US-46
I-80
I-280
NJ-46
Pkwy
State
Garden
Bay
Newark
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
NONSTRUCTURAL
Passaic River Study N.J. & N.Y.
PLAN 28F

FIGURE C-63

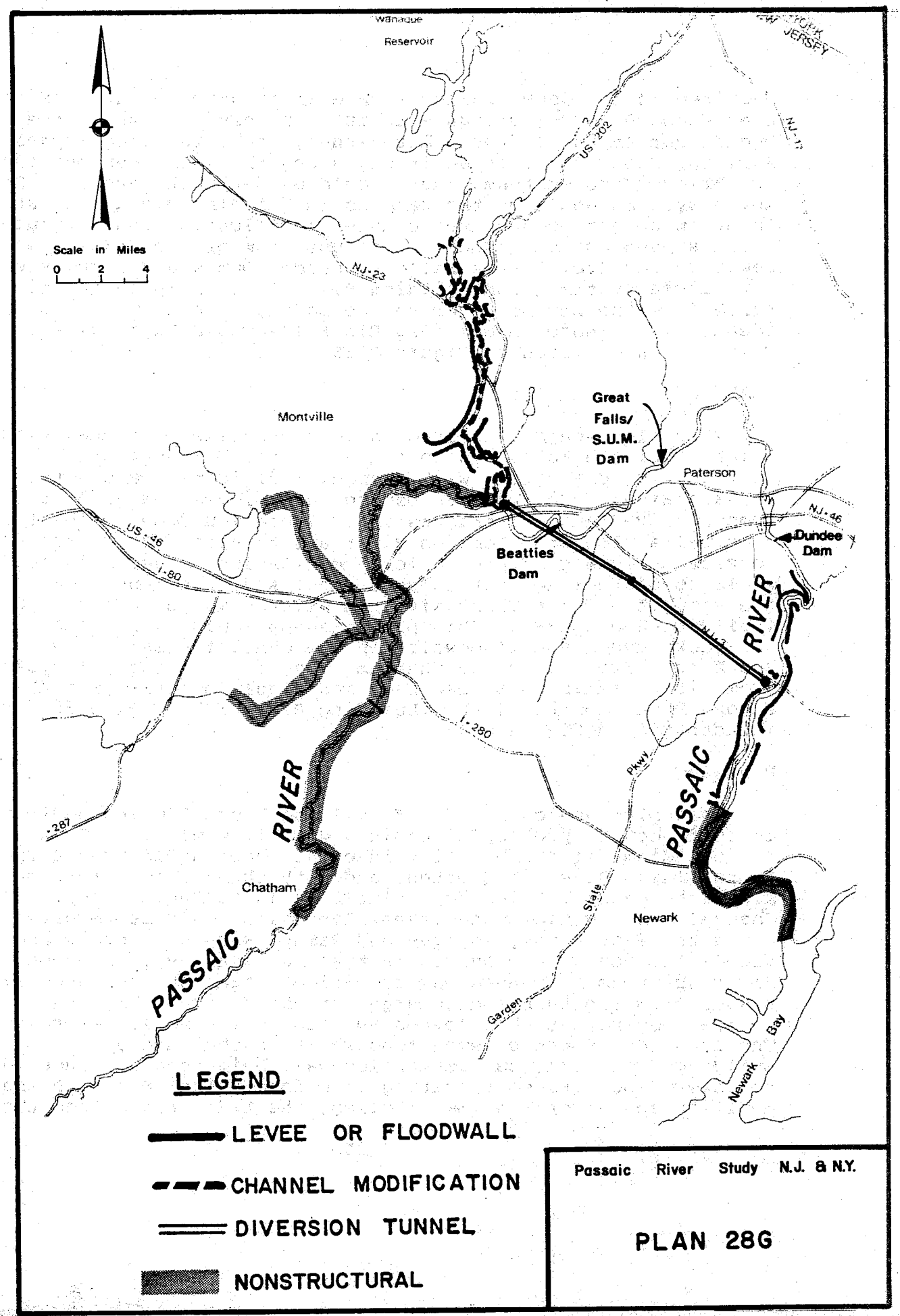

Wanaque
Reservoir
NEW YORK
JERSEY
US-202
NJ-23
Scale in Miles
0 2 4
Montville
Great
Falls/
S.U.M.
Dam
Paterson
NJ-46
Dundee
Dam
US-46
I-80
Beatties
Dam
PASSAIC RIVER
I-280
Parkway
PASSAIC RIVER
Chatham
State
Newark
Garden
Newark Bay
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
NONSTRUCTURAL
Passaic River Study N.J. & N.Y.
PLAN 28G

FIGURE C-64

required in the Lower Valley from downstream of Dundee Dam to the Second River to mitigate against increased flows at the tunnel outlet in Clifton. Altogether, these features represent Building Block 23A. In addition, along the main stem between Two Bridges and Chatham, there would be set-back levees. These levee systems would be the same as in Building Block 13A but lower in height because the channel modification would reduce flood stages on the Passaic River upstream of Two Bridges. The Lower Valley from Little Falls to Dundee Dam would require only five levee systems from Building Block 13A, while in the tidal reach from the Second River to the mouth, levees and walls identical to those in Building Block 13A would be required. Plan 30a is depicted on Figure C-65.

PLAN 30B

This plan would consist of a 40-foot diameter tunnel with an inlet at Little Falls and an outlet at the Third River in Clifton, in conjunction with channel modification along the Passaic River from Beatties Dam to Two Bridges and along the Pompton River and its tributaries. There would be levees and floodwalls along the Pompton River and tributaries to provide consistent levels of protection. Mitigation levees and floodwalls to protect against induced damages at the tunnel outlet in the vicinity of the Third River in Clifton would be included (Building Block 23B). This plan element would be combined with set-back levees and floodwalls in the Central Passaic River reach from Two Bridges to Chatham, five levee/floodwall systems from Little Falls to Dundee Dam, and tidal levees from the Second River to the mouth (Building Block 13A). Plan 30B is illustrated in Figure C-65.

Plan 30C

This plan would consist of Building Block 23C and additional levee/floodwall protection basin-wide. It would include a 40-foot diameter tunnel, with inlet at Pompton Plains and outlet at the Third River in Clifton, and with channel modification along the Passaic River from Little Falls to Two Bridges. Channel modifications and levee/floodwalls would be required along the Pequannock, Wanaque and Ramapo Rivers. Levees and floodwalls would be provided in the Lower Valley from Second River upstream to Dundee Dam to mitigate against increased flood stages from the tunnel discharges at Third River. In the Central Basin, set-back levees and floodwalls would be provided. The location of these levee/floodwalls is the same as in Building Block 13A, but levee/floodwall heights are reduced due to lower flood stages resulting from the Central Basin channel modification. For the Lower Valley, the tidal reach from the

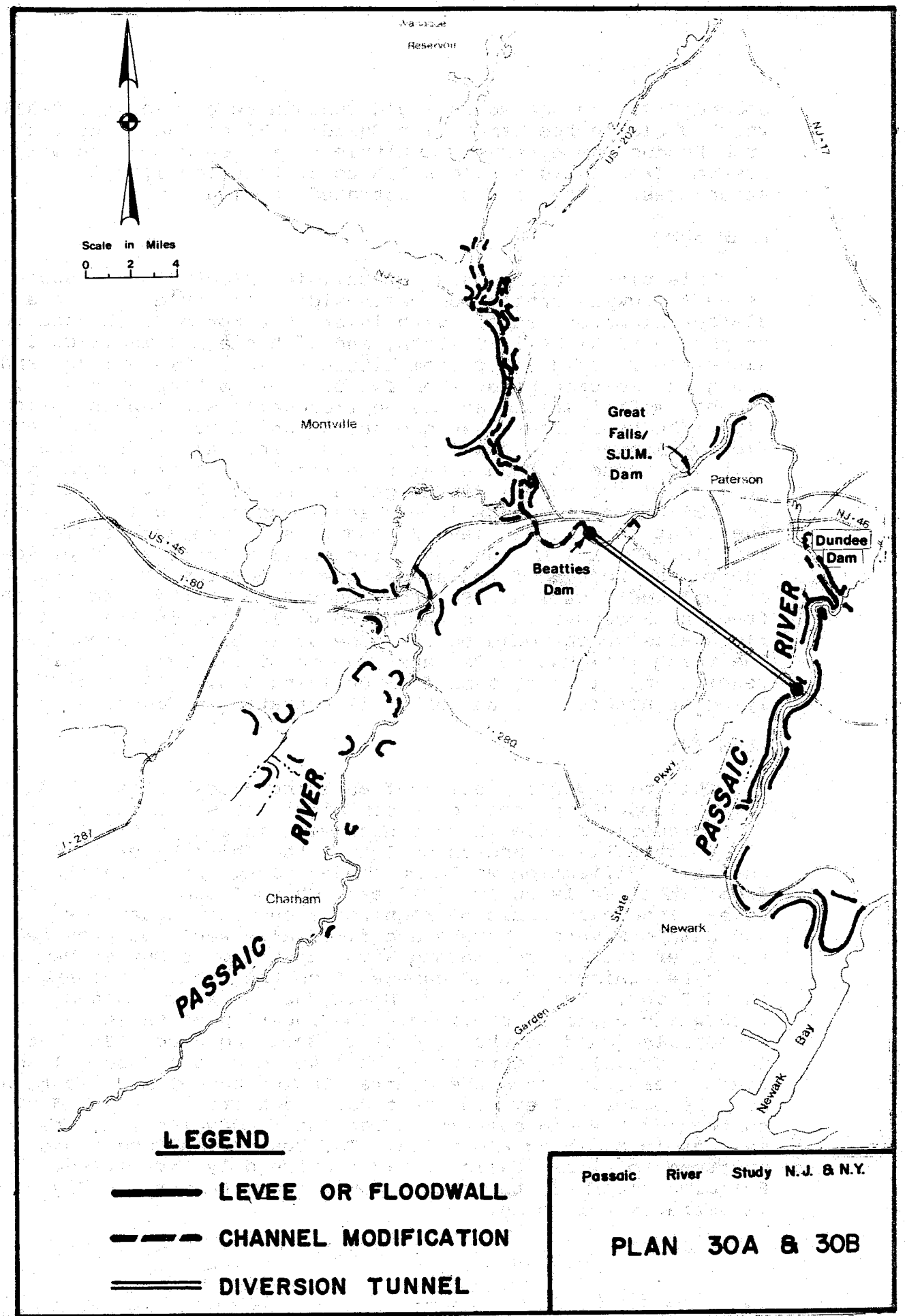

Scale in Miles
0 2 4
Reservoir
US-202
NJ-17
NJ-23
Montville
Great Falls/ S.U.M. Dam
Paterson
NJ-46
Dundee Dam
Beatties Dam
US-46
I-80
I-280
I-287
Pkwy
PASSAIC RIVER
PASSAIC RIVER
Chatham
State
Newark
Garden
Bay
Newark
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
PLAN 30A & 30B

FIGURE C-65

Second River to the mouth would contain levees and floodwalls which would be the same as in Building Block 13A. The reach from Dundee Dam upstream to Little Falls would require only five systems from Building Block 13A to protect low lying structures. Plan 30C is illustrated in Figure C-66.

PLAN 30D

This plan would consist of Building Block 23D and additional levee/floodwall protection basin-wide. It would include a 35-foot diameter tunnel, with inlet at Pompton Plains and outlet at the Third River in Clifton, and with channel modification along the Passaic River from Little Falls to Two Bridges and along the Pompton River from Two Bridges to Pompton Plains. Channel modifications and levee/floodwalls would be required along the Pequannock, Wanaque and Ramapo Rivers. Levees and floodwalls would be provided in the Lower Valley from the Second River upstream to Dundee Dam to mitigate against increased flood stage from the tunnel discharges at the Third River. In the Central Basin, set-back levees and floodwalls would be provided. The location of these levee/floodwalls is the same as in Building Block 13A, but levee/floodwall heights would be lower due to the reduced flood stages resulting from the Central Basin channel modification. For the Lower Valley, the tidal reach from the Second River to the mouth would contain levees and floodwalls which would be the same as in Building Block 13A. The reach from Dundee Dam upstream to Little Falls, would require only five systems from Building Block 13A to protect low lying structures. Plan 30D is illustrated in Figure C-67.

PLAN 30E

This plan would consist of Building Block 23E and additional levee/floodwall protection basin-wide. It would include a 40-foot diameter double inlet tunnel with inlets at Little Falls and Pompton Plains and an outlet at the Third River in Clifton. Channel modification would be needed along the Passaic River from Little Falls to Two Bridges. Channel modifications and levee/floodwalls would be required along the Pequannock, Wanaque and Ramapo Rivers. Levees and floodwalls would be provided in the Lower Valley from Second River upstream to Dundee Dam to mitigate against induced damages from the tunnel discharges at Third River. In the Central Basin, set-back levees and floodwalls would be provided. The location of these levee/floodwalls would be the same as in Building Block 13A, but levee/floodwall heights would be lower due to reduced flood stages resulting from the Central Basin channel modification. For the Lower Valley, in the tidal reach from the Second River to the mouth would contain levees and floodwalls would be the same as in Building Block 13A. The reach from Dundee Dam upstream to Little Falls, would require only five systems Building Block 13A to protect low lying structures. Figure C-68 illustrates this plan.

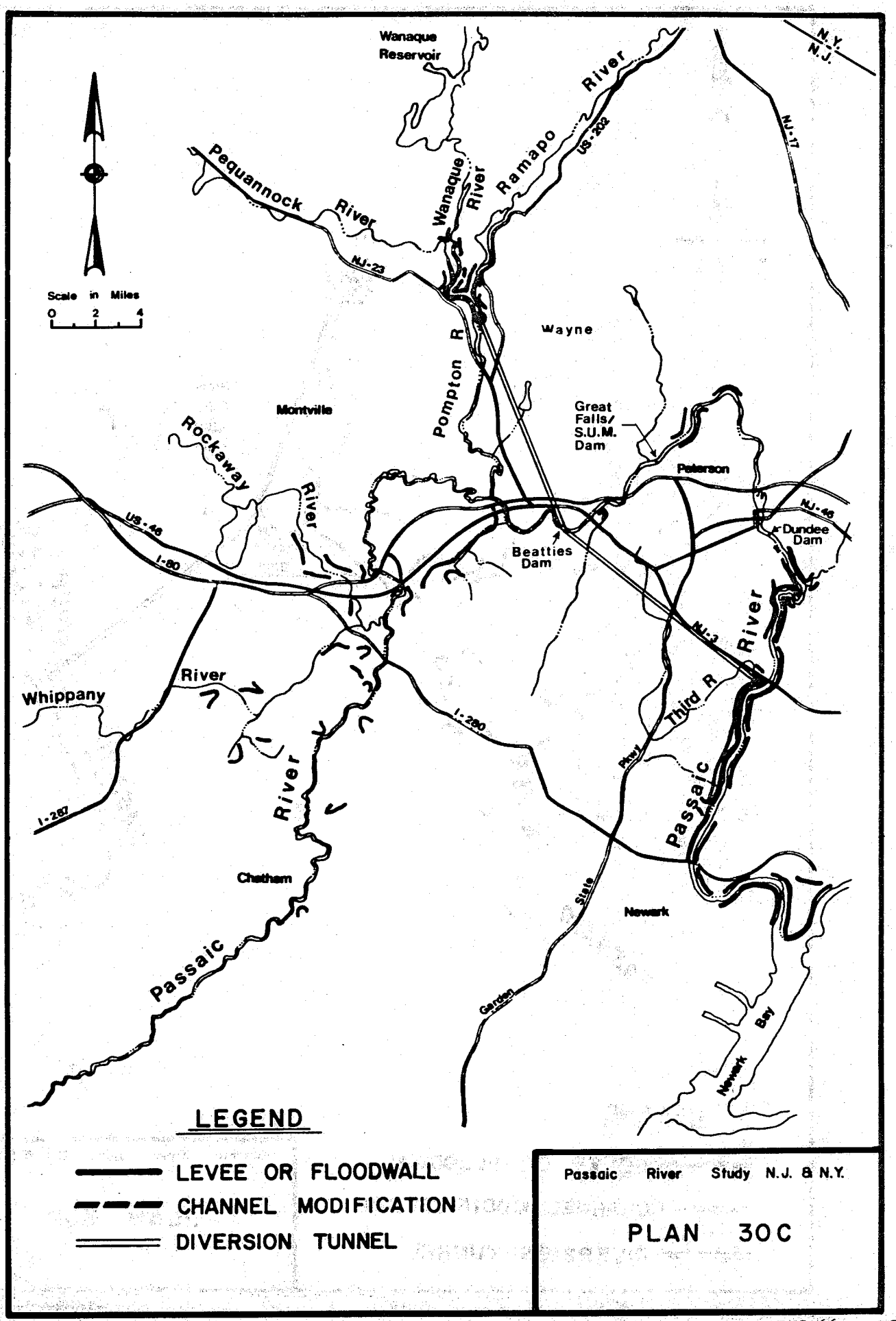

Wanaque Reservoir
N.Y.
N.J.
Pequannock River
Wanaque River
Ramapo River
US-202
NJ-17
NJ-23
Scale in Miles
0 2 4
Wayne
Pompton R
Montville
Great Falls/ S.U.M. Dam
Rockaway River
Paterson
US-46
NJ-46
I-80
Beatties Dam
Dundee Dam
NJ-3
Passaic River
Whippany River
Third R
I-280
Pkwy
I-287
Passaic River
Chatham
State
Newark
Garden
Newark Bay
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
PLAN 30C

FIGURE C-66

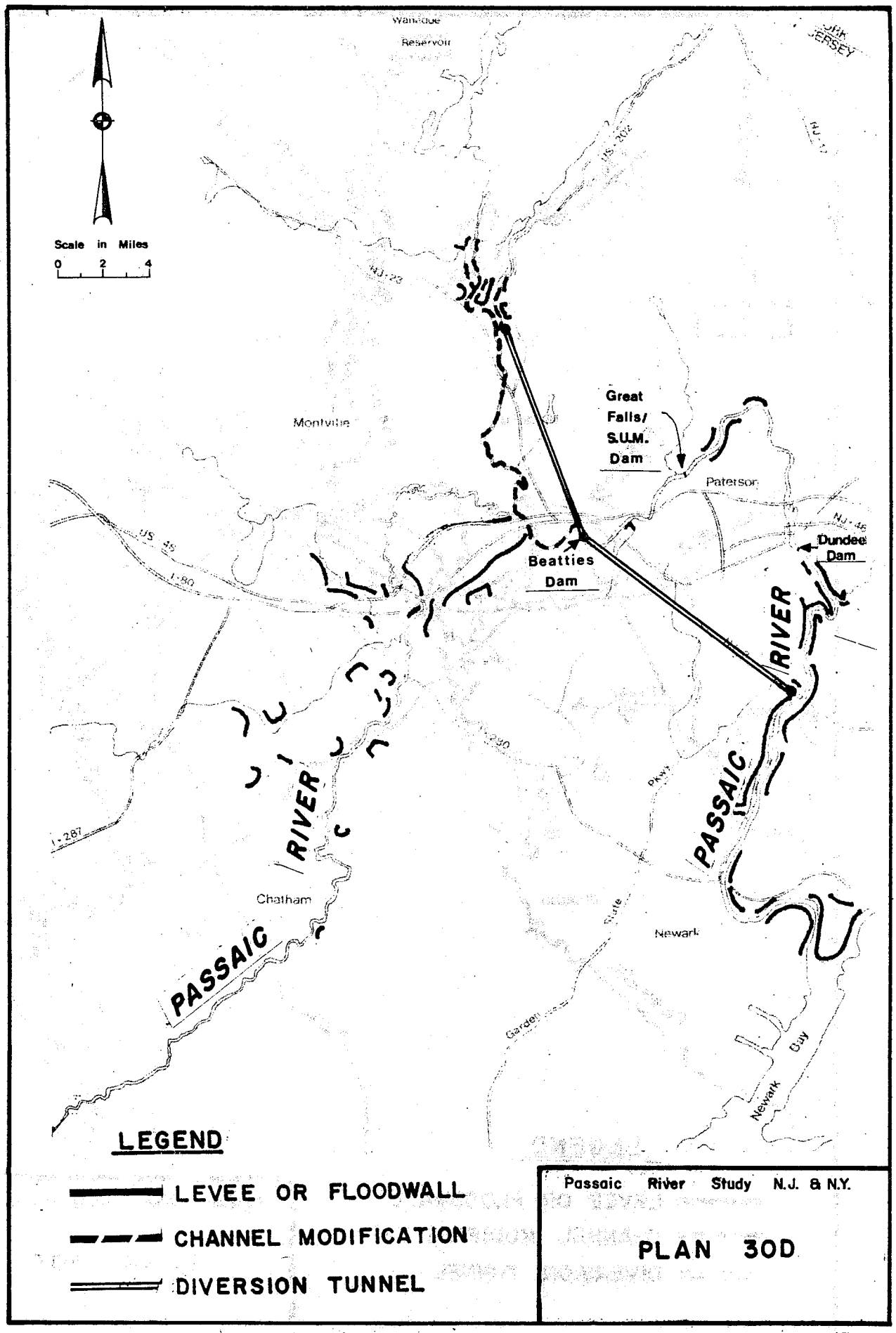

Scale in Miles
0 2 4
Great Falls/ S.U.M. Dam
Beatties Dam
Dundee Dam
Montville
Paterson
Chatham
Newark
PASSAIC RIVER
PASSAIC RIVER
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
PLAN 30D

FIGURE C-67

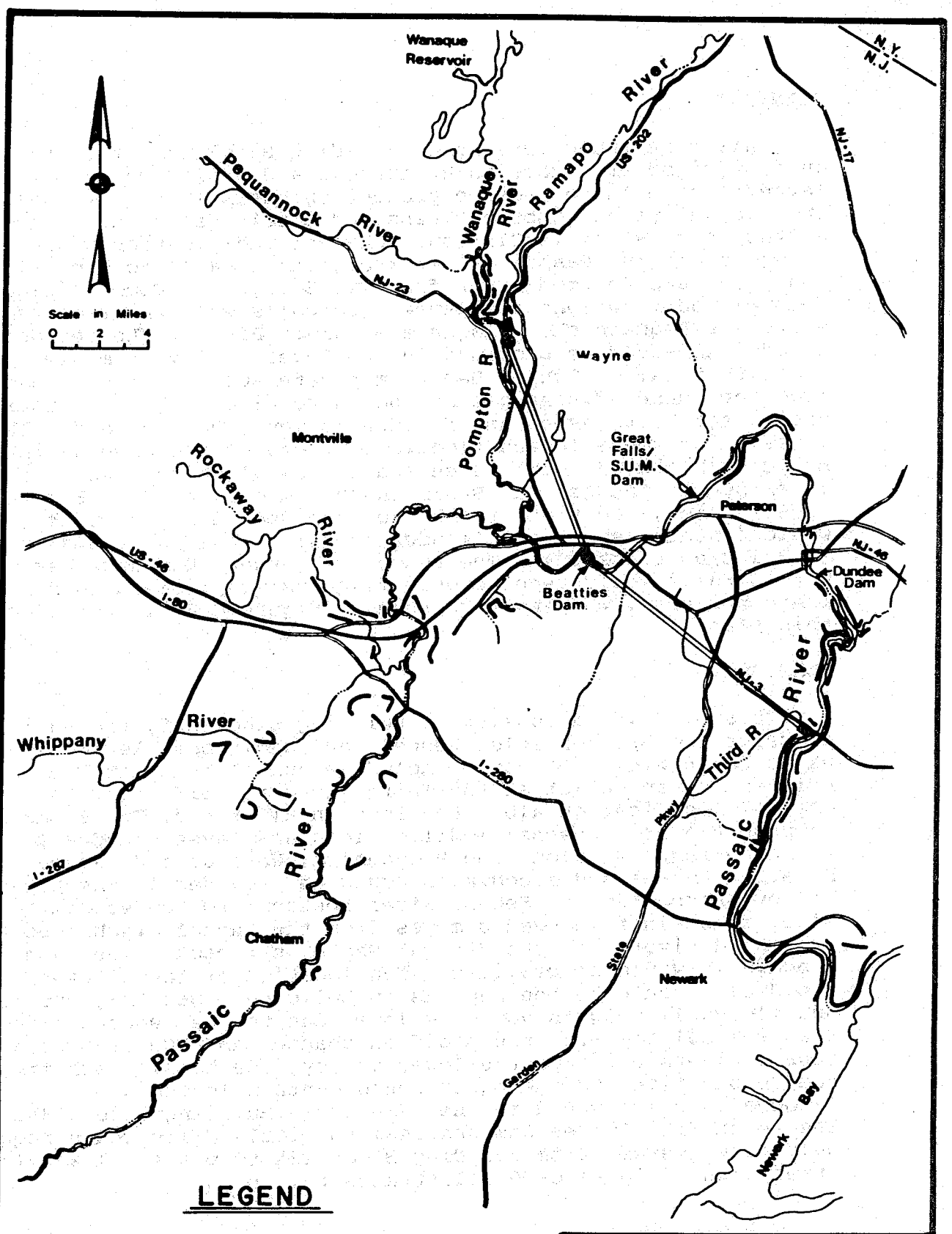

Wanaque Reservoir
Pequannock River
Wanaque River
Ramapo River
N.Y.
N.J.
NJ-17
US-202
NJ-23
Scale in Miles
0 2 4
Wayne
Pompton R
Montville
Rockaway River
Great Falls/ S.U.M. Dam
Paterson
US-46
I-80
Beatties Dam
NJ-46
Dundee Dam
NJ-3
Third R
Passaic River
Whippany River
I-280
Parkway
I-287
Chatham
Passaic River
State
Newark
Garden
Newark Bay
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
PLAN 30 E

FIGURE C-68

PLAN 30F

This plan would consist of Building Block 23F, the 35/40-foot diameter double inlet tunnel, and additional levee/floodwalls to provide protection basin-wide. It would include inlets at Pompton Plains and Little Falls and an outlet at the Third River in Clifton. Channel modification would be needed along the Passaic River from Little Falls to Two Bridges and along the Pompton River from Two Bridges to Pompton Plains. Channel modifications and levee/floodwalls would be required along the Pequannock, Wanaque and Ramapo Rivers. Levees and floodwalls would be provided in the Lower Valley from the Second River upstream to Dundee Dam to mitigate against induced damages from the tunnel discharges at the Third River. In the Central Basin, set-back levees and floodwalls would be provided. The location of these levees/floodwalls would be the same as in Building Block 13A, but levee and floodwall heights would be lower due to the Central Basin channel modification. For the Lower Valley, the tidal reach from the Second River to the mouth would contain levees and floodwalls which would be the same as in Building Block 13A. The reach from Dundee Dam upstream to Little Falls would require only five systems from Building Block 13Ato protect low lying structures. Figure C-69 illustrates this plan.

PLAN 30G

This plan would consist of Building Block 23G, the 40-foot diameter Two Bridges Inlet tunnel, and additional levee/floodwalls basin-wide. It would include a tunnel inlet at Two Bridges and an outlet at the Third River in Clifton, with channel modification along the Pompton River from Two Bridges to Pompton Plains. Channel modifications and levee/floodwalls would be required along the Pequannock, Wanaque and Ramapo Rivers. Levees and floodwalls would be provided in the Lower Valley reach from the Second River upstream to Dundee Dam to mitigate against induced damages from the tunnel discharges at the Third River. In the Central Basin, set-back levees and floodwalls would be provided. The location of these levee/floodwalls would be the same as in Building Block 13A, but levee and floodwall heights would be lower due to the reduced flood stages resulting from the modified channel and Two Bridges inlet tunnel diversion. For the Lower Valley, the tidal reach from the Second River to the mouth would contain levees and floodwalls which would be the same as in Building Block 13A. The reach from Dundee Dam upstream to Little Falls would require only five systems from Building Block 13A to protect low-lying structures. Figure C-70 illustrates this plan.

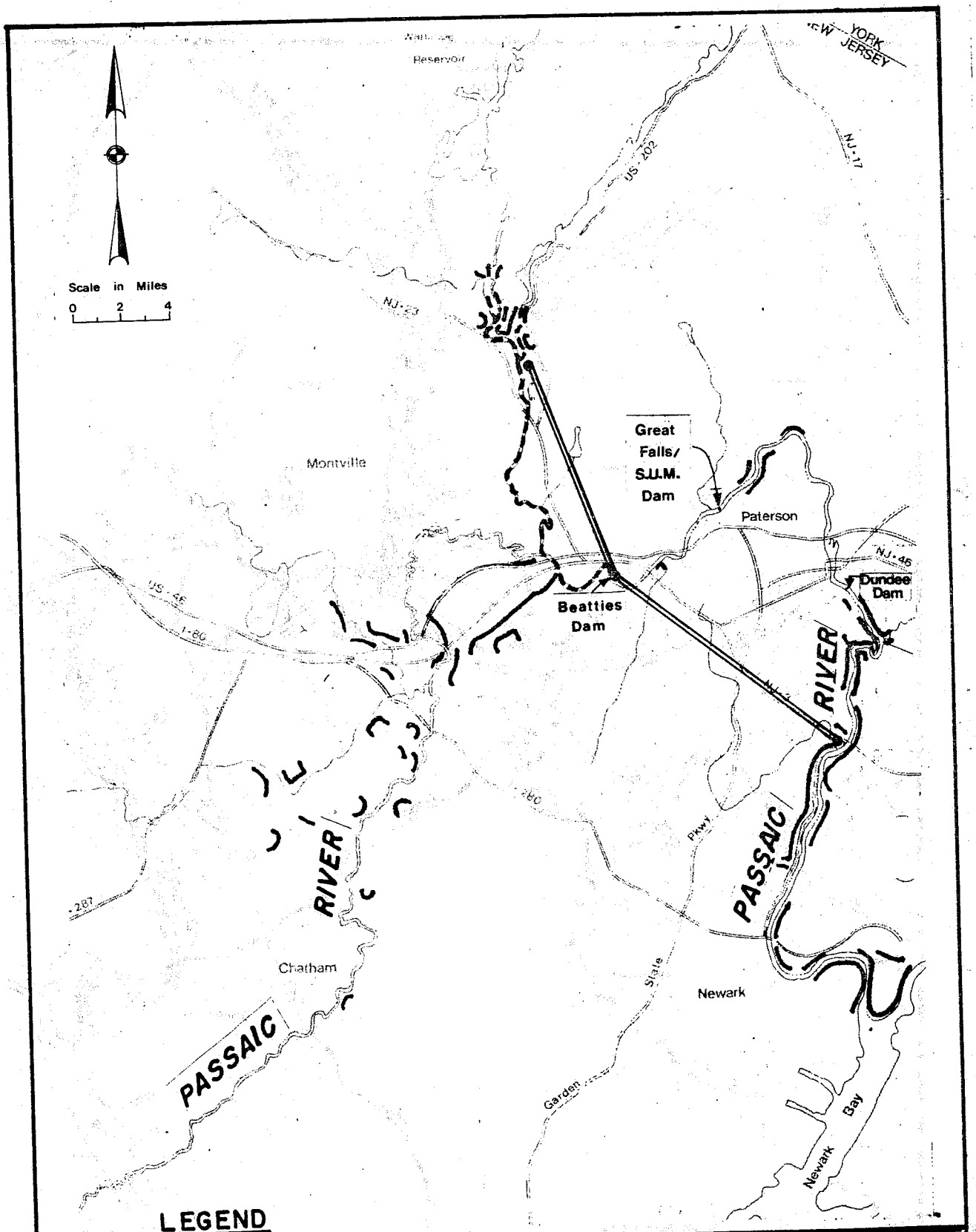

Reservoir
NEW YORK
JERSEY
US 202
NJ 17
NJ 23
Scale in Miles
0 2 4
Great Falls/ S.U.M. Dam
Montville
Paterson
NJ 46
Dundee Dam
Beatties Dam
US 46
I-80
PASSAIC RIVER
PASSAIC RIVER
Pkwy
287
Chatham
Garden State
Newark
Newark Bay
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
PLAN 30F

FIGURE C-69

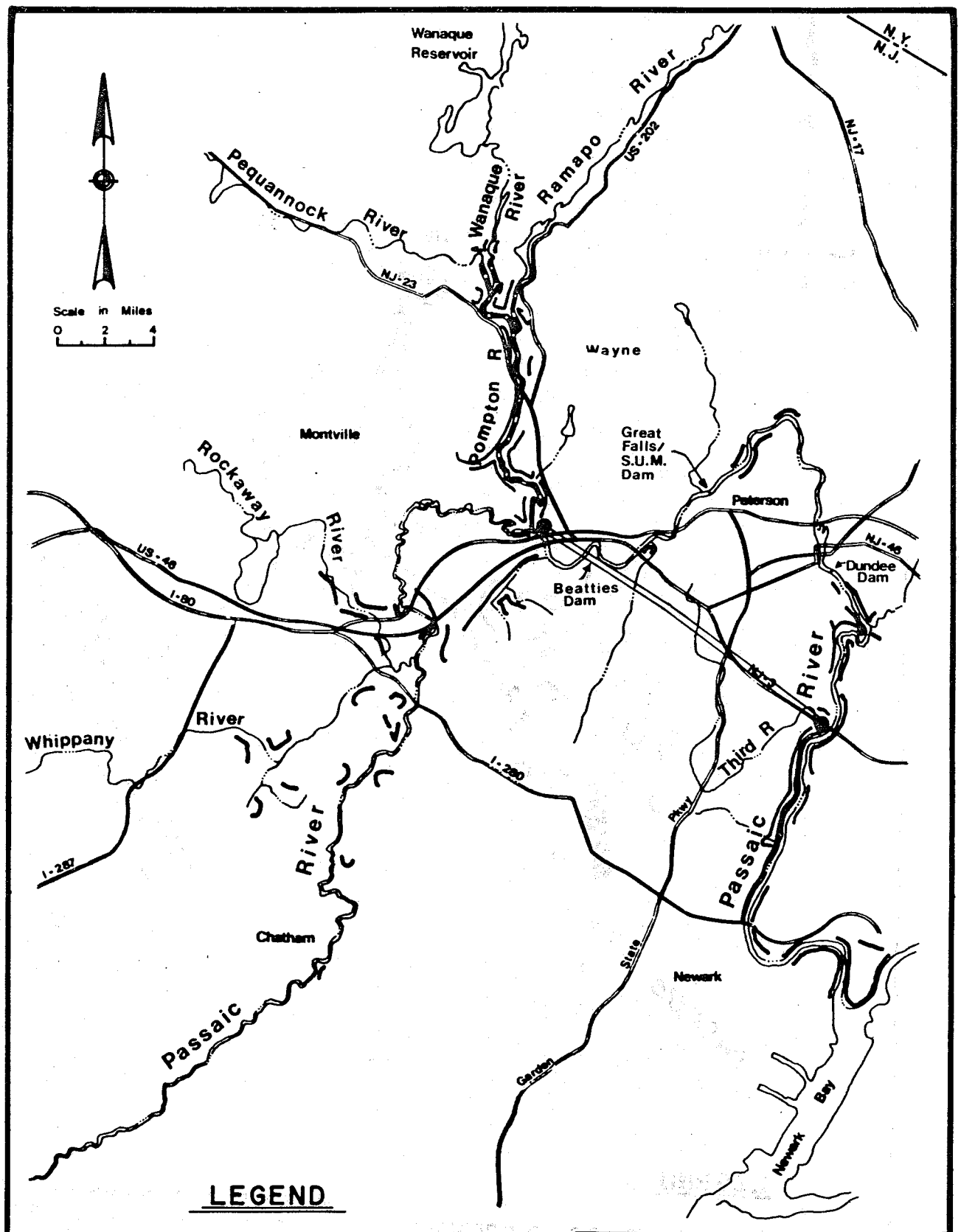

Wanaque Reservoir
Pequannock River
Wanaque River
Ramapo River
N.Y.
N.J.
US-202
NJ-17
NJ-23
Scale in Miles
0 2 4
Wayne
Pompton R
Montville
Great Falls/ S.U.M. Dam
Rockaway River
Paterson
US-46
I-80
NJ-46
Dundee Dam
Beatties Dam
Whippany River
Third R
I-280
Pkwy
Passaic River
I-287
Chatham
Passaic River
State
Newark
Garden
Bay
Newark
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
PLAN 30G

FIGURE C-70

PLANS 31A-G - TUNNELS, LEVEE/FLOODWALLS, CHANNEL MODIFICATION

The development of Plans 31A-G considered the applicability of levees and floodwalls and channel modifications to the major tunnel alignments. Because of the nature of the flooding, channel modifications are not effective in the tidal area, nor in the reach from Two Bridges to Chatham. Therefore, for Plans 31A-G, these reaches would be protected by levees and floodwalls. In addition, it is noted that channels and levee/floodwalls are required as functional component of the tunnel diversion building blocks as described in Building Blocks 23A through 23G. Therefore, these plans would be the same as Plans 30A through 30G which utilize levees and floodwalls to provide basin-wide protection. Therefore, Plans 31A through 31G were given no further consideration.

PLANS 32A-G - TUNNELS, NONSTRUCTURAL, CHANNEL MODIFICATION

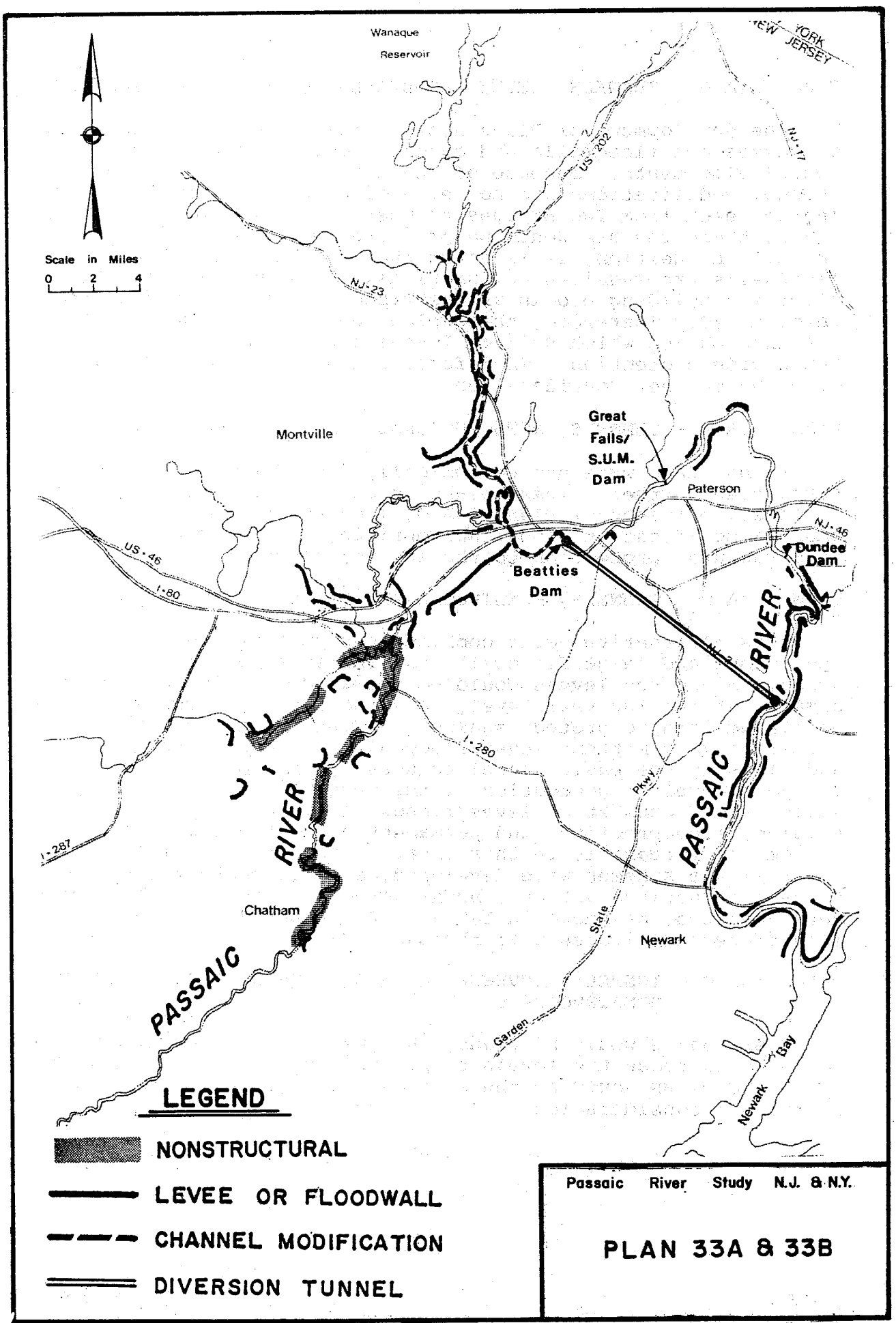
Plans 32A-G were not economically justified and were not considered further. These plans essentially replace the levee/floodwall portions of Plans 30A-G, located in those areas where channel modification is not appropriate, with comprehensive nonstructural protection to the 100 year level.

PLANS 33A-G - TUNNELS, NONSTRUCTURAL, LEVEE/FLOODWALLS

This alternative would combine nonstructural measures with the tunnel and levee/floodwall alternatives described in Plans 30A-G. Since the levees would be designed to eliminate residual damages at the 100 year level, nonstructural measures would also be implemented to protect against 100 year flooding. The resulting intermittent levee/floodwall and nonstructural additions to the basic tunnel schemes would provide a uniform 100 year level of protection to the Central Basin. The Lower Valley would consist of levee/floodwall systems only, since raising, floodproofing, and permanent evacuations are not economically feasible in this area. Since several different tunnel/levee schemes were developed, a complimentary array of these alternatives with the nonstructural features incorporated were analyzed, as shown in Table C-60. Plans 33A-G are illustrated in Figures C-71 through C-76.

PLANS 34A-G - TUNNELS, LEVEE/FLOODWALLS, CHANNEL MODIFICATION, NONSTRUCTURAL

Plans 34A-G would be Plans 31A-G with nonstructural measures added to increase the levels of protection. As noted under Plan 31, those plans would be the same as Plans 30A-G and were given no further consideration.



C-363

FIGURE C-71

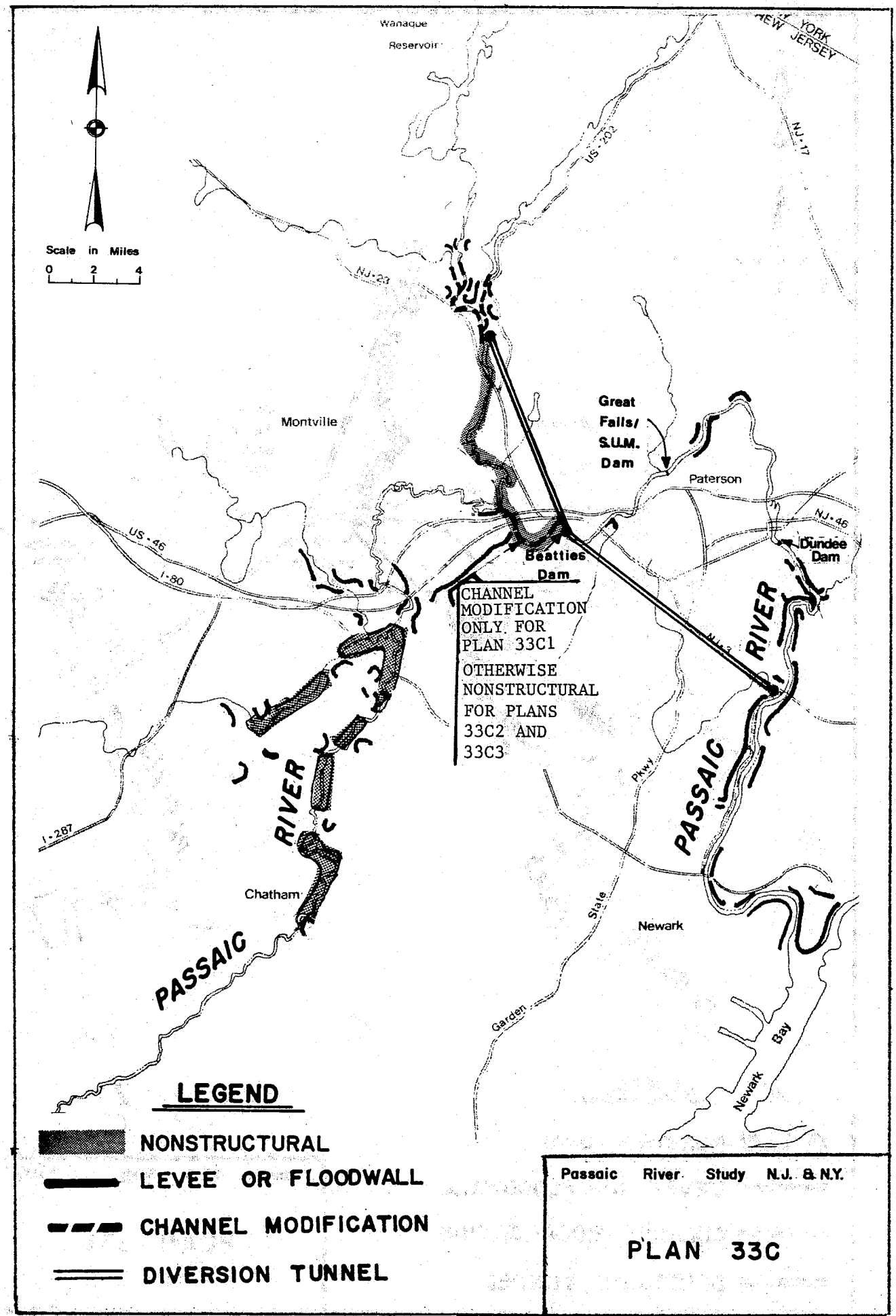

Wanaque
Reservoir
NEW YORK
NEW JERSEY
US-202
NJ-17
NJ-23
Scale in Miles
0 2 4
Montville
Great
Falls/
S.U.M.
Dam
Paterson
NJ-46
US-46
I-80
Beatties
Dam
Dundee
Dam
CHANNEL
MODIFICATION
ONLY FOR
PLAN 33C1
OTHERWISE
NONSTRUCTURAL
FOR PLANS
33C2 AND
33C3
PASSAIC RIVER
PASSAIC RIVER
I-287
Chatham
Pkwy
State
Garden
Newark
Newark
Bay
LEGEND
NONSTRUCTURAL
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
PLAN 33C

FIGURE C-72

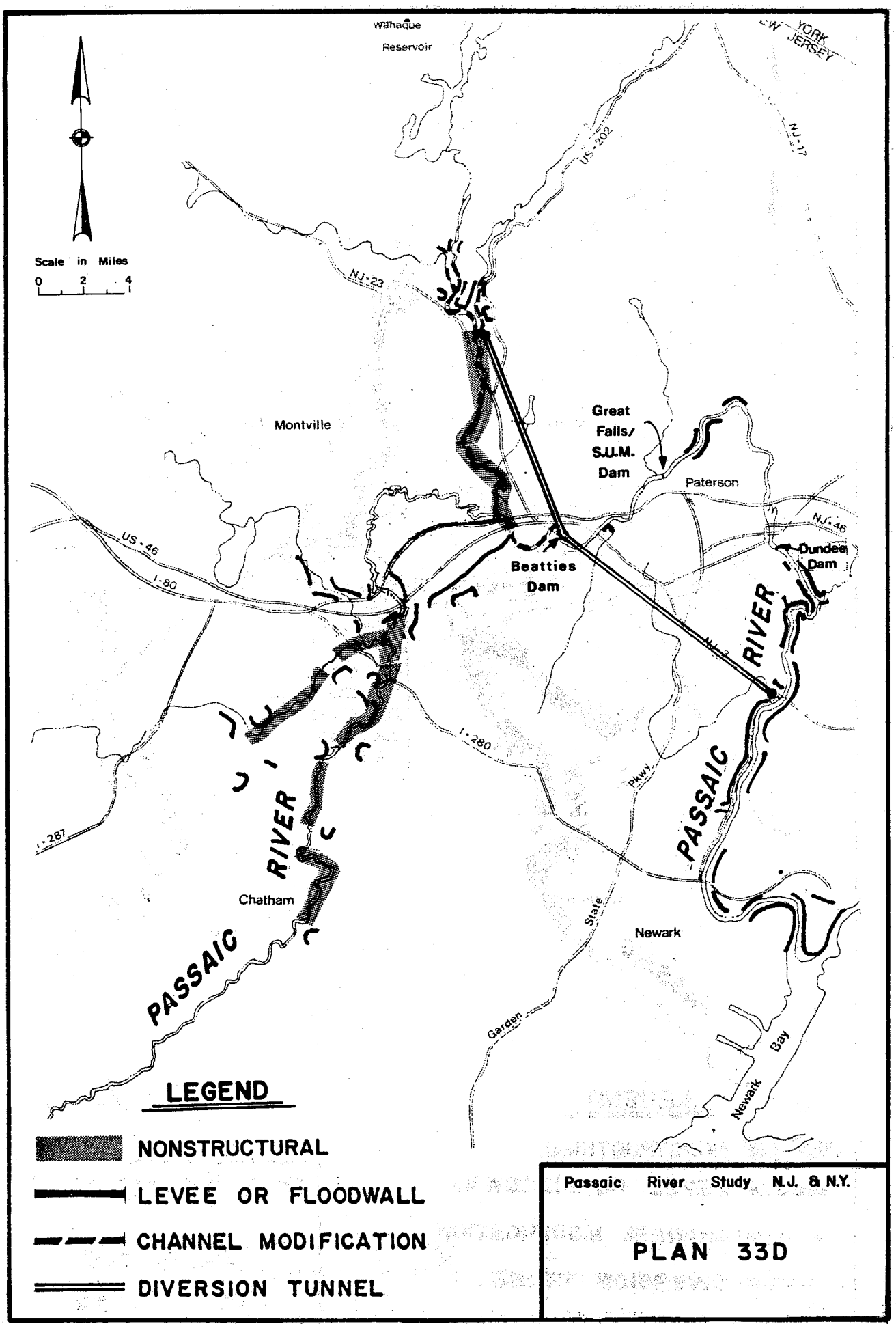

Wanaque
Reservoir
NEW YORK
NEW JERSEY
US-202
NJ-17
NJ-23
Scale in Miles
0 2 4
Montville
Great
Falls/
S.U.M.
Dam
Paterson
NJ-46
US-46
I-80
Beatties
Dam
Dundee
Dam
PASSAIC RIVER
I-280
Pkwy
I-287
Chatham
PASSAIC RIVER
State
Newark
Garden
Newark Bay
LEGEND
NONSTRUCTURAL
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
PLAN 33D

FIGURE C-73

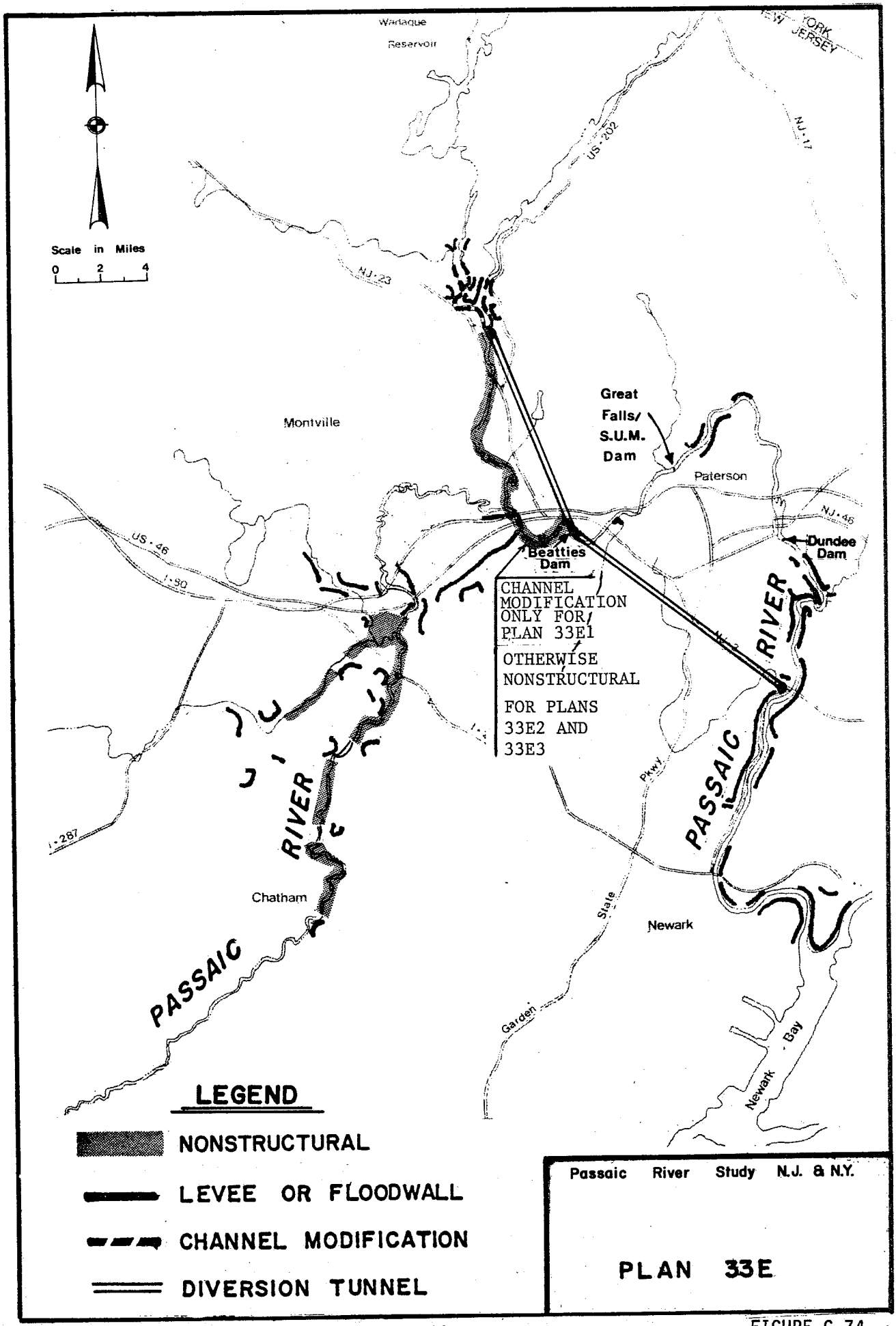

Wanaque
Reservoir
NEW YORK
JERSEY
US-202
NJ-17
NJ-23
Scale in Miles
0 2 4
Great
Falls/
S.U.M.
Dam
Montville
Paterson
NJ-46
US-46
I-80
Beatties
Dam
Dundee
Dam
CHANNEL
MODIFICATION
ONLY FOR
PLAN 33E1
OTHERWISE
NONSTRUCTURAL
FOR PLANS
33E2 AND
33E3
PASSAIC
RIVER
PASSAIC
RIVER
I-287
Chatham
Pkwy.
State
Newark
Garden
Newark Bay
LEGEND
NONSTRUCTURAL
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
PLAN 33E

FIGURE C-74

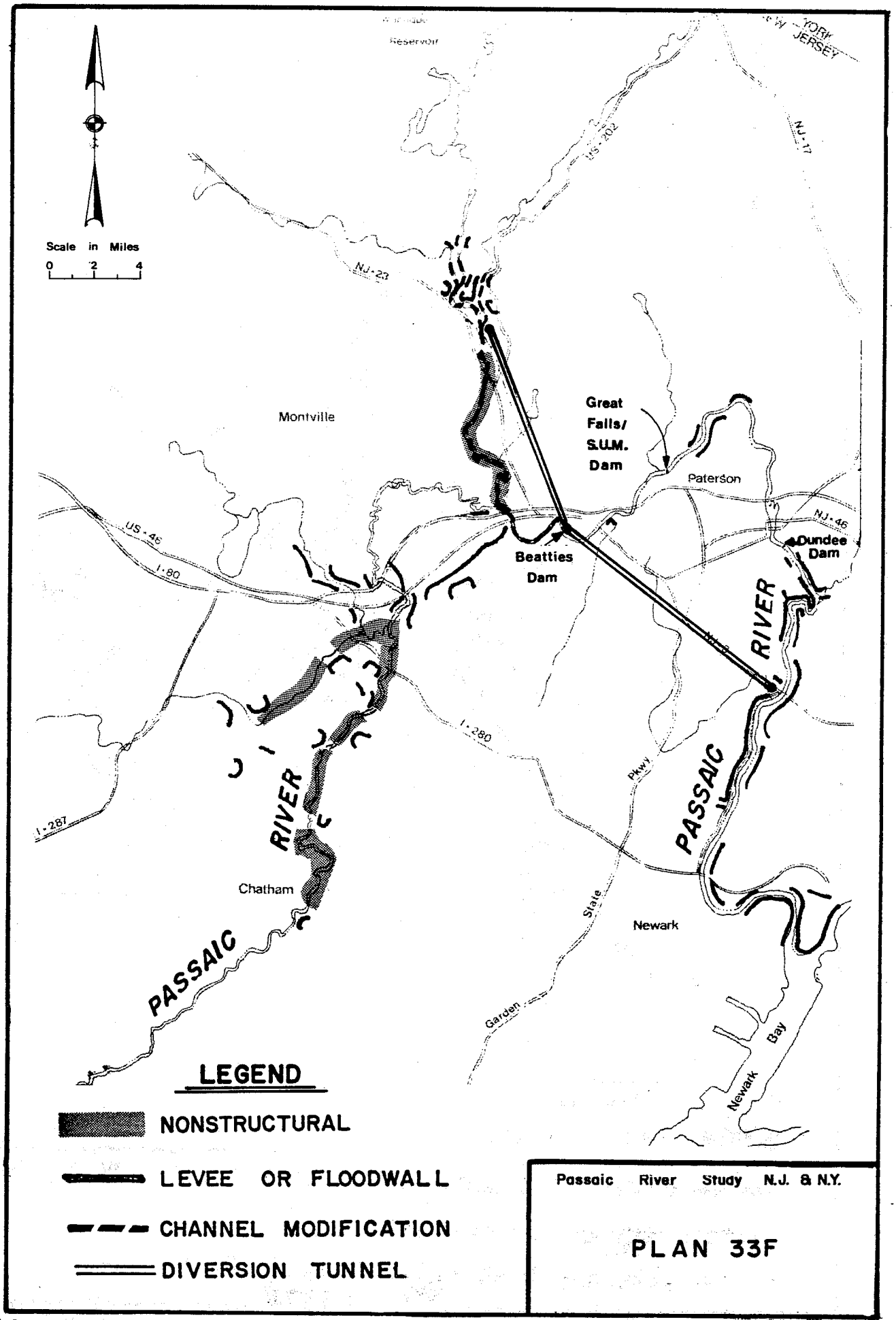

Scale in Miles
0 2 4
Reservoir
NEW YORK
JERSEY
NJ-23
US-202
NJ-17
Montville
Great
Falls/
S.U.M.
Dam
Paterson
US-46
I-80
NJ-46
Dundee
Dam
Beatties
Dam
PASSAIC RIVER
I-280
I-287
Chatham
PASSAIC RIVER
Pkwy
State
Garden
Newark
Newark
Bay
LEGEND
NONSTRUCTURAL
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
PLAN 33F

FIGURE C-75

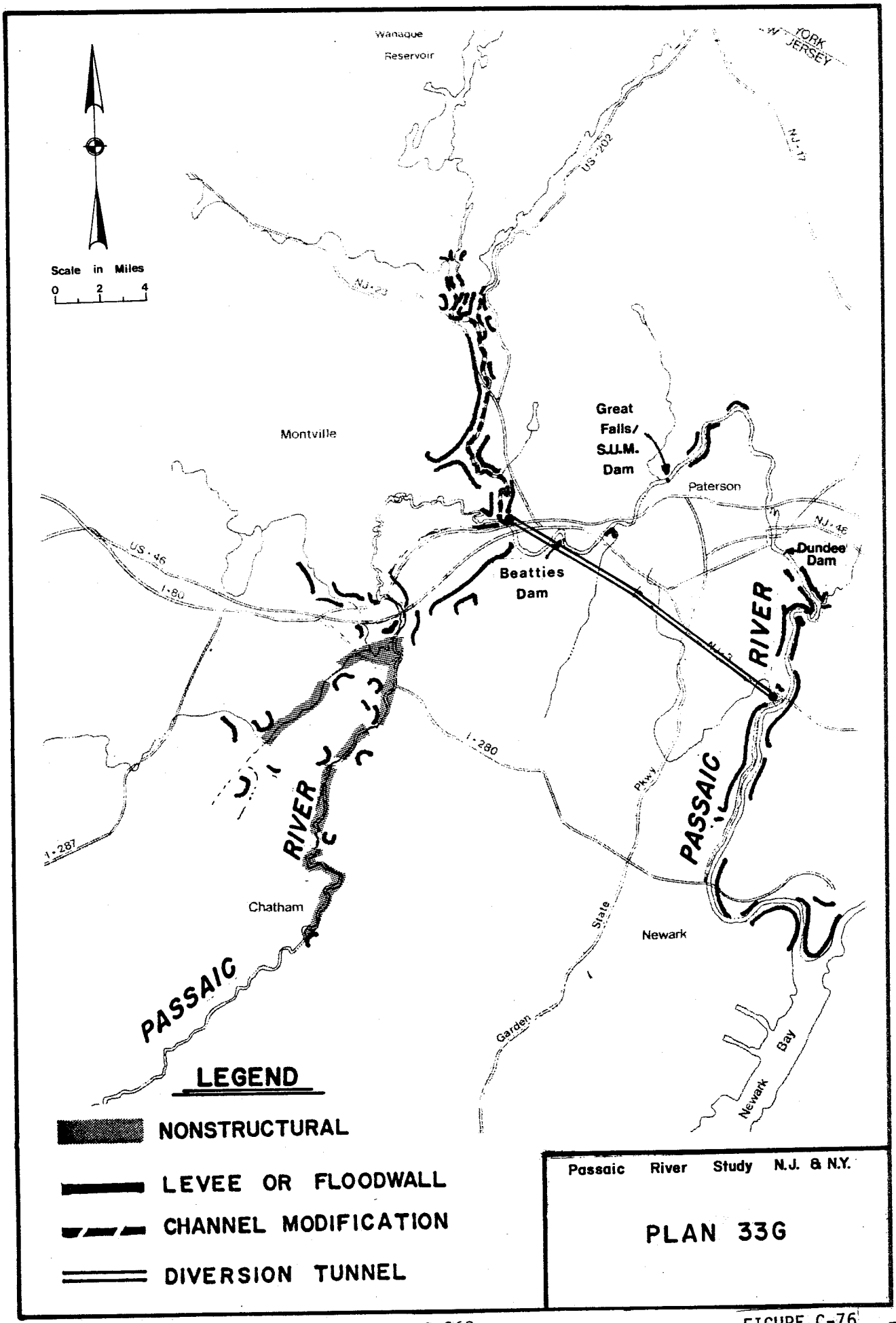

Wanaque
Reservoir
NEW YORK
NEW JERSEY
US-202
NJ-17
NJ-23
Scale in Miles
0 2 4
Montville
Great
Falls/
S.U.M.
Dam
Paterson
NJ-46
Dundee
Dam
Beatties
Dam
US-46
I-80
PASSAIC
RIVER
I-280
Pkwy
I-287
Chatham
State
Newark
Garden
Newark
Bay
LEGEND
NONSTRUCTURAL
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
PLAN 33G

FIGURE C-76

SUMMARY

The economic analysis of Intermediate Stage alternatives is summarized in Table C-33. As can be seen from this table, a number of alternatives had potential as the NED Plan, those containing tunnel diversion having a Beatties Dam inlet (tunnel plans with suffix letters "A" and "B"), a Pompton inlet (suffix "D") and a Dual inlet (suffix "E" plans). Overall, Plan 30A had the maximum excess benefits.

SECTION 6 - EVALUATION AND SCREENING OF INTERMEDIATE STAGE ALTERNATIVES

GENERAL

Impact assessment, evaluation and screening studies were conducted to identify, measure and compare the significant economic, environmental and social effects of the Intermediate Stage Alternatives. These effects were analyzed and formed the basis for evaluating the beneficial and adverse contributions of the alternatives. They also provided a basis for subsequent iterations of the planning process and ultimately for selection of the most desirable plan of protection for the main stem Passaic River.

The initial evaluation activities involved determining the extent to which the alternatives responded to the National Economic Development objective and completeness criteria. Based on this evaluation, a number of alternatives were screened from further analysis. Additional evaluation studies assessed the final array of intermediate plans as to their response to the problem and opportunity statements, environmental impact assessment and social acceptability towards implementation.

MAIN STEM PLAN FORMULATION REACHES

As previously discussed, the main stem study area was initially considered as three formulation reaches: Lower Valley, Central Basin and Upper Passaic. Since no plans were found to be economically feasible for the Upper Passaic this reach was eliminated from further study. To facilitate the evaluation analysis and the comparison and screening of Intermediate Stage alternatives for the Lower Valley and Central Basin, these areas were further divided into five plan formulation reaches as follows:

1. Lower Passaic River under tidal control, from the mouth at Newark Bay upstream to Route 3 at Clifton;

2. Lower Passaic River from Route 3 upstream to Beatties Dam;

3. Passaic River from Beatties Dam upstream to Two Bridges;

4. Pompton Valley, including the entire Pompton River and Lower Ramapo, Pequannock and Wanaque Rivers; and

5. Central Passaic River from Two Bridges upstream to Chatham, and including the Lower Rockaway and Whippany Rivers.

The location of these reaches is displayed in Figure C-77. The plan features for each of the Intermediate Stage alternatives are displayed for these five reaches in Table C-60.

Flooding in the densely urbanized Lower Passaic River downstream of Dundee Dam can be caused by either fluvial flows originating from upstream or by tidal surges entering from Newark Bay. However, tidal stages dominate fluvial stages of corresponding recurrence frequencies only in the Lower Passaic reach from the mouth upstream to Route 3 at Clifton. Therefore, the design of all project works downstream of this point is controlled by tidal elevations (exclusive of any project induced effects). This is the basis for the stratification of Reach 1 above.

For the portion of the Lower Passaic River upstream of Route 3 to Beatties Dam, the controlling flood elevations result from fluvial events (Reach 2 above).

Flooding in the area lying between Beatties Dam and Two Bridges (Reach 3 above) results from inadequate and constricted channel capacity in conjunction with the effects of Beatties Dam, and can be caused by flows entering from the Pompton and/or Passaic Rivers.

Flooding in the Pompton Valley (Reach 4) results from inadequate channel capacity and large flows entering this reach. It is noted that the peak 100 year discharge (32,515 cfs) entering the Upper Pompton River is actually greater than the 100 year discharge entering the Lower Passaic at Little Falls (27,533 cfs). This is because flooding in the suburban Passaic River reach upstream of Two Bridges (Reach 5 above) is characterized by a reversal of flow from the Pompton River upstream to low-lying areas in the Central Passaic Basin, and along the lower Rockaway and Whippany Rivers.

A detailed discussion of the characteristics of main stem flooding was presented in Section 4. The five reaches proved important in translating the complex array of Intermediate Stage alternatives into a simpler, more definitive listing of basic plans:

ARRAY OF INTERMEDIATE PLANS

As presented in Table C-33, twelve "Building Blocks" were found feasible: 1E, 7A, 7B, 13A, 20 and 23A-G. These "Building Blocks" were assembled to formulate 36 economically feasible plans (8, 14A, 14B, 15A, 15B, 16A, 16B, 28A-G, 30A-G and 33A-G). The results of the screening and evaluation activities to identify alternatives warranting detailed study are discussed in the following paragraphs and are summarized in Table C-62.

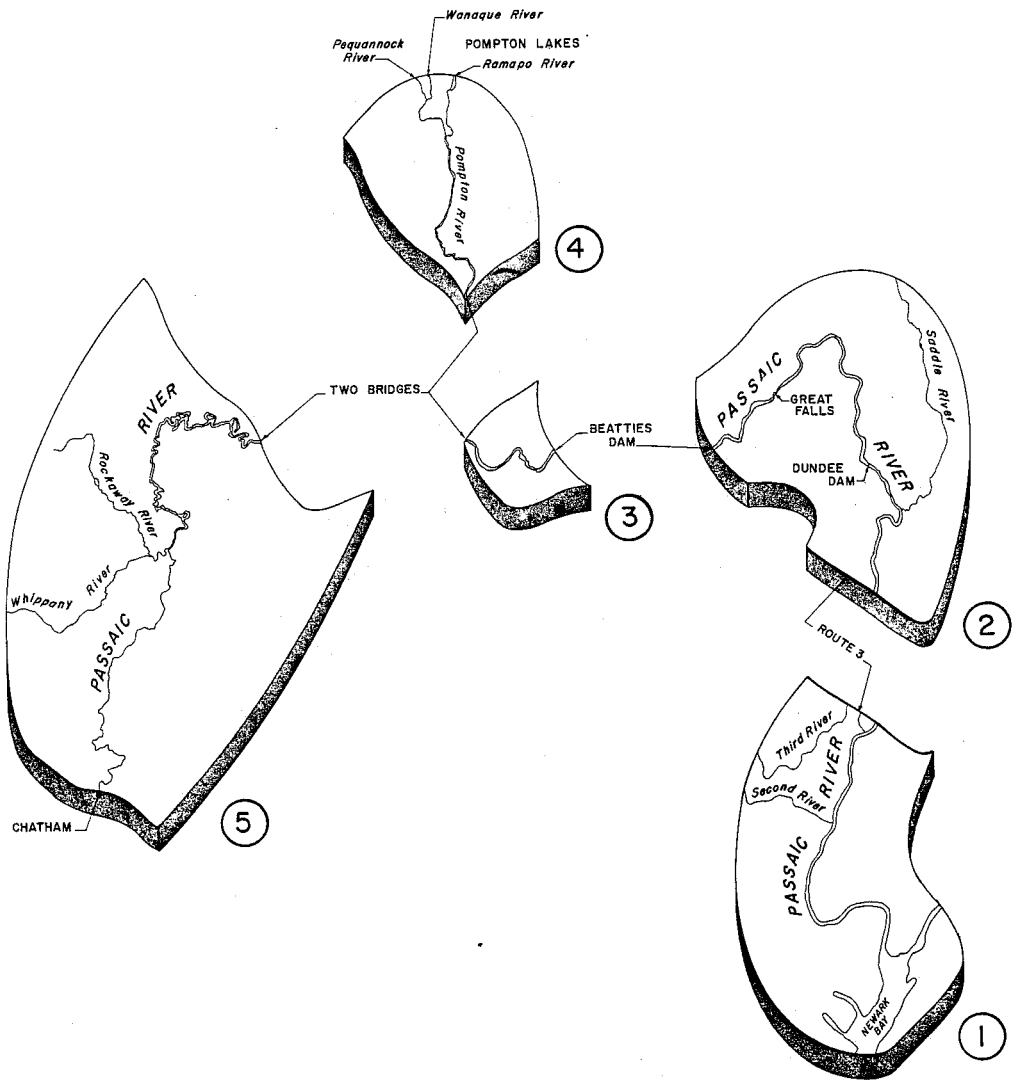
REACH-1 = MOUTH – ROUTE 3

REACH-2 = ROUTE 3 – BEATTIES DAM

REACH-3 = BEATTIES DAM – TWO BRIDGES

REACH-4 = POMPTON VALLEY

REACH-5 = TWO BRIDGES – CHATHAM



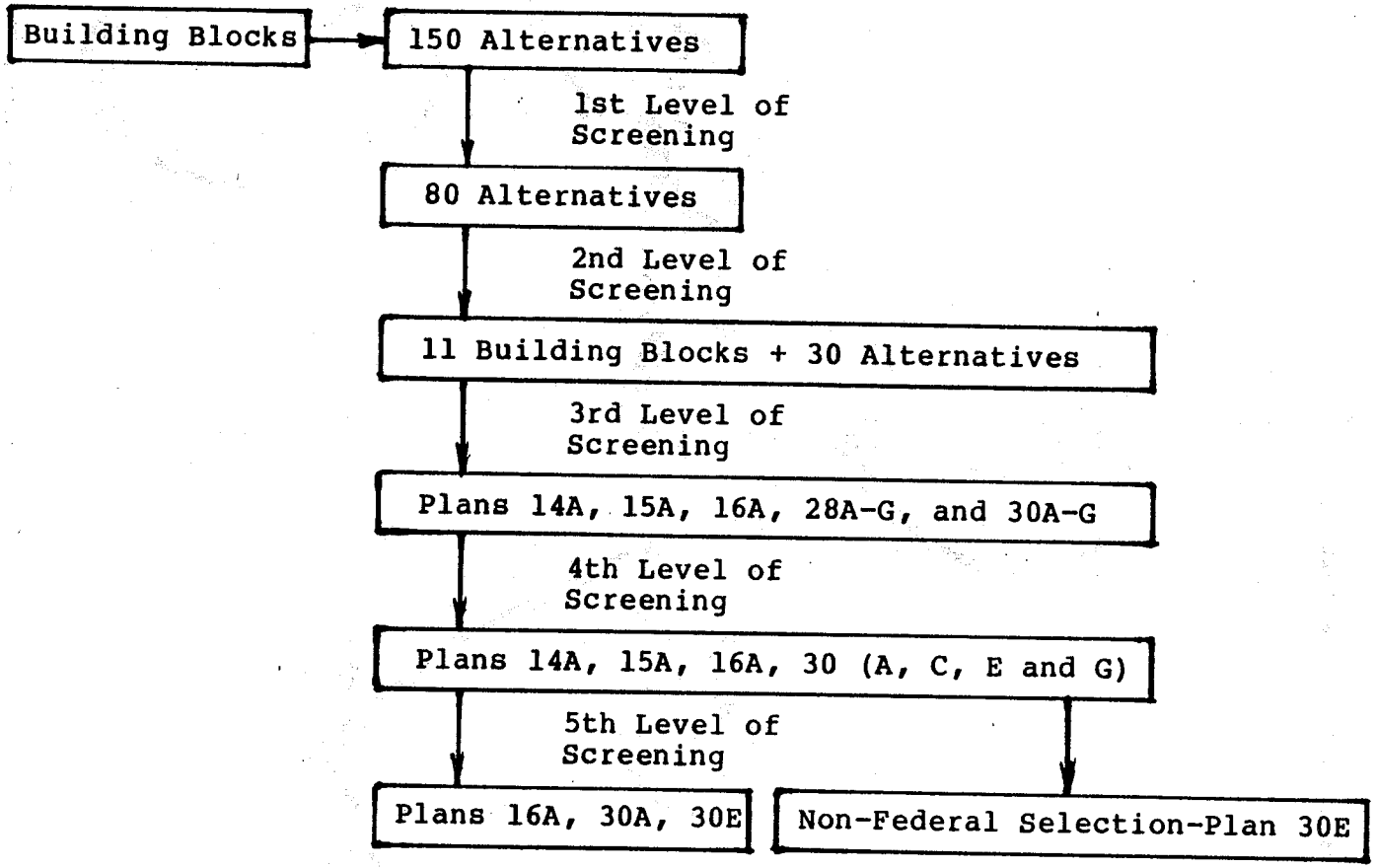
Passaic River Study N.J. & N.Y.

DETAILED FORMULATION REACHES

FIGURE C-77

TABLE C-62

SUMMARY OF PLAN SCREENING



Initial Screening. The initial screening of the Intermediate Stage alternatives was based on NED and completeness criteria. "Building Blocks" were not viewed as plans since they generally provided incomplete, intermittent and often highly variable levels of protection. Formulating plans by combining economically feasible "Building Blocks" with other "Building Blocks" (or portions thereof) which were justified on a last added basis increased the economic efficiency of the original "Building Block." For these reasons there was no need to consider "Building Blocks" as independent alternative plans, since by using them to develop more complete and efficient alternatives they were automatically carried forward. A summary of the significant screening results is presented below for each "Building Block" and Intermediate Plan:

a. As presented in Table C-33, 36 plans were found to be economically feasible. Tunnel diversion measures were central to approximately 80% of the plans found feasible.

b. The #23 "Building Blocks" were really just the tunnel diversion components central to Plans 28 and 30. Therefore, by considering Plans 28 and 30, the #23 "Building Blocks" were automatically carried forward. As a result, there was no need to directly consider #23 further, except for optimization purposes, as discussed in Section 8.

c. As shown on Table C-33, the plans most efficient from a NED standpoint were alternatives involving tunnel diversions (Plans 28 and 30), plans combining channel modification and levees (15A), and channel modification, levees and nonstructural measures (16A). Note that feasible elements of tunnel diversion, nonstructural, channel modification, and levee/floodwall "Building Blocks" (23, 3A, 7A and 13A, respectively) were combined to make up these plans.

d. Plan 16B was eliminated since the nonstructural components of this plan, which had been substituted for the Central Basin levee/floodwall elements of Plan 15A, were not incrementally justified.

e. The feasible elements of the nonstructural "Building Block" (#3A - 10 year level of protection) and the levee/floodwall "Building Block" (13A) combined to form Plan 14A, which was also economically feasible.

f. Channel modification measures (as contained in "Building Block" 7 and Plans 15 and 16) were feasible along the main stem downstream of Two Bridges, and along the Pompton River, but were found impractical along the main stem Passaic River upstream of Two Bridges.

g. Channel modification for the Lower Valley reach lying between Route 3 and Beatties Dam was found economically feasible ("Building Blocks" 7A and 7B), but was not incrementally feasible as a last added element to tunnel diversion schemes. Since this was the only location where channel work could be combined with tunnel plan elements, this precluded further consideration of Plans 29, 31, 32 and 34. Note that "Building Blocks" 23 include channel modification in Reaches 3 and/or 4 as part of the basic design of the tunnel diversion. The inclusion of such channel work does not constitute a combination of tunnel and channel measures, but is rather a necessary feature inherent in the integrity of the diversion concept.

h. "Building Block" 7B Lower Valley channel modification was screened from further consideration because it provided less protection and less excess benefits than "Building Block" 7A.

i. Permanent Evacuation (#1) was not economically feasible for the study area as a whole or for large portions thereof; however, it is marginally economically feasible at a few individual locations within the 10 year floodplain ("Building Block" 1E).

j. Plans 8 and 14B were eliminated from further evaluation since they provided incomplete and highly variable levels of protection by combining limited permanent evacuation ("Building Block" 1E) with "Building Blocks" 7A and 13A, respectively. In addition, other plans provided greater excess benefits than Plans 8 and 14B.

k. The following measures were found to be impractical and/or not economically justified: Existing Reservoirs (#17), New Reservoirs (#18), Aquifer Recharge (#21) and Tidal Barrier (#27). Likewise, alternatives involving combinations of these measures were found to be impractical (i.e., Plans 19, 22 and 24).

l. No measures were found to be economically feasible for the Upper Passaic River study reach (i.e., main stem upstream of Chatham, N.J.).

m. Plans 33A-G demonstrated that the addition of nonstructural measures at areas not protected by levees and/or tunnel works contained in Plans 30A-G is not incrementally feasible. However, the case by case substitution of nonstructural measures in lieu of individual levee systems is feasible at a limited number of locations. Consideration of such options is discussed in more detail later in this section.

n. Other alternatives which were screened out based on National Economic Development (NED) considerations (either negative or marginally justified) included "Building Blocks" 3A, 3B, and 3C, and Plans 5, 8, 9, 10A, 10B, 12, 13B, 15B, and 16C.

In summary, the plans remaining at this stage included: Plans 14A, 15A, 16A, 28A-G, 30A-G.

For the purpose of screening it was also noted that several of the plans for each of #28 and #30 were really just different scales of the same tunnel alignment. Since optimization studies in the Detailed Planning Stage considered each of the detailed plans at different scales (see Section 8 of this report) it was decided that only the most efficient scale of development for each alignment need be identified for presentation purposes. The other plans were considered later as part of project optimization studies. This eliminated Plans 28/30 (B, D and F).

Therefore, the remaining eleven intermediate plans which formed the basis for the translation into basic plans for presentation to the public were #'s 14A, 15A, 16A, 28 (A, C, E and G) and 30 (A, C, E, and G). Note that these plans included portions of "Building Blocks" 3A, 7A and 13A. However, even this array of plans was not as intimidating as the number implied since most of the alternatives were comprised of one of the four key tunnel diversion elements in combination with a similar variety of surface elements.

The array was further simplified when NED criteria was applied to the key elements of Plans 28 and 30 within the framework of the five plan formulation reaches previously discussed. The central elements for each of these plans (i.e., Plans 28A and 30A; 28C and 30C; etc.) were identical, with each based on the corresponding "Building Blocks" 23A; 23C; etc.). The difference between Plans 28 and 30 was with the peripheral plan elements in the Lower Valley (Reaches 1 and 2) and Central Basin (Reach 5). In all cases Plan 30 elements for these two areas were more complete and economically efficient. The levee/floodwall protection in Plans 30 (A, C, E and G) was more extensive and produced greater excess benefits than the nonstructural protection in Plans 28 (A, C, E and G).

In fact, all of the remaining alternatives (#'s 14A, 15A, 16A and 30 (A, C, E and G) except for the #28 plans would protect the mouth to Route 3 (tidal) and Central Basin reaches via 100 year levees/floodwalls. The #28 plans would provide limited 10 year protection within these reaches only at site specific areas where found feasible.

Therefore, the #28 plans were screened from further direct consideration based on NED efficiency although it was recognized that local interests may have preferred such nonstructural measures at the tidal and Central Basin reaches. As a result, the public presentation of the remaining alternatives (Plans 14A, 15A, 16A, 30A, 30C, 30E and 30G) highlighted the fact that the nonstructural measures were also economically justified at limited areas within the tidal and Central Basin reaches and could be substituted for specific levee systems on an optional basis. This further simplified the presentation of the plans to the public. Of course, it was also pointed out that such nonstructural options would result in lower levels of protection and less excess benefits, and would probably require a cost sharing adjustment if selected by local interests.

SEVEN BASIC INTERMEDIATE PLANS

In terms of public involvement and the choice that was made by local interests, there were no more than 4 to 5 perceived alternative plans in each of the five reaches when measures and/or effects of measures were considered. Although there were several plans, they really represented varied combinations of the same component "Building Blocks" in different reaches.

A listing of the remaining seven plans, categorized by each of the five plan formulation reaches is presented in Table C-63. The various options for each reach became evident upon review of this table. For example, in the Lower Valley tidal Reach 1, the only measure which would provide economically justified comprehensive protection was the levee/floodwall alternative. At a few selected locations, however, nonstructural measures (10 year level of protection) could optionally substitute for a levee system.

In the Lower Valley Reach 2, the trade-offs were between extensive levee/floodwall systems between Route 3 and Beatties Dam at Little Falls, channelization, a combination of channel modification, levees and floodwalls, or tunnel plans supplemented by sections of limited levees and floodwalls to provide a uniform level of protection.

Reach 3 between Beatties Dam and Two Bridges can be protected through the use of channel modification (either leading to a channel/levee system for the Lower Valley, or in conjunction with a tunnel inlet at Beatties Dam or Pompton Plains), protection by the Two Bridges Inlet, or by 10 year nonstructural measures to specific incrementally justified areas.

TABLE C-63

Summary of Plan Features by Plan Formulation Reach -
Final Array of Intermediate Plans
Passaic River Basin

	Reach				
	1	2	3	4	5
Plan	Tidal	Rt 3-Little Falls	Little Falls-Two Bridges	Pompton Valley	Central Basin
14A	LV/FW[1]/	LV/FW	NS	NS	NS/ LV/FW[1,2]/
16A	LV/FW[1]/	CH	NS	NS	NS/ LV/FW[1,2]/
15A	LV/FW[1]/	CH/LV/FW	CH	CH/LV/FW	LV/FW[1,2]/
30A	LV/FW[1]/	TU/LV/FW	BI/CH	CH/LV/FW	TU/LV/FW[1,2]/
30G	LV/FW[1]/	TU/LV/FW	TBI	CH/LV/FW	TU/LV/FW[1,2]/
30C	LV/FW[1]/	TU/LV/FW	CH	PI	TU/LV/FW[1,2]/
30E	LV/FW[1]/	TU/LV/FW	BI/CH	PI	TU/LV/FW[1,2]/

Legend:

LV/FW	-	Intermittent 100 yr Levee/Floodwall Systems
NS	-	10 yr Nonstructural Measures
CH	-	100 yr Channel Modification
CH/LV/FW	-	100 yr combination channel modification, levees and floodwalls
TU/LV/FW	-	Levees and floodwalls necessary to protect against improved 100 yr event in combination with tunnel diversion building block
BI/CH	-	Beatties Inlet Tunnel with channel from Little Falls to Two Bridges
TBI	-	Two Bridges Inlet Tunnel
PI	-	Pompton Inlet Tunnel with associated surface works on Pompton Tributaries

1/ Possible optional substitution of 10 Yr nonstructural at limited locations.

2/ Levees in the Central Basin are setback levees which are located at the outermost limit of the floodplain landward of the riverbank.

Along the Pompton River (Reach 4) the alternative measures included a channel/levee/floodwall scheme, limited nonstructural measures, or a tunnel diversion that effectively required no improvements in the Pompton Valley.

The trade-offs in the Central Basin (Reach 5) included those between setback levees, limited nonstructural measures, or tunnel plans which would lower flood profiles and must be supplemented by setback levees and/or nonstructural measures.

In most cases, the choice of measures and their effects were made for each project reach and then matched to one of the basin-wide plans displayed in Table C-63. The description of the seven plans (Plans 14A, 15A, 16A, 30A, 30C, 30E and 30G) which formed the final array of intermediate plans available for evaluation and consideration for the detailed planning stage is contained in Section 5 of this Appendix. Economic data for these alternatives is contained in Table C-64.

PRESERVATION OF NATURAL STORAGE

The preservation of natural flood storage areas in the Central Basin ("Building Block" 20), as described in Section 5, would reduce future increases in flood flows and associated flood damages by preventing the development of floodplain lowland areas. However, it would have no impact on the existing flood problem. Therefore, the preservation of natural storage areas was not considered as an independent solution to the basin's flood problem. Rather, this measure can be considered in conjunction with any of the seven basic intermediate plans to provide a more effective and complete plan of protection.

EVALUATION OF INTERMEDIATE PLANS

Further evaluation studies focused on the seven remaining intermediate plans. These plans were evaluated within a much broader context, as opposed to the NED and completeness criteria that were used for the initial screening studies. A full range of economic, environmental and other criteria were utilized in evaluating this final array of intermediate plans. These seven alternatives also formed the basis for presentations made to the public and non-Federal sponsor which resulted in much input into the screening process. The assessments made of these alternatives, including a summary of local input, is contained in the following paragraphs.

Economic Assessment Summary. Economic data for the seven basic intermediate plans and preservation of natural storage are contained in Table C-64. This data reflects refinements to significant or sensitive cost items, such as method of channel construction and interest during construction.

TABLE C-64
ECONOMIC SUMMARY OF BASIC INTERMEDIATE PLANS
(OCT. 85 PRICE LEVEL, 8-5/8 %, $1,000'S)

PLAN	TOTAL INVESTMENT COST	ANNUAL COST	ANNUAL O&M	TOTAL ANNUAL COST	ANNUAL BENEFITS	B/C RATIO	NET BENEFITS
14A	395,000	34,200	3,100	37,300	39,700	1.06	2,400
16A	452,000	39,100	2,700	41,800	46,000	1.10	4,200
15A	926,000	79,900	7,100	87,000	87,600	1.01	600
30A	960,000	82,800	5,800	88,600	98,100	1.10	9,500
30G	1,054,000	90,900	5,700	96,600	99,000	1.02	2,400
30C	997,000	86,000	3,900	89,900	98,700	1.10	8,800
30E	1,004,000	86,600	3,900	90,500	100,700	1.10	10,200
PRESERVATION	16,000	1,400	0	1,400	3,700	2.60	2,300

The cost of the Pompton River channel modification from the Passaic River confluence to Pompton Plains increased as a result of the reassessment of channel construction methods and the constraints imposed by the highly developed area in which the construction work would be performed. Several construction methods including floating dredges and draglines were evaluated. Limited work and stockpiling areas and the need to move large volumes of excavation through local streets to distant disposal areas restricted progress. Possibly only a small portion of the excavation could be utilized for the construction of levees. In addition, a review of levees and floodwalls showed that in some areas, concrete floodwalls of considerable size were required because many residential structures are located on the edge of the Pompton River. In several areas along the lower Pompton, it would be less costly to purchase the first row of structures and construct levees.

The annual operation and maintenance (O&M) costs for structural surface works such as channel modifications, levees and floowalls are higher than O&M costs for nonstructural measures or subsurface diversion tunnels. This is reflected in the total O&M costs in Table C-64. For example Plan 30A, which has extensive surface works in the Pompton Valley, has higher O&M costs than Plan 30E, which protects this area by means of a subsurface tunnel.

As can be seen from Table C-64, the alternative with the greatest net NED benefits is Plan 30E, the Dual Inlet Tunnel Plan. Following is the ranking of the seven basic plans in order of NED efficiency:

RANK	PLAN	EXCESS BENEFITS ($1,000)
1	30E	$10,200
2	30A	9,500
3	30C	8,800
4	16A	4,200
5	14A	2,400
5	30G	2,400
7	15A	600

The most significant cost item not reflected in the economic analysis above involves potential fish and wildlife mitigation. The cost of such mitigation would impact to a more significant degree on plans with structural surface works in the Pompton Valley. Thus, the net NED benefits of Plans 15A, 30A and 30G would be reduced in a greater proportion than the other alternatives if this information was incorporated into the analysis.

An analysis of the intermediate planning stage economic data for Preservation of Natural Storage, indicated that this measure would be incrementally justified on a first added basis with excess benefits of almost 2.3 million dollars as shown in Table C-64.

Environmental Assessment Summary. The environmental effects of the intermediate plans were discussed in detail as part of the Intermediate Planning Stage report documentation. The significant physical elements which contribute to differences in plan impacts, highlighted by reach, are presented below. Again, Table C-63 is a useful reference for this section.

Reach 1 - Mouth to Route 3. Levee/floodwalls are the major components incorporated into all plans in this reach. The only difference being tunnel diversion Plans 30(A, C, E, and G) would require increases in the height and extent of the levee/floodwalls. Levees/floodwalls in the Lower Valley would primarily impact on very limited terrestrial resources.

Ordinarily, terrestrial resources would suffer direct loss of extensive acreage of animal habitat during levee construction. Indirect losses from levees and floodwalls would occur over the project's life because of the interruption of overbank flooding, a critical function for recharging the soil with nutrients and groundwater.

In most cases, however, these impacts would be minimal because the floodplain has already been severely altered and filled in. Where residential, commercial and industrial structures were built on filled-in floodplains, most of the animal habitat has already been eliminated. The physical barrier of a floodwall may isolate some wildlife from the water, but this effect would be minor because the urban setting sustains only a few species. Compared to floodwalls, levee slopes would allow wildlife better access to the water. However, because levee ground cover is sparse and uniform, it would not camouflage some species of mammals, reptiles and amphibians, causing them to be more susceptible to predation. Where present, wildlife corridors would be eliminated, isolating the few remaining wildlife habitats and populations.

The tunnel outlet, at its proposed location on the left bank of the Third River at the confluence with the Passaic River, would cause no impacts on terrestrial resources at this site since it has already been considerably altered from its natural state. Its existing use is as a heavy equipment and truck storage area for a construction company. The tunnel plans

are not expected to have significant effects on the indigenous fish and invertebrates in the lower Passaic River because the tunnels would be used infrequently, water velocities would be dissipated to a large extent by use of a siphon tunnel, and anaerobic water would be aerated after it leaves the tunnel.

Reach 2 - Route 3 to Beatties Dam. The key feature to five of the seven plans (Plans 14A, 30A, 30G, 30C and 30E) in this reach is again levees/floodwalls. The main element of Plan 16A is channel modification, while Plan 15A combines channel modification with levee/floodwall works.

Plans 14A and 15A require by far the largest extent of levees/floodwalls and would have the most severe impact on terrestrial resources. The four tunnel diversion plans also require levees/floodwalls in limited areas, thus greatly reducing the effect on terrestrial resources. Major impacts of levees and floodwalls were previously discussed under Reach 1, however, the riverside land use between Route 3 and Beatties Dam changes from commercial and industrial to residential, with slightly more riparian strands.

Plans 16A and 15A each require channel modification in this entire reach, thereby significantly impacting on the aquatic resources. Generally, aquatic habitats would be affected the greatest during both the construction and maintenance phases of channel modification plans. During construction, river bottom excavation would lower and widen the channel. Instream debris and all aquatic vegetation would be removed. Some natural meanders would be cut off. Because the channel bottom would be lowered, the side slopes would be cleared of vegetation and cut back at a gentle slope to prevent collapsing banks. The primary effect of this would be to increase the channel's gradient and decrease its sinuosity in order to move floodwater efficiently. In-channel erosion would be controlled by lining the affected channel bottom with riprap. Aquatic productivity would be reduced during river bottom excavation both from the effects of turbidity as well as from the loss of aquatic plants and other food organisms. Some fish would be destroyed by the machinery. Removal of instream debris, such as fallen trees, boulders and other impediments to flowing water, and regrading the river bottom would improve hydraulic efficiency, but at the expense of eliminating the variability of flows. This loss would cause a decline in overall fish and invertebrate diversity and productivity. The eddies and stilling pools which fish prefer as habitats would be lost and changed to a uniform current, from which fish tend to emigrate. Finally, the removal of overhanging trees and banks would reduce shade and leaf litter from the water and riparian habitats, the primary source of nutrients available for microscopic biota, the ultimate source of food for gamefish.

Reach 3 - Beatties Dam to Two Bridges. In this reach a major element which is common to Plans 15A, 30A, 30C and 30E is modification of the Passaic River channel from Beatties Dam upstream to Two Bridges, while Plans 30A and 30E also include works associated with the tunnel inlet at Beatties Dam. Nonstructural measures would be the primary elements of Plans 14A and 16A. The only element of Plan 30G located in this reach would be the inlet works located in the Two Bridges area. By far, the channel modification elements of Plans 15A, 30A, 30C and 30E would have the most severe impacts to the aquatic resources, with minimal terrestrial resource impacts as noted by the discussion of channel modification effects under Reach 2. Plans 14A, 16A, and 30G would have minimal terrestrial impacts and basically no effect on aquatic resources. It should be noted that each of these plans would have an adverse effect on the wetlands in the Great Piece Meadows. However, this wetland impact would be mitigated through modifications made to the existing Beatties Dam.

The proposed tunnel intakes at Beatties Dam (Plans 30A and 30E) and Two Bridges (Plan 30G) would permanently eliminate about one acre and 3.5 acres of wildlife habitat, respectively. Construction equipment storage and disposal of excavated material would temporarily affect another one acre of adjacent land for both plans. These activities would displace wildlife from the construction site. However, since the existing natural area is small, many of the sensitive species have already been eliminated due to the proximity of man. Also, many species of wildlife cannot acquire all of their life requirements at these areas. The acreage used temporarily would be restored and enhanced.

Reach 4 - Pompton Valley. In the Pompton Valley, the key elements of Plans 14A and 16A would be the application of limited nonstructural measures. These floodproofing, raising and evacuation measures would cause minimal to no impact on the terrestrial and aquatic resources. Plans 15A, 30A and 30G would have the most severe effect on groundwater and the terrestrial and aquatic environment because these plans rely on the combination of Pompton River channel modification, levees and floodwalls in conjunction with limited channel modification, levees and floodwalls along the Pequannock, Wanaque and Ramapo Rivers. Plans 30C and 30E would have lesser effects on groundwater and terrestrial and aquatic resources since these plans would eliminate the need for structural local protection works downstream of the tunnel inlet. The contrasting impacts associated with this reach constitute one of the most significant trade-offs between intermediate alternatives.

Reach 5 - Two Bridges to Chatham. The major component of all plans in this reach would be setback levees, as presented in Table C-63. These plans would have effects on terrestrial resources similar to the levees discussed under Reach 2, however, some of these levees would be placed in wetlands, which are more productive than the Lower Valley's ground cover. Setback levees would have a minimal impact on aquatic resources.

Setback levees differ from levees and floodwalls in that they are not constructed on or near the riverbank. Rather, setback levees are located at the outermost limit of the floodplain landward of the riverbank. They are designed to preserve floodplain flood storage. By including areas of a floodplain within a flood control plan, setback levees would not increase floodwater stages or velocities to the extent caused by channelside levees and floodwalls.

Plans 14A and 16A would also include nonstructural measures between Two Bridges and the upstream limit of Deepavaal Brook. However, as discussed for Reach 4, these measures would have minimal to no impact on terrestrial and aquatic resources.

The preservation of natural storage areas, which could be added to any of the seven plans in this reach, would have beneficial environmental impacts. The acquistion of environmentally sensitive wetlands would ensure their preservation for posterity as a natural plant and animal gene pool repository. The protected land would also assure the sustentation of rare, threatened, and endangered state species who rely on the fish and wildlife habitats that occur there. The reserved wetlands would act as a refuge for upland species and as a corridor for animal movements.

Based on the assessment of environmental effects, a relative ranking of the plans was made and is presented in Table C-65. As indicated by the results of this analysis, it was determined that the best plans from an Environmental Quality (EQ) standpoint were Plans 14A and 16A, while the worst were Plans 15A and 30A.

Evaluation Criteria. Guidelines for the evaluation of alternative plans for Federal water and related land resources activities are contained in the Water Resources Council's Principles and Guidelines. Evaluation of the plans of improvement for the study area are based on technical, economic and other criteria with varying emphasis on the different economic, social, and environmental components reflected in the planning objectives. Principles and Guidelines require that one of the alternative plans must optimize National Economic Development (NED). However, due to the nature and severity of flooding in the basin, several additional criteria were adopted to

TABLE C-65

RELATIVE RANKING OF PLAN EFFECTS ON SIGNIFICANT ENVIRONMENTAL RESOURCES

SIGNIFICANT RESOURCES				TUNNEL PLANS			
	LV/FW-NS	LV/FW-CH-NS	LV/FW-CH	Beatties Plan	Two Bridges	Pompton	Dual
LOWER VALLEY	14A	16A	15A	30A	30G	30C	30E
Wetlands	5	6	7	1	1	1	1
Anadromous Fish	1	6	7	2	2	2	2
Terrestrial Resources	5	1	6	2	2	2	2
Aesthetics	2	1	7	2	2	2	2
Cultural Resources	2	1	7	2	2	2	2
Water Quality	1	2	3	4	4	4	4
Air Quality	5	6	7	1	1	1	1
Noise	5	6	7	1	1	1	1
CENTRAL BASIN							
Wetlands *	2	2	4	4	1	4	4
Aquatic Resources	1	1	4	4	3	4	4
Buried Valley Aquifer	1	1	3	3	7	3	3
Aesthetics	2	2	4	4	1	4	5
Cultural Resources	2	2	4	4	1	4	4
Water Quality	2	2	4	4	1	4	4
Air Quality	2	2	4	4	1	4	4
Noise	2	2	4	4	1	4	4
POMPTON VALLEY							
Wetlands	1	1	5	5	5	3	3
Aquatic Resources	1	1	5	5	5	3	3
Buried Valley Aquifer	1	1	5	5	5	1	1
Aesthetics	1	1	5	5	6	3	3
Cultural Resources	1	1	5	5	6	3	3
Water Quality	1	1	5	5	5	3	3
Air Quality	1	1	5	5	5	3	3
Noise	1	1	5	5	5	3	3
Points	48	51	122	86	73	68	69
Rank	1	2	7	6	5	3	4

LV = Levee
FW = Floodwall
CH = Channel
NS = Non-Structural

NOTE: Lowest point score and ranking has least environmental effect.

* The addition of preservation of natural storage areas, which would have beneficial environmental effects, would not change the ranking of the plans.

facilitate an evaluation of plan performance. These criteria placed additional weight on the plan's ability to reduce the economic losses sustained in the basin. It is noted that the NED criteria cannot always be met and that full response may be sacrificed for overriding considerations which may become evident as a result of plan evaluation. The summary evaluation of Plans 14A, 15A, 16A and 30 (A, C, E, G) are presented in Table C-66.

EVALUATION AND SCREENING OF INTERMEDIATE PLANS

A comparison analysis was used as the basis for selecting the plans to be carried into the Detailed Planning Stage. The process used to compare the plans consisted of a trade-off analysis of the beneficial and adverse effects of each alternative and the responses to specific evaluation criteria such as tests of acceptability, efficiency and completeness.

Table C-64 presents economic data for the intermediate plans, while Table C-65 summarizes the relative rankings of the plans in relation to the basin's significant environmental resources. Table C-66 presents a summary of NED impacts and includes plan evaluation data for other criteria as well. For Tables C-65 and C-66, the relative importance of each resource, impact or criteria was assessed based on an in-house study team approach. The development of such an evaluation was part of an attempt to develop more insightful results. The potential for bias is recognized; however, it is considered that the results as presented are more indicative of the relative merits of the alternatives.

The results from Tables C-64, C-65 and C-66 were further evaluated and used to develop Table C-67, which summarizes the study team's assessment of the plans. Table C-67 includes those criteria which were deemed the most significant in plan evaluation. These criteria were: (1) NED ranking (from Table C-64); (2) EQ ranking (from Table C-65); (3) acceptability to the non-Federal sponsor (from Table C-66); (4) acceptability to the public (Table C-66); and (5) completeness (Table C-66). Based on these criteria, a grand summary evaluation of the seven plans was developed, along with a straight raw score and overall ranking. Examination of the data in these tables indicated the significant trade-offs made between plans.

The results of the trade-off analysis indicated that Plan 30E, the Dual Inlet Tunnel Plan, was the one which ranked the highest based on the evaluation criteria. It is shown in Table C-67 with the lowest raw score. This plan was strongly supported by a portion of the basin's interests. Furthermore, it is the NED Plan. Plan 30E would provide a 100 year level of protection throughout most of the five planning reaches. It

TABLE C-66 SUMMARY OF INTERMEDIATE PLAN EVALUATION
(Oct. 85 Price Level, 8-5/8% Interest Rate, $1,000's)

EVALUATION CRITERIA	WITHOUT PROJECT	14A	16A	15A	30A	30G	30C	30E
EXCESS ANNUAL BENEFITS ($1,000's)	0	2,400	4,200	600	9,500	2,400	8,800	10,200
AVERAGE ANNUAL EQUIVALENT BENEFITS ($1,000's) 1/	0	39,700	46,000	87,600	98,100	99,000	98,700	100,700
RESIDUAL AVERAGE ANNUAL EQUIVALENT DAMAGES (1,000's) 2/	95,100	58,200	51,900	20,600	13,400	12,700	12,900	11,500
RESIDUAL 500 YR STAGE DAMAGE ($1,000's) 2/	2,371,000	2,371,000	2,267,000	1,526,000	1,224,000	1,115,000	1,196,000	1,021,000
B/C RATIO	N/A	1.06	1.1	1.01	1.1	1.02	1.1	1.1
TOTAL INVESTMENT COST ($1,000's)	0	395,000	452,000	926,000	960,000	1,054,000	997,000	1,004,000
ANNUAL O&M ($1,000's)	0	3,100	2,700	7,100	5,800	5,700	3,900	3,900
TOTAL ANNUAL COST ($1,000's)	0	37,300	41,800	87,000	88,600	96,600	89,900	90,500
PREVENT LOSS OF LIFE	NONE	MODERATE	MODERATE	HIGH	HIGH	HIGH	HIGH	HIGH
PRESERVE TRANSPORTATION FACILITIES	NONE	MODERATE	MODERATE	HIGH	HIGH	HIGH	HIGH	HIGH
LEVEL OF PROTECTION PROVIDED	0	10-100YR	10-100 YR	100YR	100YR	100YR	100YR	100YR
EFFICIENCY	NONE	LOW	LOW	HIGH	VERY HIGH	VERY HIGH	HIGH	VERY HIGH
ACCEPTABILITY								
NON-FEDERAL SPONSOR	NONE	LOW	LOW	MODERATE	HIGH	VERY HIGH	HIGH	VERY HIGH
PUBLIC	NONE	MODERATE	HIGH	LOW	HIGH	HIGH	HIGH	VERY HIGH
COMPLETENESS	NONE	PARTIALLY COMPLETE	PARTIALLY COMPLETE	PARTIALLY COMPLETE	COMPLETE	COMPLETE	COMPLETE	COMPLETE
EFFECTIVENESS	NONE	LOW	LOW	HIGH	HIGH	HIGH	HIGH	HIGH

1/ INCLUDES BENEFITS DUE TO INUNDATION REDUCTION, AFFLUENCE, RESIDENTIAL INTENSIFICATION, TRAFFIC FLOW, INDUSTRIAL CONTENT GROWTH, ADVANCE BRIDGE REPLACEMENT, AND FIA COST REDUCTION WHERE APPLICABLE.

2/ EXCLUDES UPPER PASSAIC BASIN.

TABLE C-67

SUMMARY RANKING OF INTERMEDIATE PLANS
PASSAIC RIVER BASIN

Plan	SIGNIFICANT CRITERIA RANKING 1/					TOTAL RAW SCORE	OVERALL RANKING
	NED (From Table C-64)	EQ (From Table C-65)	NON-FED SPONSOR (From Table C-66)	PUBLIC ACCEPTABILITY (From Table C-66)	COMPLETENESS (From Table C-66)		
14A	5	1	7	6	7	26	6
16A	4	2	6	2	6	20	5
15A	7	7	5	7	5	31	7
30A	2	6	4	3	2	17	2
30G	5	5	3	3	2	18	4
30C	3	3	2	5	4	17	2
30E	1	4	1	1	1	8	1

1/
where 1 = most desirable plan .... 7 = least desirable

would produce moderate adverse environmental effects in the sensitive wetlands of the Central Basin by minimizing impacts through the use of setback levees and a gated Beatties Dam. This plan contains virtually no surface works in the Pompton Valley. Plan 30E was carried into the Detailed Planning Stage for further study.

Plan 30A ranked second, both overall and in terms of NED efficiency. Since it was considered to be a potential NED candidate it was selected for further study in the Detailed Planning Stage in spite of the significant adverse environmental impacts it would cause in the Pompton Valley.

Plan 30C (Pompton Inlet Tunnel Plan) was tied for second place overall (see Table C-67) based on many of the same favorable impacts as the Dual Inlet Plan (30E). Plan 30C's major trade-off is for marginally less environmental impacts than Plan 30E since no construction or operation of a Beatties inlet would be required for the single inlet design of 30C. However, this slight environmental gain over Plan 30E was at the expense of less NED efficiency and completeness. From a NED standpoint, Plan 30C ranked third. The flexibility provided by a second inlet in Plan 30E which would also protect against large Passaic River main stem events results in a more complete plan than Plan 30C. This flexibility is highly desirable to Lower Valley communities and is the reason Plan 30C is not as publicly acceptable as Plan 30E.

Plan 30G, the Two Bridges Inlet Plan, ranked fifth in NED efficiency and fourth overall. The major trade-off produced by this alternative is that it precludes the need for 3.6 miles of channel modification between Beatties Dam and Two Bridges, instead extending the length of the tunnel underground for an additional 2 miles. As a result, the adverse environmental impacts of this plan are less than those of Plan 30A.

Plan 16A, which includes 10 year nonstructural measures for the Pompton Valley and Beatties Dam to the upstream limit of the Deepavaal Brook reaches, was ranked fourth from a NED standpoint and a strong second based on EQ criteria. The major trade-off with Plan 16A is that it achieves such rankings at the sacrifice of completeness. This is because it would provide only a 10 year level of protection for Reaches 3 and 4, the primary floodprone areas in the basin. Although this alternative is clearly not acceptable to Pompton Valley/Central Passaic communities, it is supported by environmental groups and some Lower Valley municipalities. The segment of the public which supports "buyout" plans for the Central Basin area fueled

interest in the concept behind this alternative. Such a plan provides a striking contrast to the tunnel plans in both physical impacts and local opinions. Since it was the highest ranked non-tunnel plan and was ranked fifth overall, it was selected for additional consideration in the Detailed Planning Stage.

Plan 14A ranked sixth overall. It was tied for next to last place from a NED standpoint, but first based on EQ criteria. This alternative, which would include only levee/floodwalls and nonstructural works, and no channel modification measures, would produce the least impacts to fish and wildlife resources of all the plans considered. In light of its relatively low NED standing, along with other deficiencies in the completeness and local sponsor criteria, this plan was eliminated from further consideration.

Plan 15A was ranked last overall by the study team. Its low ranking was due to the poor NED rating and extensive environ- mental impacts. Additionally, because it would act to increase the flood discharge entering the Lower Valley at Little Falls by eliminating the flow reversal in the Central Passaic, this plan has the most extensive system of surface works of all the alternatives considered. Therefore, this alternative was screened from further study.

SUMMARY OF STATE AND LOCAL INPUT

Subsequent to the completion of the Intermediate Planning Stage Report, study findings were coordinated with the State of New Jersey. In addition to discussing the study results, coordination focused on what direction the public involvement program should take given that an array of alternatives were available.

The primary public involvement issues between the Corps of Engineers and the New Jersey Department of Environmental Protection (NJDEP) revolved around the schedule and focus of the program. Both agencies agreed that the clear communication of alternatives, plan trade-offs and effects should be an objective of the program. It was also agreed that the goal of the program was to actively include the public in the development and screening of plans, while ensuring that a solid base of support for an implementable solution was developed.

New Jersey favored a broad-based, 24-month program in which initial public involvement activities focused more on the education of the Basin's interests, while a developing strategy for ensuring a coalition of support could evolve. They envisioned narrowing the array of alternatives to one plan by the end of 24 months.

The position of the Corps, however, was that the ongoing Subbasin Coordination Program had already addressed many of the educational needs of the basin. Although educational aspects needed to be included, it was felt that the emphasis of public involvement activities should move more quickly into the coordination of alternative plans. The Corps envisioned a program of approximately 9 to 12 months, which would track with the study schedule. This effort would have focused on generating public inputs regarding the Intermediate Planning Stage findings. It was expected that the effort would have been vigorous enough to generate a public screening and evaluation that would have been the measuring stick for narrowing the alternatives down to four or five plans, and subsequently to one or two. Discussions regarding the direction of the program were ongoing from August to December 1983. Finally, a compromise 18-month program was agreed to in which the NJDEP would work with the Corps of Engineers to screen the plans down to two or three alternatives after approximately 6 months, and would select one plan at the end of the program. It was felt that such a schedule, although longer than that originally planned, would allow the public to participate actively in plan evaluation and refinement, while addressing the State's ambition to build a consensus of support for an implementable plan. Since NED requirements would have allowed the detailed planning studies for several alternatives to move ahead concurrent with the public involvement program, the compromise program was acceptable. The adjusted program was initiated in February 1984, with a jointly sponsored "kickoff" public meeting in Lincoln Park on April 3, 1984.

Impact of April 1984 Flood. Two days after the Lincoln Park public meeting, the Passaic River Basin was hit with the worst flooding in recent history. The devastating rainfall of April 5-6, 1984 caused flooding ranging from a 25 year event on the Passaic River at Little Falls to a 50 year event on the Pompton River, with runoff far exceeding the rainfall because of snowmelt and thawing ground. In total, approximately 9,400 residents were evacuated from their homes, with flood damages estimated over $330 million.

This disastrous flooding also created significant political action. Governor Kean toured the flood area by helicopter on April 6 and the severity of damage resulted in his declaration of disaster and call for remedial action. Within a week, NJDEP officials announced that the State of New Jersey would select an alternative for detailed Corps of Engineers study by June 1984. This 2-1/2 month plan selection schedule constituted a dramatic shift from the planned 18-month program.

NJDEP Public Involvement. The State's intention to select a flood damage reduction plan for the Passaic River Basin by the end of June 1984, was made public at an April 19 public meeting at Wayne, N.J. A series of 8 work meetings were set up over the following weeks at Pompton Lakes, Totowa, Parsippany-Troy Hills, and Nutley (2 at each location), all sponsored by the NJDEP. At each meeting, the Corps of Engineers presented the results of the Intermediate Planning Stage study, with a focus on the seven basic plans, and options. The Intermediate Planning Stage Report and summaries of the plan formulation process, and descriptions of the alternatives were widely distributed, stimulating many questions and requests for additional information. In response to public interest, numerous other meetings were scheduled with municipal officials and engineers,local citizen groups, environmental organizations and business organizations.

At a June 12, 1984 public meeting at Wayne, N.J., the NJDEP announced the tentative selection of the Dual Inlet Tunnel Plan as the alternative the State desired the Corps to study in more detail. A detailed description of the Dual Inlet Tunnel Plan was presented at this meeting and expressions of reaction and input were solicited from the public before the final decisions which were made by the end of the month.

Summary of Issues. Many important and major issues and pertinent concerns were expressed at the 8 meetings which were held from April to June 1984. Throughout the series of NJDEP meetings, there were a number of issues which surfaced repeatedly. These concerns primarily revolved around the time-frame and basis for the State's plan selection; the time-frame for implementation of potential project support for a tunnel diversion solution versus other types of alternatives; concern for the potential impacts and high cost of a tunnel; logistical questions regarding the sharing and financing of the non-Federal costs of alternatives; and questions regarding various site-specific elements of the plans.

Significant controversy surfaced regarding the State's timetable for selecting a plan and the Corps schedule for completing and implementing a project. Throughout the meetings the planners heard repeated pleas from flood victims and municipalities in the Pompton Valley and Central Basin for quick action to solve the flood problem. The desire for haste in decision making, future planning and implementation were cited as problems at all of the meetings. On May 30, 1984 the Basin was hit with more severe flooding, approximately equal to the 1968 flood, a 15-year event. Therefore, the concern and vocal support for quick action was often strongly and emotionally expressed. There was, however, especially at the local and county government levels, a quick transition to a rational understanding of the need for further study and more detailed planning.

In contrast to the concern voiced for quick action, there was also significant opposition to the State's accelerated schedule for making a decision. This concern was voiced primarily by Lower Valley municipalities and environmental interests. Their concern was that this period did not allow enough time for local decision makers to review the plans, work with their engineers and residents, and meet with the Corps to develop a sound basis for their official positions. A related concern revolved around how New Jersey would reach its decisions. The State's basis for selecting a plan was often questioned. Would unanimous municipal support for a plan be required? Would a majority be sufficient? Or would a consensus be required? Such questions usually manifested themselves in requests to NJDEP for extending the June deadline to allow for more local review and input into the plan selection process. While concerns regarding the State's decision-making time-frame were divided, the opinion that the schedule was too short was a predominant view among these interests.

Concern was also expressed regarding the length of time required to implement a plan. The 15 to 20 year period to implement a major Corps project for the Passaic River Basin was viewed as unacceptable by most of the Basin's interests, including many of those who were critical of the State's short decision-making deadline. The concern for accelerating the implementation of a solution led many interests to support alternatives such as buyout plans that were viewed as having a shorter implementation schedule. In addition to acquisition plans, other alternatives suggested for immediate implementation included clearing and snagging projects, construction moratoriums, and storm water management measures. Support for acquisition and moratorium alternatives were primarily voiced by Lower Valley interests who wanted these measures applied in the Central Basin. Support for storm water management was widespread, while primarily Central Basin communities requested consideration of clearing and snagging measures. Lincoln Park was the lone Central Basin community to support the moratorium concept.

The most comprehensive list of alternative suggestions was furnished by the Passaic River Coalition. The State acknowledged the merits of many of the measures in the Coalition's 21 point program and included provisions for land acquisition, restrictions on floodplain development, snagging and clearing, storm water management, and others into their overall flood control program for the Passaic River Basin. However, even where there was agreement regarding the conceptual merit of specific measures, the degree to which the State sought to implement them was often an issue with their proponents.

By far, the heaviest support was voiced for the tunnel plans, specifically the Dual Inlet Tunnel Plan. The comprehensive and high level of protection available, the flexibility of having two tunnel inlets, and the minimum amount of surface works and associated environmental impacts were the factors cited in support of the Dual Inlet plan. Negative factors cited most often included the high cost of the plan (and all of the Corps plans for that matter), the long time-frame for implementation, the location of the outlet, and concern about potential induced effects in the Lower Valley. The most significant of these issues was the worry that the tunnel plan with an outlet at the Third River would just transfer the Central Basin's flooding problems to the Lower Valley. An often asked question was: why couldn't the tunnel outlet be moved further downstream, perhaps to Newark Bay? An issue that was companion to this concern was the potential of a tunnel plan to curtail recreational opportunities and commercial access to the river in the Lower Valley.

In particular, the outlet location issue was the most significant among Lower Valley communities downstream of Route 3. It was pointed out that Corps studies have conclusively demonstrated that none of the plans would result in the protection of one area at the expense of another; the Corps could not recommend such a plan. The concept of all of the plans was to protect both areas. For the tunnel plans, the diversion of flood flows would result in flood stages that could be safely contained by modifying the lower Passaic River levee system that is already necessary to protect against the tidal flooding. In the area between Wallington and North Arlington the required levees and floodwalls would be increased in height to safely handle all flows. At the 100-year flood stage, the water level would be 3 to 5 feet below the top of the levee/floodwalls. The largest impacts on levee heights and extents would be at the outlet itself. Much of the increase in levee/floodwall height is along Route 21, and no residences or other structures would have to be acquired as part of the plans. The area of expanded protection would lie from just upstream of the Second River, at the Newark City border, upstream to the City of Passiac. Downstream of the Second River, the larger capacity of the Passaic River would dissipate the effects of the tunnel flow. Therefore, downstream of this point, in Newark, Harrison, East Newark and Kearny the tunnel diversion would have no effect on levees which are proposed to protect against tidal flood elevations.

It was also pointed out that diversion tunnels outletting at other downstream locations, including directly into Newark Bay, were evaluated as part of the Passaic River Basin Study. They were found to be economically infeasible. Generally, the cost of each additional mile of underground tunnelling is approximately $40-50 million. An additional six miles of

tunnel, costing some $300 million, would be required for an outlet into Newark Bay. Clearly, this is not economically feasible when it is realized that the savings resulting from less extensive levee systems would be minimal, since levees and floodwalls would still be required to protect against tidal flooding.

Finally, it was explained that questions of access would be addressed in concert with local desires, subsequent to the State's plan selection, during the detailed engineering of the plan. Where access is vital, the Corps worked with the municipality during the Detailed Planning Stage to develop another levee alignment that was suitable. If that wasn't possible, then openings would be accommodated in the line of protection with the use of closure structures or gates during flood events. There are many areas where this will be necessary. In fact, past Corps of Engineers plans for the Lower Passaic included such provisions.

Neither of these issues were put to rest prior to the State's selection of a plan. Coordination with Lower Valley communities and counties, such as Essex County, continued through the Detailed Planning Stage.

Likewise, the issue of how the State would apportion the non-Federal share of the project cost was not resolved. The State's position was that this was a complicated issue that could not possibly be fully resolved prior to plan selection. They did not want to cloud the issue of which plan was preferable with questions regarding the many options for financial arrangements. During the Detailed Planning Stage, the State studied the array of options available to them, and developed a formula for apportioning non-Federal costs among local interests.

Finally, there was an overwhelming response by municipal interests and citizens for additional information regarding the alternative plans. Many local meetings were held prior to the State's selection of a plan, and many more have been held since to discuss specific plan elements with each community.

State Selection of a Plan. On June 12, 1984, the NJDEP announced its tentative selection of the Dual Inlet Tunnel Plan for the Passaic River Basin. This selection was finalized on June 28, 1984 at a meeting in Trenton, N.J. between Col. F.H. Griffis, New York District Engineer, and Robert E. Hughey, New Jersey's Environmental Protection Commissioner. The selection was formally confirmed by letter of the same date. This letter requested that the Corps of Engineers proceed with detailed formulation of the selected plan.

Commissioner Hughey cited the following as the basis for selecting the Dual Inlet Tunnel Plan:

1. It provides basin-wide protection at the 100-year design storm as a minimum;

2. It causes minimum surface disruption from the construction of levees and floodwalls;

3. It causes the least disruption to the rivers and streams in the basin through channel modifications;

4. It causes the least disruption to transportation and services within the basin through bridge and highway modifications and relocation of water, sewer, gas, electric, telephone and other services;

5. It provides comprehensive protection through flexibility of operation of two inlets;

6. It minimizes maintenance costs;

7. It incorporates protection of inland wetlands, floodways and floodplains; and

8. It minimizes disruption during construction.

The Commissioner also noted that an alternative plan, the Two Bridges Inlet Tunnel Plan, although not meeting all their criteria, does have the positive effect of not requiring channel modification of the Passaic River between Two Bridges and Beatties Dam. Therefore, they requested that during the detailed planning phase of the project, the Corps of Engineers investigate means to incorporate the benefit of the Two Bridges inlet location so as to eliminate or further reduce channel modification work between Two Bridges and Beatties Dam.

The State also acknowledged that all of the economically feasible plans which afford consistent 100-year protection require that the levee and floodwall systems in the tidal area be expanded both in height and length to afford protection from increased tunnel discharges. In this regard they requested that during the detailed planning phase of the project, the Corps investigate means to minimize the extent of additional levees and walls over and above those required for protection against tidal flooding.

As part of the expression of support for the Dual Inlet Tunnel Plan, the State also announced a number of other measures aimed at providing a comprehensive Flood Control Program for the Passaic River Basin. These measures were discussed previously in Section 2 under NON-FEDERAL FLOOD CONTROL PROGRAMS.

ALTERNATIVES SELECTED FOR DETAILED PLANNING

Based on the discussion contained in the paragraphs above, the alternatives selected for the Detailed Planning Stage were:

Plan 16A - Levee/Floodwall/Nonstructural/Channel Plan
Plan 30A - Beatties Inlet Tunnel Plan
Plan 30E - Dual Inlet Tunnel Plan

The input received from the non-Federal Sponsor confirmed that Plan 30E should be carried forward. In addition, since the net benefits for a number of the plans were of the same order of magnitude, and because of requests made by the State of New Jersey, Plans 30C and 30G were carried into the Detailed Planning Stage only as part of studies for identifying and optimizing the NED Plan. This is discussed further in Section 8.

Other plan elements identified for further evaluation in the Detailed Planning Stage included preservation of natural storage areas, fish and wildlife mitigation measures, and the acquisition of a limited number of frequently flooded structures. These measures were considered to be potentially compatible with any of the three basin-wide alternatives selected for further analysis, subject to incremental economic justification on a last-added basis.

SECTION 7 - PLAN FORMULATION - DETAILED STAGE

DETAILED PLANNING INVESTIGATIONS

The detailed planning stage for flood control works in the Passaic River Basin consisted of refining the design of plans carried forward into detailed development. This was done by incorporating the most up-to-date information available that would represent the conditions expected to prevail at the time of construction and during the years to follow. Considered were a range of related subjects such as the existing and future hydrologic and hydraulic design conditions, as well as each plan's hydraulic effectiveness, its economic efficiency (including incremental justification), its public acceptability, and its resulting environmental effects. The major tasks included in the detailed planning investigations are summarized below.

Establishment of Project Base Year. The first step taken before the desired plans could be refined consisted of establishing the base year design conditions. This meant providing data which would most likely represent the physical condition of the streams, including stream discharges, the channel configuration, any bridge modifications or structural alterations adjacent to the streams that would affect design considerations. Once these base conditions were established, the direction of detailed planning was set.

The choice of the base year was dictated mainly by the construction schedule of the plans considered for detailed investigation. In each case, the time frame required to complete construction of the plan, when considered in light of even optimistic estimates of the review and authorization process for this type of project, indicated that the use of the year 2000 as the base year was appropriate.

Finalizing of Without Project Conditions. To insure that a consistent, technically sound, and clearly defined without project basis was available for the evaluation of alternatives carried into detailed development, the most up-to-date information available was gathered and analyzed. The results served as the basis for NED optimization studies that followed. Key items included in finalizing the without project conditions were:

> Hydrology - update of frequency curves to include the April 1984 flood, and the last 7 years of record, recalibration of the HEC-1 model based on revised frequency curves, HEC-1 model verification of the April 1984 flood, incorporation of the results and the NJDEP review of Preservation of Natural Storage Study into without project conditions, and the update of future hydrology based on revised frequency curves;

Hydraulics - finalize the hydraulic flowlines based on revised discharges, verification of the April 1984 flood, and evaluation of effects of alternatives on sediment movement;

Economics - 1980 census update, post flood study for the April 1984 flood, final calibration of the EAD model (including stratification of revised reaches needed for incremental analysis), and finalizing the methodology for other benefit categories;

Environmental - complete all baseline fish and wildlife, water quality, and 404 studies, examination and incorporation of environmental and engineering design measures to avoid or minimize environmental impacts, development of a fish and wildlife mitigation plan, further coordination with USEPA and NJDEP regarding potential hazardous and toxic substance sites, and continuation of environmental scoping activities.

Early detailed planning focused on the update of the hydrologic frequency curves and the post flood data from the April 1984 flood which were viewed to be the most important without project items.

Refinement of Design and Cost Estimates. For each alternative brought forward, cost estimates and designs were refined by incorporating the data described in the preceding paragraph and reviewing previous estimates and assumptions from several viewpoints. These are described below:

Hydraulics. Through peer review, including hydraulic experts, both inside and outside of the Corps, it was determined that the Mannings "n" value for the coefficient of friction losses used in preliminary tunnel design was too conservative. The suggested range went as low as 0.012. An "n" value of 0.013 was, therefore, selected. This seemingly insignificant change increased tunnel design capacities by about 15%. This meant that tunnel design capacities and the resultant effects on the hydrology and hydraulic data prepared during the original formulation of alternatives were not readily comparable with similar data for the plans developed during detailed planning investigations. However, all plans presented in the following sections have been adjusted unless noted otherwise.

Additional hydraulic studies included the refinement of the design of all project components with extensive sensitivity analyses to determine optimum sizes and configurations of plan elements including tunnels, inlet and outlet structures, and transition channels, as well as the operating rules.

In order to determine the most effective tunnel scheme, develop operating rules and determine design parameters, a hydraulic program was developed to simulate the complex hydraulic nature of the Dual Inlet Tunnel. This program utilized the runoff hydrographs at the inlet locations, the hydraulic parameters of a specific tunnel plan configuration, and the specified operating rules to simulate actual operation of the tunnel during a flood event. By itself, it enabled many sensitivity measurements of plans. It also became the link that enabled simulation of the tunnel plan in the HEC-1 hydrology model to measure plan effects throughout the basin. For the Dual Inlet Tunnel Plan, this methodology enabled the optimization of both the main tunnel and potential spur tunnels. Tunnel effects could be translated to streamflow in HEC-1, whereupon another program interfaced with the HEC-2 hydraulic program allowed the conversion of flows to flood elevations. This data was then transferred through another utility program to the Expected Annual Damages (EAD) program whereby benefits were determined for the plan.

Hydrology. The HEC-1 hydrologic model was utilized extensively for measuring the effects of various sized plan components, particularly for tunnels. The model was also used for determining the most effective rules for operating these plans to allow maximum effectiveness in flood damage reduction, and also to allow for mitigation for fish and wildlife purposes and the preservation of wetlands. In addition, there were analyses of natural floodplain storage areas in the Central Basin to determine those areas most critical in terms of contributions to future flooding and, therefore, prime areas for floodplain preservation. Historical flooding events including the October 1903 flood and the recent April 1984 flood were modeled both to reproduce the events and to simulate their occurrence with the plan in place.

Foundations and Material Investigations. An extensive subsurface investigations program was undertaken along the alignment of the tunnel to confirm its constructability, and to provide data on rock characteristics and the groundwater conditions at the tunnel profile elevation. This information was used to develop the cost estimates. Thirty-one holes were drilled, mostly by the Mobile District USACE, ranging in depth from 200 to 500 feet below the surface. The U.S. Geological Survey also performed seismic explorations in the Preakness Valley to supplement the drill holes and provide bedrock profiles in an area where there was concern about a buried valley.

Additional borings were also performed in the vicinity of channels and levees in the Central Basin and the Pompton River headwaters to assure the constructability of proposed designs. Bedrock and soil samples were also tested to determine their engineering properties. In many areas, available information was provided by the New Jersey Department of Transportation, Passaic Valley Sewerage Commission, North Jersey District Water Supply Commission, local and county agencies, and private firms for use in evaluating the constructibility of plan components.

Screening of Incremental Elements. Levees, floodwalls, and other independent features of the plans brought forward into detailed development were further screened through a "last added/first added" analysis. Investigation of individual components of the detailed plans concentrated on those elements which, through refinement, would provide more efficient protection to flood prone areas. A more detailed discussion of this work can be found in Section 8 - OPTIMIZATION.

Incremental Degree of Protection. Economic data for each plan brought forward was reviewed to establish the relationship between "with plan" damage/frequency functions and changes in the size or geometry of tunnels or channels. Investigations of different scales of development of these alternatives sought to either equal or surpass the economic efficiency of the intermediate plans. Details of these analyses are discussed in Section 8 - OPTIMIZATION.

Incorporation of Preservation of Natural Storage. Coordination with NJDEP on adopted and proposed floodway limits continued throughout detailed planning. Where floodways have been adopted, the actual limits were used in these determinations. In other cases, the best estimates available at the time were used. The detailed investigations on preservation of natural storage included re-analyzing the hydrology using the new HEC-1 model and the rainfall/streamflow data from the last seven years. In addition, the protective status of the remaining natural storage areas and the projections of future development were reviewed and updated. These analyses resulted in the determination of areas to be acquired which, for consistency, have previously been discussed in Sections 2 and 5. Detailed planning studies also focused on determing the optimum time frame for the implementation of this element. This analysis resulted in the recommendation that the acquisition of the lands should be implemented by 1990. A more detailed discussion of the timing of implementation is contained in Section 8 - OPTIMIZATION.

Preservation of Natural Storage was found to be economically feasible both as a plan itself and as an element of multi-component plans. Preventing the loss of these storage areas would help maintain the protection level provided by the alternative plans throughout the project life. It has, therefore, been included as an element in all of the detailed plans.

Incorporation of Other Plan Elements. The inclusion of other elements, such as acquisition of residential structures (buyouts) and recreation, as part of the plan were investigated. The nature of the works and the characteristics of the areas affected limit the options for recreation. It was determined that whatever recreational features were possible, such as walkways and overlooks along levees in the Lower Valley, would be more appropriately treated under beautification rather than recreation. Coordination with the non-Federal sponsor confirmed this approach. No separable recreation elements, therefore, were included in the detailed plans. As discussed in Section 2 - WITHOUT PROJECT CONDITIONS, both the State of New Jersey and FEMA have instituted buyout programs in the Passaic Basin. The possibility of including additional buyouts, mainly along the Pompton River in Wayne and Lincoln Park, as an element of the detailed tunnel diversion plans was considered where needed to implement other measures, i.e. buyout of structures to accommodate channel modification or as part of a nonstructural measure. Although buyout of a limited number of structures may be feasible as a separate element when considered on an individual basis, this would be more appropriately treated as an interim project, as authorized in Section 1148 of the Water Resources Development Act of 1986 (PL 99-662). Therefore, buyout of structures as a separate project element was not incorporated into the detailed plans.

Fish and Wildlife Mitigation. The Fish and Wildlife Service's Planning Aid Report for the Passaic River Basin also offered input into the detailed planning investigations. The report contained many recommendations which influenced the direction and the results of detailed planning. Some of the major recommendations included constructing a weir to protect the wetlands in the Great Piece Meadows as part of the tunnel diversion alternatives, constructing low flow pilot channels and instream aquatic habitat structures, wetland planting, maintaining existing meanders, maintaining fish passage, and ensuring continued river flushing during floods. All of these recommendations were implemented, to at least some degree.

The most significant results were the inclusion of the weir in the tunnel plans and the development of operating rules for the tunnels and the weir, which would maximize flood damage reduction while also maintaining wetlands and flushing rivers. The weir would be used to allow water surface elevations in the Great Piece Meadows to be held at non-damaging flood levels either after the peak flood flows have passed or even during non-flood periods. This would ensure the periodic flooding necessary to maintain the existing vegetative cover. A weir would also be included on the Pequannock River as part of the tunnel alternatives in order to maintain water surface elevations upstream and thereby maintain existing wetlands and aquatic habitat, which would otherwise be lost with project implementation. The operating rules for the tunnels would ensure periodic flushing of the rivers by allowing up to a one year discharge to bypass the tunnels and flow through the river channels. These operating rules are discussed in more detail in Section 10.

In addition to these measures, as part of the detailed plans, existing stream meanders would be maintained wherever possible, low flow pilot channels would be included, and cobble substrate replaced in the modified channels. A full discussion of environmental design and mitigation measures eventually included in the detailed plans is presented in Section 3 of the EIS. These measures are listed in Section 10 of this appendix.

SIGNIFICANT PLAN REFINEMENT SUMMARY

Levee/Floodwall/Nonstructural/Channel Modification (Plan 16A). Plan 16A consists of a combination of levees, channel modification, and nonstructural elements. During the detailed planning stage, as a result of the levee screening discussed earlier in this section, many levee/floodwall systems were eliminated from this plan as well as from the two plans discussed below. The remaining works were optimized, as discussed in Section 8, resulting in varying levels of protection between the areas protected by different types of works and even between individual levee systems. Levee/floodwall systems were optimized individually, with design levels varying from the 100 to the 500 year. The nonstructural elements of the plan were optimized to a 10 year design level which, despite local support in parts of the basin for a buyout plan, included predominantly floodproofing and raising.

Beatties Dam Single Inlet Tunnel Diversion Plan (Plan 30A). This plan, presented as the Beatties Dam Inlet Plan, was a candidate NED plan from the Intermediate Planning Stage. The location of the inlet for this plan was reviewed to ensure that the most economically favorable location was selected. The initial location of the inlet was at Little Falls downstream of Beatties Dam. Consideration was given to locating the inlet on

Stag Island a short distance upstream of Beatties Dam and upstream of the rock ledge in the riverbed near the dam. Proper design would allow this inlet to function with or without Beatties Dam. Any responsibility for the dam's modification or maintenance required by the downstream location, therefore, could be avoided. This design would eliminate the need for the flow restrictor structure and shorten the channel upstream of Beatties Dam by almost 2,000 feet including the required excavation through the rock ledge. The tunnel, however, would be lengthened by almost 3,000 feet and a large basin with gates, similar to that described in the Pompton tunnel plans, would be required. An assessment of these alternatives indicated that the upstream inlet would be less costly, although not by a large margin, and easier to operate and maintain because of its simpler design and fewer components.

Another possibility reviewed was moving the inlet further upstream to Two Bridges as proposed in the Two Bridges Inlet Plan in Stage 2. The obvious trade-off in this instance is the channel length between the inlet at Stag Island and the additional tunnel length to the Two Bridges location. The cost of the almost 9,000 feet of large diameter tunnel was determined to be more expensive than the increment of channel cost. The inlet at Stag Island, upstream of Beatties Dam, is used in the Single Inlet Plan. The Two Bridges scheme was, however, carried forward into the detailed optimization stage to verify these results and prevent overlooking a potential NED alternative.

The cost of the Passaic River channel modification upstream of the tunnel inlet was revised to reflect a shortening of the modification due to the tunnel inlet relocation. The cost for the remaining Passaic River channel modification was increased as a result of a reassessment of both channel construction methods and construction constraints imposed by the urbanized area, similar to the analysis of the Pompton River in the intermediate planning stage.

In addition to the refinements discussed above, the features of the plan were optimized as discussed in Section 8. As part of the optimization analysis, three scales of the tunnel were analyzed in conjunction with works on the Pompton River sized to carry the design flow to the tunnels. It was determined that the optimum scale of Plan 30A consists of a 35-foot diameter tunnel with channel modification on the Pompton River. Therefore, the levees and floodwalls along the Pompton River were eliminated from the final iteration of Plan 30A. The optimization analysis results in varying levels of protection between the areas protected by different types of works and even between individual levee systems. Levee/floodwall systems were optimized individually, with design levels varying from the 100 to the 500 year.

Consideration was also given to utilizing channel modification in the Lower Valley instead of the integral levees and floodwalls, and to relocating the tunnel outlet location. These investigations are described in the following documentation of Plan 30E.

Pompton/Passaic Dual Inlet Tunnel Diversion Plan (Plan 30E). Early in the detailed planning stage, it was determined that the location of the Passaic River inlet of this plan would be more cost effective if located upstream of Beatties Dam. This analysis, described in the previous section on the Beatties Single Inlet Plan, led to a relocation of the tunnel alignment which lengthened the lower limb by almost 3,000 feet to the northwest and shifted the lower end of the upper limb almost 1,500 feet further westward. While this move did not alter the overall length of the tunnel significantly, it did result in changes to the plan.

A review to determine the feasibility of locating the second inlet in the vicinity of Two Bridges, as requested by the State of New Jersey, was conducted. The first approach was to realign the tunnel directly from the Third River outlet to Two Bridges and then to the Pompton Inlet location. A cost comparison indicated that the combined additional lengths of the upper and lower legs of the tunnel would cost more than the trade-off of channel costs between Two Bridges and Stag Island. Also, geological studies revealed a subsurface indentation, possibly a buried valley, that placed competent bedrock well below the alignment of the tunnel. Construction of the tunnel through this area would require removal of the TBM, changing to soft ground excavation methods, and then returning the TBM to the tunnel face to continue rock excavation, lowering excavation rates and raising unit excavation costs. This would result in higher project costs as well as greater uncertainty in the overall estimates. The route was therefore eliminated.

When geological studies confirmed adequate subsurface conditions along the original route, a spur tunnel was considered between the inlet location at Two Bridges and the tunnel west of Route 23, along an alignment north of Route I-80. The spur would have a smaller diameter than the main tunnel. The resulting trade-off is 1.2 miles of tunnel, 22 feet in diameter, versus the channel between Stag Island and Two Bridges. In this instance, the spur tunnel proved to be the more cost effective alternative. The advantages of the spur include focusing construction activities at the tunnel workshaft site and avoiding the disruption along the entire Stag Island to Two Bridges river reach that occurs with channel construction; a shortened construction period; and a large reduction in maintenance costs compared with those associated with channel

plans and surface features in general. In addition, the smaller volumes of clean tunnel spoil offer easier disposal and are, perhaps, marketable. The reduced channel disturbances are also preferred for preservation of the natural fishery habitat.

Another suggestion which was investigated involved relocating the Pompton Inlet to the north of the old Morris Canal feeder dam on the Pequannock and Ramapo Rivers. While this move would add 2,000 feet to the tunnel length, this location would be more effective in lowering flood stages in Pompton Plains and the surrounding areas, reducing requirements for levee protection. The cost of the additional tunnel would amount to about $20 million as compared to a cost for all of the levee systems amounting to almost the same amount. The tunnel would not eliminate, but only reduce the size of the systems, therefore, this change was not considered feasible.

A study was undertaken, at the request of the State of New Jersey, to determine the feasibility of utilizing a channel modification in lieu of levees and floodwalls integral to the tunnel in the Lower Passaic River.

With the tunnel plan in place, significantly higher flows would flow through the Lower Passaic River from the outlet to Newark Bay. These higher flows would result in correspondingly higher stages both downstream (a result of the higher flows) and upstream (due to backwater conditions) of the tunnel outlet. With the outlet located at the Third River, the higher stages would be experienced in the reach from the bend in the river between Passaic City and Wallington downstream to the Second River confluence. To mitigate against these higher stages, levees and floodwalls were included in the plan throughout nearly this entire area.

A preliminary channel modification was based upon a post-tunnel construction 100-year recurrence interval fluvial flood on the Passaic River, occurring coincidentally with a 1-year recurrence interval tide elevation of 5.5 NGVD at the River's mouth. The purpose of the channel modification was to convey the peak 100-year discharge following tunnel construction through the Second River-Third River study reach at a level no greater than that which exists under present 100-year fluvial flood/1-year tide conditions. By doing so, the channel modification would mitigate the effects of the increased peak 100-year discharges resulting from the tunnel and eliminate the need for the proposed mitigation levee/floodwall systems.

While this would have the same mitigating effect as the levees and floodwalls, no channel modification would have any effect on tidal stages which are a contributing cause to flooding in the Lower Passaic River. The total benefits associated with a channel modification scheme in the Lower Passaic River would, therefore, be lower than those associated with levees and floodwalls.

This channel modification would extend from a point located 8,900 feet downstream of the Second River to just upstream of the Third River. It is important to note that, although the effect of the post-tunnel 100-year fluvial flood on the Passaic River would only extend downstream to a point 1,100 feet upstream of the Second River confluence, it would be necessary to begin the channel modifications further downstream. This was done in order to provide an overall friction slope suitable for the proposed channel shapes and widths.

Heavy development along the banks necessitated the use of retaining walls in several areas of the modification. The proposed channel modifications consist generally of a 210 foot bottom width trapezoidal channel and a 260 foot wide flume. To meet space limitations and avoid the need for structure removal or relocation, the flume width would narrow to 230 feet for a distance of approximately 1,200 feet in the reach immediately upstream of the Second River confluence. The trapezoidal portions of the channel would be unlined with 2 horizontal to 1 vertical bank slopes. The depth of the channel would make the use of concrete retaining walls extremely expensive and economically infeasible. The flumes, therefore, would have vertical walls constructed from steel sheet piling driven into the subsoil and anchored with tie-backs.

To simplify the analysis of this plan, three existing bridges crossing the modification reach (Conrail, Rutgers Street, and Kingsland Avenue) were removed from the HEC-2 model at the start of the analysis. However, the river cross-sections immediately upstream and downstream of each bridge were retained to partially simulate the presence of either a modified or new bridge at each location. Based upon the foundation information available, the bottoms of the footings of the Rutgers Street and Kingsland Avenue bridges are above the invert of the proposed channel modifications.

The 100-year design depth in the flumes and trapezoidal channel is approximately 29 feet and is controlled by the depth of flow at the downstream end of the channel modifications. The resultant 100-year water surface elevations within the study reach upstream of the Second River agree closely with existing conditions, with maximum variations of approximately 0.3 feet. Design velocities in the proposed channels range from approximately 5 to 7 feet per second.

In addition to the high costs of the sheet piling and bridge replacements, it was discovered that there were extensive utility crossings as well as bedrock within the proposed excavation area for the channel modification. Preliminary costs for this channel modification plan were estimated at about $150 million compared to about $110 million for the levees and floodwalls. In view of the significantly higher cost as well as the fewer benefits realized with a channel modification in the Lower Passaic River, this element was eliminated from further consideration.

The Third River outlet was reviewed in terms of both its immediate location and the possibility of relocating the outlet further downstream to eliminate effects of the large discharges and the local protection necessary to mitigate for these effects. In the immediate area, a location was considered on the west bank of the Passaic River which would extend the tunnel 800 feet to a point north of the Third River confluence and east of the McCarter Highway (Route 21). This would result in a simpler project because the Route 21 bridge would no longer require replacement, with the accompanying traffic delays during construction; the Third River channel would not have to be enlarged; and the outlet would be oriented to direct flows more effectively downstream along the Passaic River. While costs for both the original outlet and the new location are about the same, the new location presents a cleaner construction job with fewer uncertainties and annoyances about bridge replacement and traffic delays and eliminates the need for relocating the Passaic Valley Sewerage Commission's trunk lines. The Passaic River site was, therefore, selected over the Third River site.

Early in the study, consideration was given to locating outlets in Newark Bay and the vicinity of the Second River - Passaic River confluence. The benefit to cost ratio for Plan 30E with either of these alternative outlet locations is detailed in Section 10. The bedrock geology for the Newark Bay-outlet route was assumed to be similar to that used for the lower limb of the Dual Inlet Tunnel Plan since specific information is not available. The Newark Bay option would not only add about 35,000 feet to the total tunnel length, it would also require the tunnel diameter to be increased by one foot to maintain the same level of protection. However, no levees and floodwalls would be required to protect against tunnel discharges. Difficult construction conditions would be encountered at the outlet location. The outlet would have to be built offshore, adjacent to the navigation channels, and through 100 or more feet of bay sediments before hitting bedrock. The additional tunnel work would extend the construction period by at least 18 months. The Newark Bay outlet option would add approximately $300 million to the investment cost of the Dual Inlet Tunnel Plan. An outlet in the vicinity of the Second

River would be located upstream of the Conrail Bridge in River Bank Park, Kearny. The Second River option would add almost 10,000 feet of tunnel to the Dual Inlet Tunnel Plan and extend the period of construction by about one year, while not entirely eliminating increased flood stages upstream. Approximately 8.2 miles of levees and floodwalls would still be required to protect against the tunnel discharge although the scale of the protection would be reduced. The Second River outlet would increase the investment cost of the Dual Inlet Tunnel Plan by an additional $100 million for an equivalent level of benefits. The resulting design change would not be incrementally feasible. Therefore, the outlet location on the Passaic River near the Third River was affirmed.

In addition to the refinements, the plan elements were optimized as discussed in Section 8, resulting in varying levels of protection between the areas protected by different types of works and even between individual levee systems. Levee/ floodwall systems were optimized individually, with design levels varying from the 100 to the 500 year.

SECTION 8 - OPTIMIZATION

GENERAL

An optimization analysis was undertaken to determine the scale at which each of the alternatives considered in the Detailed Planning Stage maximize net economic benefits. The alternatives included in the analysis were the Levee/Floodwall/ Nonstructural/Channel Plan (16A), the Beatties Inlet Tunnel Diversion Plan (30A), and the Pompton-Passaic Dual Inlet Tunnel Diversion Plan (30E). The tunnel plans were optimized in incremental steps, beginning with the identification of the optimum route and scale of the tunnel diversion elements only (e.g. "Building Block" 23), exclusive of any independent tidal or fluvial levees. Independent levee/floodwalls and other measures were then added to the most economically efficient tunnel scheme on an incremental basis. Incremental economic analyses were performed on such independent plan elements to determine NED efficiency, and their optimum scales were identified. In addition, in order to confirm that alternatives previously screened in the Intermediate Planning Stage do not generate significantly greater net benefits when considered at other scales, alternatives with such NED potential were also included in optimization studies. For tunnel diversion plans this meant including the Two Bridges Inlet and Pompton Single Inlet tunnel routes in the optimization study. The structural features of the detailed alternatives were analyzed incremental to the preservation of natural flood storage element. The NED Plan was identified, and last added and first added analyses were performed to examine the economic efficiency of separable plan components.

ANALYSIS OF INCREMENTAL DEGREE OF PROTECTION

To determine the optimum economic level of flood protection, the detailed alternatives and/or tunnel diversion routes were evaluated for at least three scales of development. All design flows were based on flow conditions reflecting the level of urbanization expected by the year 2040. Project costs were developed for each alternative scale, and the ability of each plan to reduce flood damages was determined. Net national economic benefits were measured and optimization relationships compiled both graphically and in tabular fashion. The results were analyzed to justify incremental increases in the degree of protection towards identifying the optimum scale of development for each alternative. Plan 16A was evaluated individually, while the tunnel diversion elements of Plans 30A and 30E were considered along with the Two Bridges, and Pompton Single Inlet

routes as part of a combined Tunnel Diversion optimization study. The two alternatives with the greatest excess benefits at their optimum point were further examined to determine if their economic efficiency could be further increased by adding independent plan elements, such as tidal levees and floodwalls, or by combining the tunnel with other measures, such as the Preservation of Natural Storage. The results for Plan 16A and the tunnel diversion optimization studies are presented below.

Plan 16A - Levee/Floodwall/Nonstructural/Channel Plan. As developed in the Intermediate Planning Stage this alternative had a variable level of protection with the levee/floodwall and channel modification elements scaled at the 100 year level, while the Central Basin nonstructural measures were designed at the 10 year level of protection. The reason the plan did not provide a uniform level of protection is because the nonstructural measures are not economically feasible at scales above the 10 year level. This plan is somewhat unique since it consists of three independent measures which can each function at different levels of protection. For the purposes of determining the optimum scale of development it was not considered necessary that a uniform level of protection be required. Therefore, the optimization study for Plan 16A was aimed at identifying the optimum scale for each of the plan elements. For each of the Lower Valley tidal levees and floodwalls, scales of 50, 100 and 500 year levels of protection were considered. The same scales were examined for the Lower Valley channel element and the Central Basin fluvial levees and floodwalls. The optimization analysis resulted in the elimination of several tidal and fluvial levee/floodwall systems, carried forward from the Intermediate Planning Stage, since they were not incrementally justified. For the nonstructural elements, the scales examined were based upon the 10, 50 and 100 year levels of protection developed in the Intermediate Planning Stage. The results indicate that the optimum scale for this plan consists of a combination of Lower Valley channel modification at the 100 year scale, Lower Valley tidal levees/floodwalls at the 500 year level, Central Basin fluvial levees/floodwalls at scales ranging from the 100-500 year level, and Central Basin and Pompton Valley nonstructural measures at the 10 year level of protection. The preservation of 5,350 acres of natural storage is also included in the Detailed Plan 16A. The optimization of this plan element is discussed later in this section under Preservation of Natural Storage. Table C-68 presents the economic data for the incrementally feasible elements of Plan 16A, as well as for the comprehensive plan.

Table C-68

INCREMENTAL DEGREE OF PROTECTION - PLAN 16A
(Oct. 85 Price Level, 8-5/8%)

ELEMENT	SCALE (Design Frequency in years)	ANNUAL 1/ COST ($1,000's)	ANNUAL 2/ BENEFITS ($1,000's)	NET BENEFITS ($1,000's)
TIDAL LEVEES				
Kearny Point	50	1,990	2,240	250
	100	2,090	2,650	560
	* 500	2,380	3,100	720
Doremus Ave	50	300	2,370	2,070
	100	310	2,570	2,260
	* 500	340	2,790	2,450
N.J. Turnpike	50	90	2,370	2,280
	100	100	2,580	2,480
	* 500	110	2,790	2,680
Lister Ave	50	430	3,010	2,580
	100	460	3,280	2,820
	* 500	510	3,600	3,090
South 1st St	50	320	750	430
	100	340	800	460
	* 500	400	980	580
LOWER VALLEY CHANNEL	50	14,120	16,530	2,410
	* 100	17,350	19,830	2,480
	500	23,820	24,490	670
CENTRAL BASIN LEVEES				
Passaic 3B	50	180	490	310
	* 100	200	510	310
	500	330	530	200
Passaic 10	50	70	180	110
	* 100	90	250	160
	500	140	280	140

Table C-68 (Cont'd)

INCREMENTAL DEGREE OF PROTECTION - PLAN 16A
(Oct. 85 Price Level, 8-5/8%)

ELEMENT	SCALE (Design Frequency in years)	ANNUAL 1/ COST ($1,000's)	ANNUAL 2/ BENEFITS ($1,000's)	NET BENEFITS ($1,000's)
Rockaway 1	50	70	320	250
	* 100	120	380	260
	500	190	440	250
Rockaway 2	50	190	170	-20
	* 100	230	250	20
	500	340	290	-50
Rockaway 3	50	220	370	150
	* 100	260	500	240
	500	450	530	80
Pinch Brook	50	80	1,140	1,060
	100	100	1,270	1,170
	* 500	110	1,410	1,300
CENTRAL BASIN/ POMPTON VALLEY NONSTRUCTURAL	* 10	8,710	9,340	630
	50	18,680	11,370	-7,310
	100	25,170	12,970	-12,230
COMPREHENSIVE 3/ PLAN 16A	*10-500	38,600	59,800 4/	21,200

1/ Operation and maintenance costs are only included in nonstructural elements and comprehensive Plan 16A Costs.
2/ Annual benefits for incremental plan elements only include inundation reduction and levee freeboard benefits.
3/ The comprehensive plan includes preservation of 5,350 acres of natural flood storage.
4/ Average annual equivalent benefits include inundation reduction, affluence, residential intensification, traffic flow, industrial content growth, and FIA cost reduction and path delay.
* Optimum Scale

The total first cost of Plan 16A is $385,300,000 while the total investment cost, including interest during construction, is $433,800,000. The annual costs equal $38,600,000. This plan has $59,800,000 in average annual equivalent benefits and a benefit-to-cost ratio of 1.5 to 1.

Diversion Tunnels. The optimization of the diversion tunnels required that they be optimized as to potential inlet locations and scale. Four tunnel diversion routes were examined as part of Detailed Stage optimization studies. The four plan elements are: (1) Beatties Inlet Tunnel; (2) Two Bridges Inlet Tunnel; (3) Pompton Single Inlet Tunnel; and (4) the Pompton - Passaic Dual Inlet Tunnel. All four routes were initially examined at three scales of development. For the Pompton River diversion options a fourth scale was added to further refine the identification of the optimum scale.

For the purpose of tunnel optimization each of the alternatives included only those project features necessary for the tunnel to operate as designed. Therefore, in addition to the tunnels and associated inlet and outlet works, channel modifications and levees/floodwalls necessary to safely deliver flood flows to the tunnel inlets and levees/floodwalls required to contain any induced flows exiting from the tunnels were included in the plans to be optimized. Thus, the plans considered are basically the "Building Blocks" #'s 23A, C, E and G, as modified in the Detailed Planning Stage. In this sense the alternatives so optimized are really the tunnel plan elements of comprehensive Plans 30A, C, E, and G.

The scale for each tunnel element was designated in terms of a diameter size, rather than a target level of protection. Diameter size was used because diversion measures do not produce uniform levels of protection since their maximum beneficial effects occur at specific areas of influence centered at the immediate vicinity of the inlets, and progressively diminish proceeding upstream or downstream from these locations.

As shown in Table C-69 both the Beatties Dam Inlet and the Two Bridges Inlet tunnel elements were examined with tunnel diameters of 26, 35 and 39 feet. For the 26-foot and 35-foot scales, channel modifications upstream of the inlets were required to carry the design flow to the tunnel, and for the 39-foot scale a combination of levees/floodwalls and channel modification were required for the same purpose. All three scales of the Beatties and Two Bridges tunnel routes required levee and floodwalls in the vicinity of the tunnel outlet.

4430

TABLE C-69

INCREMENTAL DEGREE OF PROTECTION - DIVERSION TUNNELS
(Oct 85 Price Level, 8-5/8% Interest Rate,
100 Year Project Life, Base Year 2000, $1,000's)

Diversion Tunnel Element	Tunnel Diameter	Investment Cost	Annual Costs 2/	Annual Benefits 3/	Net Benefits
Beatties Inlet	26'	453,500	40,140	28,400	-11,700
	35'*	661,000	58,000	66,100	8,100
	39'	907,700	79,300	73,100	-6,200
Two Bridges Inlet	26'	466,930	41,300	28,700	-12,600
	35'*	681,100	59,700	66,700	7,000
	39'	935,840	81,700	73,100	-8,600
Pompton Single Inlet	35'	638,500	56,100	54,200	-1,900
	37'	662,500	58,100	61,300	3,200
	39'*	693,300	60,800	67,600	6,800
	40'	711,800	62,400	68,500	6,100
Pompton-Passaic Dual Inlet 1/	35'	663,300	58,200	66,600	8,400
	37'	685,100	60,100	74,300	14,200
	39'*	713,000	62,500	78,800	16,300
	40'	729,800	64,000	79,700	15,700

1/ In combination with a spur tunnel with a diameter of 22 ft. from Two Bridges to main tunnel. See Table C-72 for details regarding the optimization of spur tunnel.

2/ Operation and maintenance costs are not included.

3/ Average annual equivalent benefits include inundation reduction, affluence, residential intensification, traffic flow, and FIA cost reduction.

* Optimum scale.

The Pompton Single Inlet tunnel element was scaled at the 35, 37, 39 and 40 feet diameter sizes and included channel modifications in combination with levees/floodwalls upstream of the inlets as necessary for these alternatives. Levees and floodwalls were also included in the area of the tunnel outlet for each tunnel diameter.

The Dual Inlet tunnel element was scaled at the diameter sizes of 35, 37, 39 and 40 feet for the main tunnel, all in combination with a spur tunnel diameter of 22 feet. The sizing of the spur tunnel was accomplished on an incremental basis with the economically optimum scale identified at a diameter of 22 feet for all main tunnel sizes, as discussed later in the section entitled Spur Tunnel. The Dual Inlet tunnel elements required levees, floodwalls and/or channel modifications upstream of the Pompton inlet and minor transition channel improvements in the vicinity of Two Bridges on the Passaic and Pompton Rivers. Levees and floodwalls were also required in the vicinity of the tunnel outlet.

The economic results of the optimization study for the tunnel diversions are presented in Table C-69 and graphically presented in Figures C-78,79, and 80. Figures C-78 and 79 present the relationship of the annual costs versus the annual benefits for the four tunnel plan elements, while Figure C-80 presents a plot of net benefits versus tunnel diameter sizes.

Evaluation of the optimization curves (Figures C-79 and C-80) indicates that there would be a precipitous decrease in net benefits for inner tunnel diameters greater than 40 feet. This results from the benefits leveling off as the maximum pool of benefits is approached, while the costs increase rapidly due to a change in tunnel construction methods and/or rates of progress. The basis for construction cost estimates for diversion tunnels up to and including 40 feet in diameter is the use of Tunnel Boring Machines (TBM). Subsurface data clearly indicates that conditions are highly suitable for cost efficient construction with a TBM. Machines which can bore finished tunnel diameters of up to 40 feet (including concrete liner) are forecast by engineers and manufacturers to be available in the next 3 to 7 years. Although the TBM construction of tunnels larger than 40-foot inner diameters is possible, incremental costs escalate because of slower rates of progress due to TBM head pressure problems and equipment wear on the TBM disk cutters. The net result of such cost increases is that for these larger tunnels TBM construction costs approach, and at one point will exceed, costs for conventional drill and blast methods, whereas for tunnels with finished diameters less than 40 feet the TBM method is significantly more economical.

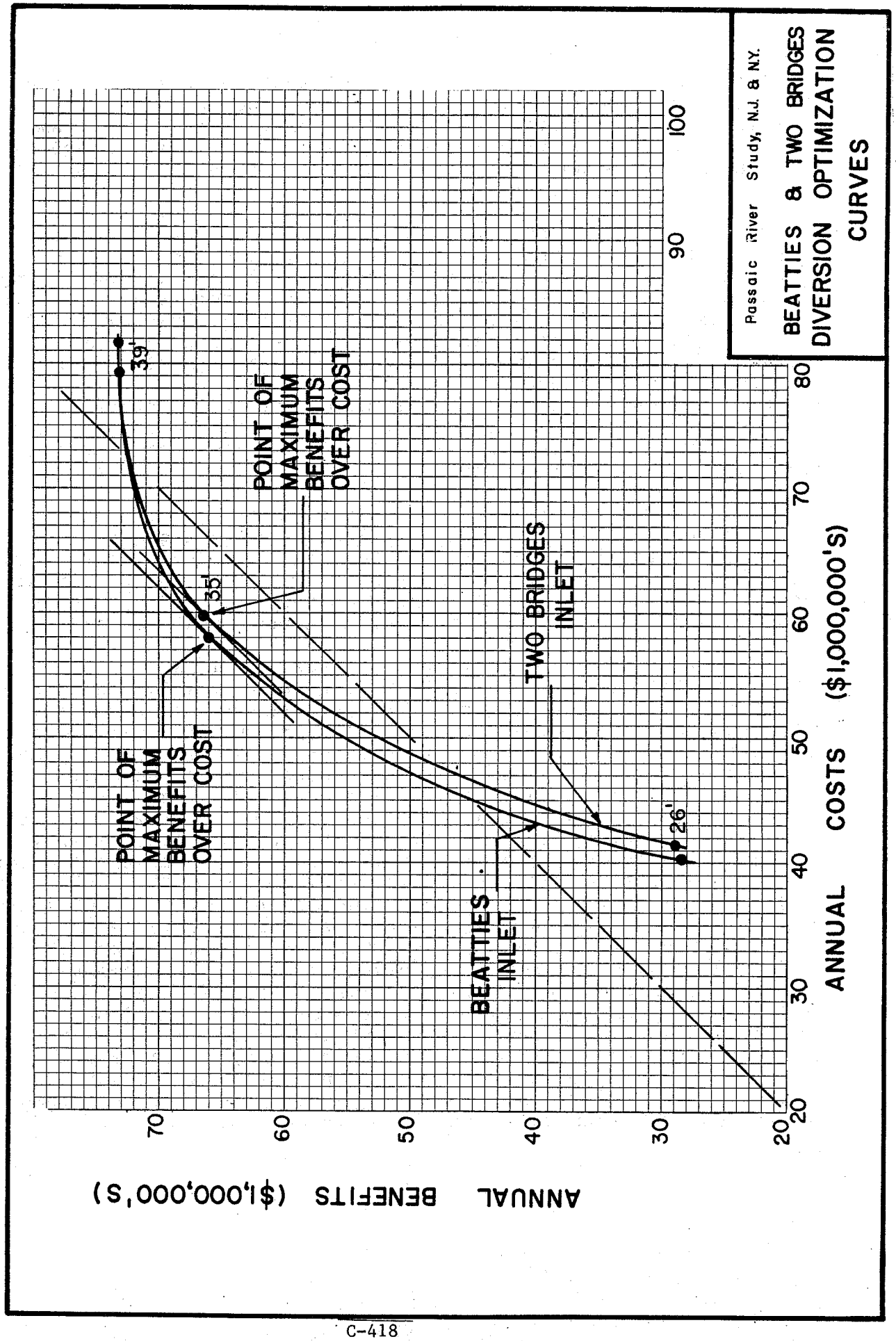
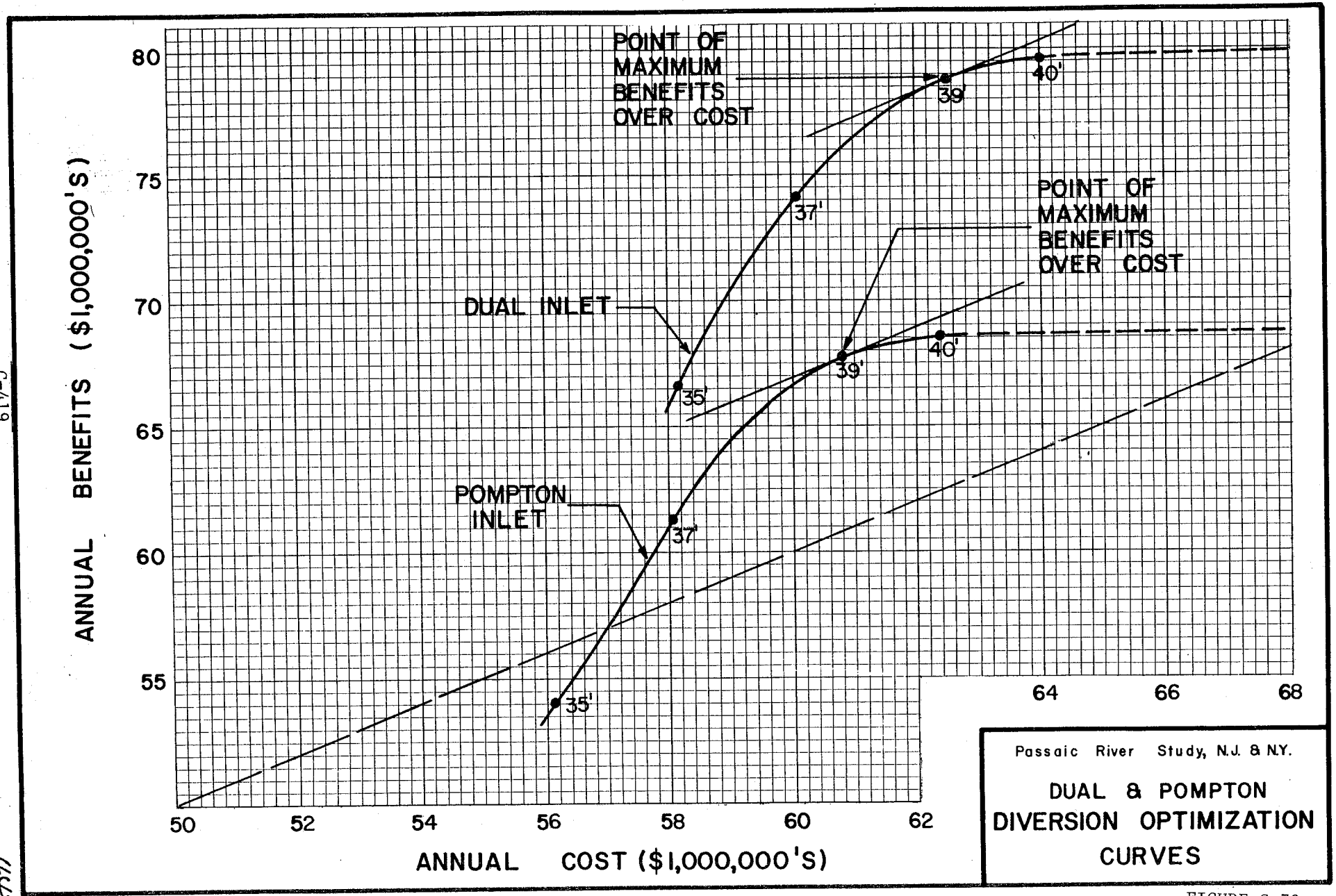

Passaic River Study, N.J. & N.Y.
BEATTIES & TWO BRIDGES
DIVERSION OPTIMIZATION
CURVES
ANNUAL COSTS ($1,000,000'S)
ANNUAL BENEFITS ($1,000,000'S)
BEATTIES INLET
TWO BRIDGES INLET
POINT OF MAXIMUM BENEFITS OVER COST
POINT OF MAXIMUM BENEFITS OVER COST
39'
35'
26'
20
30
40
50
60
70
80
90
100

FIGURE C-78



Passaic River Study, N.J. & N.Y.

DUAL & POMPTON DIVERSION OPTIMIZATION CURVES

FIGURE C-79

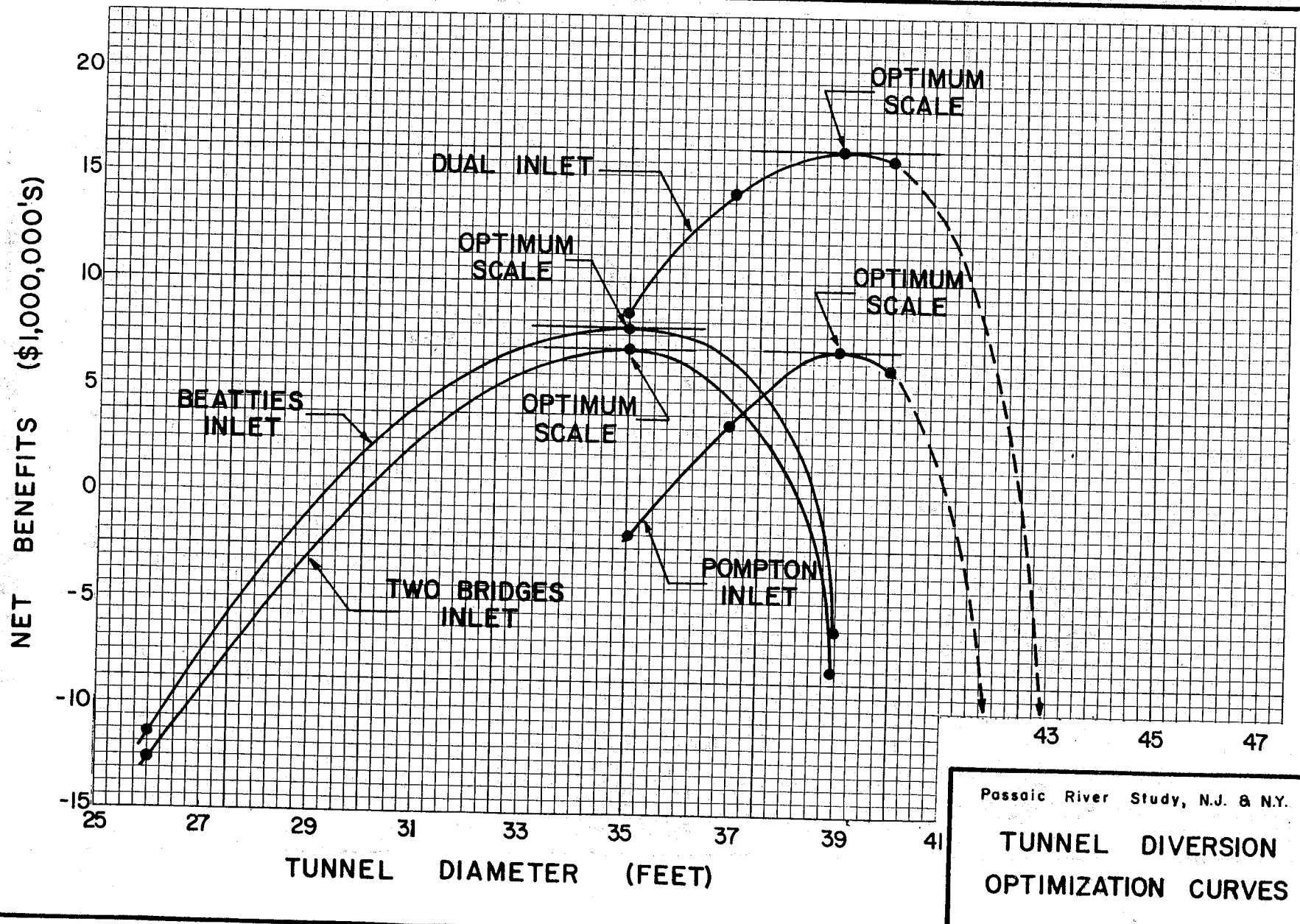

NET BENEFITS ($1,000,000'S)
20
15
10
5
0
-5
-10
-15
25
27
29
31
33
35
37
39
41
43
45
47
TUNNEL DIAMETER (FEET)
DUAL INLET
OPTIMUM SCALE
OPTIMUM SCALE
OPTIMUM SCALE
BEATTIES INLET
OPTIMUM SCALE
TWO BRIDGES INLET
POMPTON INLET
Passaic River Study, N.J. & N.Y.
TUNNEL DIVERSION OPTIMIZATION CURVES

FIGURE C-80

The results of the optimization analysis indicated that the Dual Inlet tunnel route ranked first based on net benefits while the Beatties Inlet route was second best. These two tunnel elements were sufficiently different in their physical features to warrant evaluating both in final detail. The Dual Inlet tunnel element is optimized at the 39-foot diameter main tunnel and 22-foot diameter spur tunnel scale which is equivalent to a 100 year design level. At this scale the investment cost of the tunnel element is $713,000,000 and the annual cost, which includes interest during construction, would be $62,500,000. The tunnel element would accrue $78,800,000 in average annual equivalent benefits and a benefit-to-cost ratio of 1.3 to 1. The Beatties Inlet tunnel element is optimized at the 35-foot diameter tunnel in combination with channel modifications upstream of the inlet, which is equivalent to an approximate 50 year design level. As given in Table C-69, the optimum scale of the Beatties inlet tunnel element has an investment cost of $661,000,000 and an annual cost, including interest during construction, of $58,000,000. The 35-foot diameter tunnel element would accrue $66,100,000 in average annual equivalent benefits and has a benefit-cost ratio of 1.1 to 1.

The economic efficiency of both the Beatties Inlet and the Dual Inlet tunnel plan elements is increased by the incorporation of incrementally justified plan features at their optimum scales. These incremental plan elements include levees and floodwalls to protect against tidal and fluvial flooding independent of the tunnel; preservation of natural flood storage areas, and fish and wildlife mitigation measures.

For each of the levee/floodwall systems, three levels of protection were analyzed in order to determine the optimum scale of each system. In optimizing the number of acres of natural flood storage to be preserved, all 8,620 acres of developable natural storage were considered. The fish and wildlife mitigation measures include both features classified as standard engineering practice and separable fish and wildlife measures which are incrementally justified. The optimization and first added/last added incremental justification analyses for each of the independent plan elements are documented in detail later in this section under Focus on the Passaic-Pompton Dual Inlet Tunnel Diversion Plan. Before these studies are presented, comprehensive plan data for scales considered for Plans 30A and 30E are summarized and the NED plan and scale are designated.

Plan 30A. The Beatties Inlet tunnel element is the route which ranked second best in terms of net benefits. Independent plan features were added to each scale of the Beatties Inlet tunnel element to increase the economic efficiency of this plan. The levees and floodwalls carried forward from the Intermediate Planning Stage were screened for incremental

feasibility and included in Plan 30A at their optimum scales. This resulted in the inclusion of five Lower Valley tidal levee/floodwall systems at the 500 year level of protection and twelve fluvial levee/floodwall systems in the Central Basin, including the Pompton Valley, at either the 100 year or the 500 year level. The preservation of 5,350 acres of natural flood storage and fish and wildlife mitigation measures are also included in the comprehensive Plan 30A.

The economic data for the three scales of comprehensive Plan 30A are given in Table C-70 and Figure C-81. The optimum scale of Plan 30A includes a 35-foot diameter tunnel. The total first cost for the optimum comprehensive Plan 30A is $728,200,000. The total investment cost, including interest during construction, is $892,200,000 and the annual costs equal $79,900,000. Plan 30A has $105,700,000 in average annual equivalent benefits, and a benefit-to-cost ratio of 1.3.

Plan 30E. The Dual Inlet tunnel element is the route which produces the greatest net benefits. Independent plan features were added to the four scales of the Dual Inlet tunnel element in the same manner as for Plan 30A. Five Lower Valley tidal levee/floodwalls at the 500 year level of protection, seven Central Basin fluvial levee/floodwalls ranging from the 100 year to the 500 year level, preservation of 5,350 acres of natural flood storage, and fish and wildlife mitigation measures are included in the comprehensive Plan 30E.

The economic data for the comprehensive plan are given on Table C-70 and Figure C-82. The optimum scale of Plan 30E includes a 39-foot diameter main tunnel and a 22-foot diameter spur tunnel. The total first cost of the optimum comprehensive Plan 30E is $814,100,000 while the total investment cost, including interest during construction, is $927,100,000. The annual costs of $83,000,000 and average annual equivalent benefits of $118,200,000 result in a benefit-to-cost ratio of 1.4 to 1.

DESIGNATION OF NED PLAN

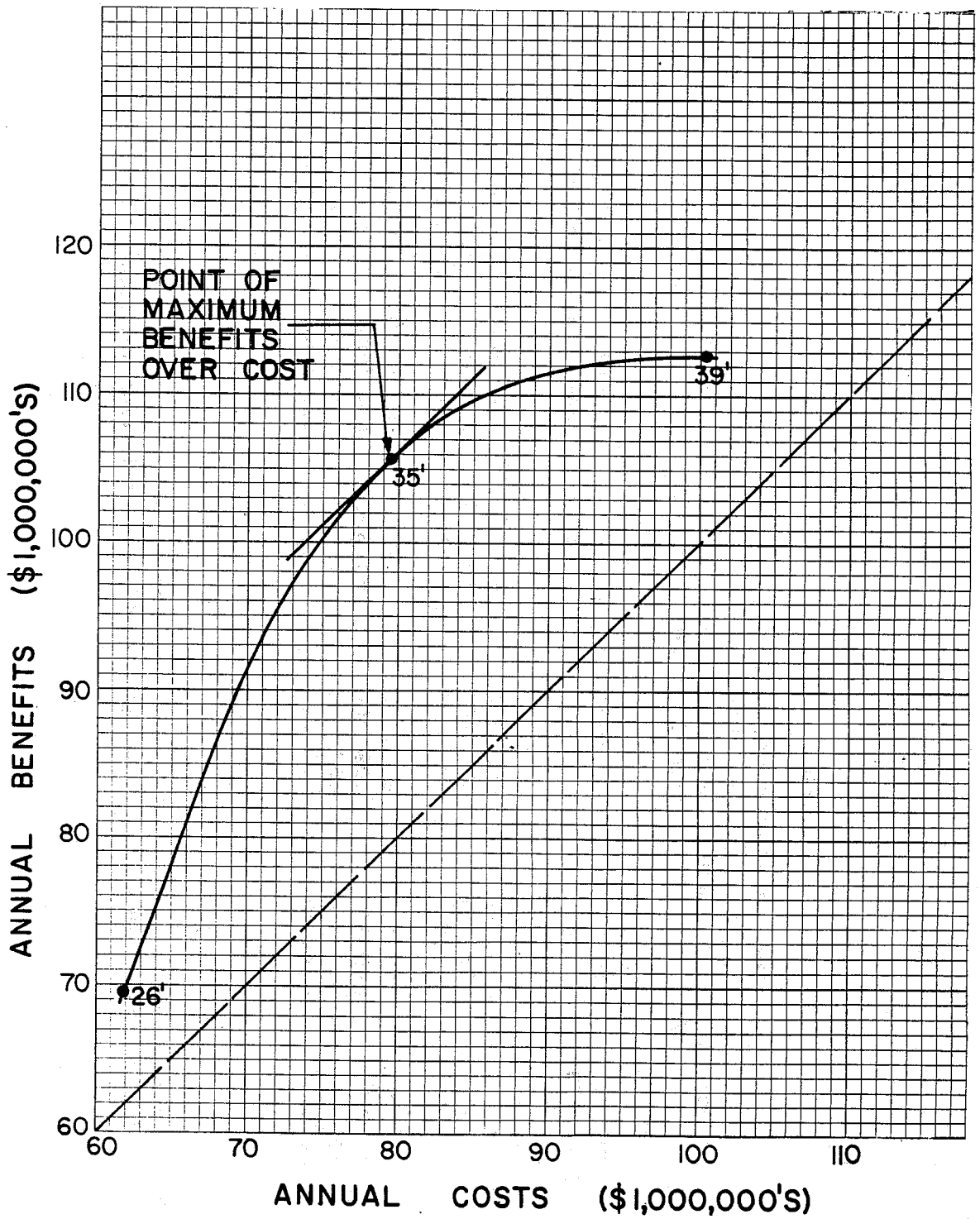
The NED plan is defined as the alternative that reasonably maximizes beneficial contributions to the National Economic Development, consistent with protecting the Nation's environment. A comparison of the optimum scales of the comprehensive Plans 16A, 30, and 30E determined that Plan 30E maximized excess benefits as shown in Table C-71. As discussed above, the optimum scale of Plan 30E is at the 39-foot diameter main tunnel and 22-foot diameter spur tunnel. It was confirmed that the addition of independent measures to the other tunnel diversion plan elements would not result in any comprehensive plan with greater excess benefits than the Pompton - Passaic Dual Inlet Tunnel Plan. In addition, larger and smaller scales of other

TABLE C-70

INCREMENTAL DEGREE OF PROTECTION
COMPREHENSIVE PLANS 30A AND 30E
(Oct. 85 Price Level, 8-5/8% Interest Rate, 100 Year
Project Life, Base Year 2000, $1,000's)

	TUNNEL DIAMETER (feet)	FIRST COSTS	INVESTMENTS COSTS	ANNUAL COSTS	ANNUAL BENEFITS *	NET BENEFITS
Plan 30A	26	596,300	683,500	61,900	69,300	7,400
	35	728,200	892,200	79,900	105,700	25,800
	39	897,800	1,121,400	100,100	112,700	12,600
Plan 30E	35/22	772,600	877,400	78,800	105,900	27,100
	37/22	790,800	399,200	80,600	114,000	33,400
	39/22	814,100	927,100	83,000	118,200	35,200
	40/22	828,100	942,800	84,500	118,900	34,400

* Average annual equivalent benefits include inundation reduction, affluence, residential intensification, traffic flow, industrial content growth, FIA cost reduction and path delay.

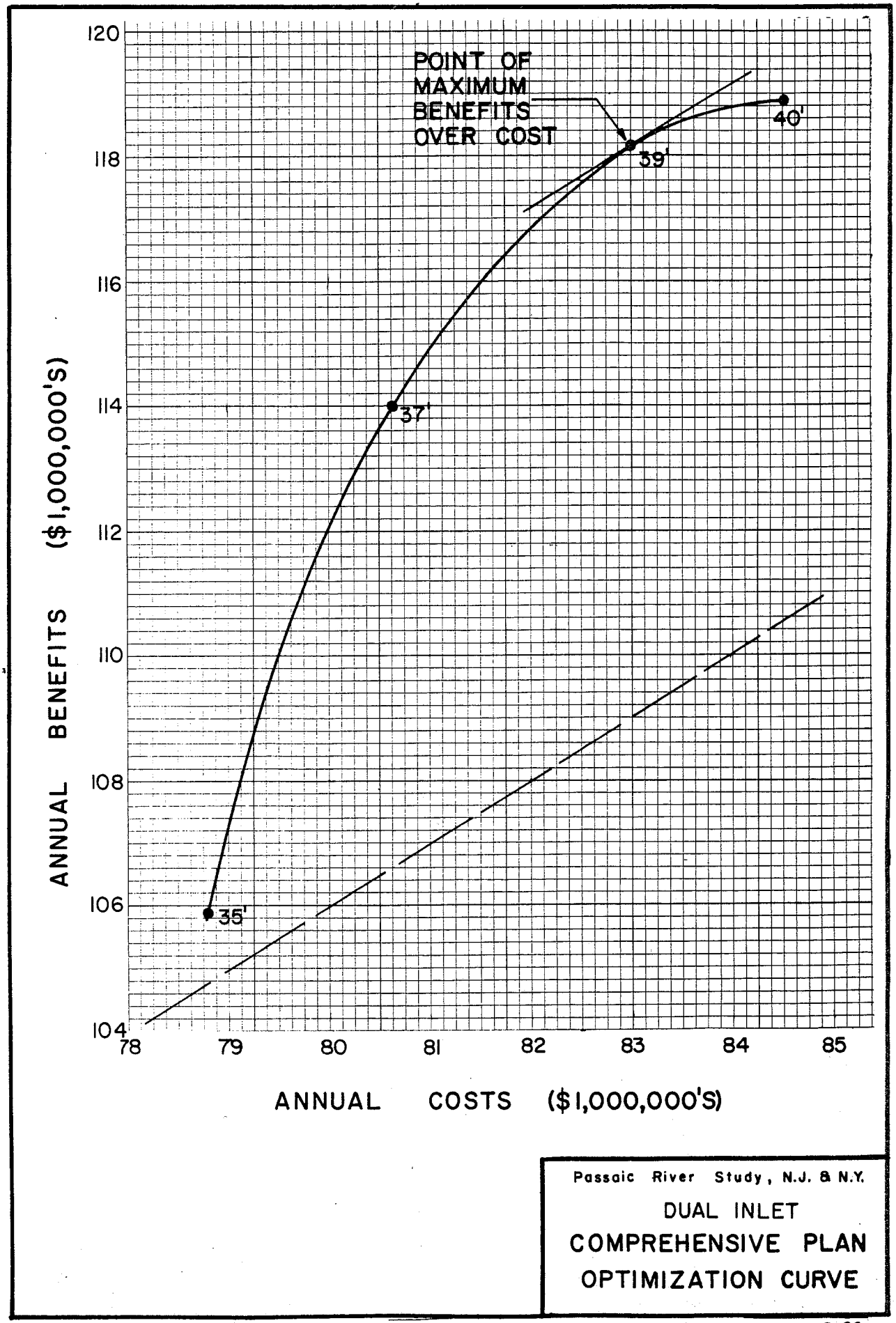


Passaic River Study, N.J. & N.Y.

BEATTIES INLET

COMPREHENSIVE PLAN OPTIMIZATION CURVE

FIGURE C-81



Passaic River Study, N.J. & N.Y.

DUAL INLET

COMPREHENSIVE PLAN

OPTIMIZATION CURVE

FIGURE C-82

TABLE C-71

DETAILED STAGE ALTERNATIVES - OPTIMAL SCALES OF DEVELOPMENT
(October 1985 Price Levels, 8-5/8% Interest Rate, $1000's)

ALTERNATIVE	FIRST COSTS	INVESTMENTS COSTS	ANNUAL COSTS	ANNUAL BENEFITS	NET BENEFITS
Plan 30E	814,100	927,100	83,000	118,200	35,200
Plan 30A	728,200	892,200	79,900	105,700	25,800
Plan 16A	385,300	433,800	38,600	59,800	21,200

non-tunnel alternatives, such as Plan 16A, were again reviewed to ensure that a potential NED plan had not been overlooked. These studies confirmed that the Dual Inlet Plan produced the greatest net NED benefits. Therefore, based on the detailed stage studies of incremental degree of protection, the Pompton-Passaic Dual Inlet Tunnel Diversion Plan is identified as the NED Plan.

FOCUS ON THE POMPTON - PASSAIC DUAL INLET TUNNEL DIVERSION (PLAN 30E)

As discussed above, Plan 30E was determined to have the greatest excess benefits of all the alternatives considered. As previously described, the entire project consists of the following: (1) Tunnel element including the main and spur tunnels, inlet and outlet works, channel modifications, and levee/floodwalls necessary for the diversion to function; (2) Lower Valley tidal and Central Basin fluvial levee/floodwalls incremental to the tunnel; (3) Preservation of Natural Storage element; and (4) Fish and wildlife mitigation. In addition, nonstructural measures such as permanent evacuation were considered as potential incremental elements to the Dual Inlet tunnel element.

The remainder of this section summarizes the optimization and incremental justification analyses for the various elements which comprise the comprehensive Pompton - Passaic Dual Inlet Tunnel Diversion Plan. Subsequent to the discussions of the analysis for the various tunnel components, a summary of the last added/first added analysis for the tunnel diversion plan element is presented.

Main Tunnel. Consideration of the main tunnel element of the Pompton - Passaic Dual Inlet Tunnel Diversion Plan (without the spur tunnel and second inlet at Two Bridges) is reflected in the optimization study of the Pompton River Single Inlet Plan element previously presented. Thus data for the main tunnel optimization is available at the diameter sizes of 35, 37, 39 and 40 feet, with corresponding design capacities ranging from 18,600 to 30,000 cfs. The design frequencies associated with these scales (expressed as return interval in years) are the 50, 75, 100 and 125 year events. Economic data for the main tunnel scales are presented in Table C-69. As can be seen from this table, net benefits are maximized at the 39-foot diameter with a 100 year design capacity. The inundation reduction benefits in the Lower Valley were generally taken as the sum of the first added integral levee/floodwall benefits and the tunnel benefits in the remaining reaches. Along the Pompton River tributaries, the inundation reduction benefits were the sum of the last added

levee/floodwall benefits and the first added tunnel/channel benefits. The costs utilized in the economic analysis included the annual costs of the tunnels, channels, levees and floodwalls and the residual equivalent annual damages associated with these plan elements. These residual damages were calculated as the increase in residual equivalent annual damages at the design elevation of the levee/floodwall systems with the comprehensive plan in place compared to the without project conditions. The total project investment cost of the main tunnel is $693,300,000 and annual costs, including IDC, are $60,800,000. The main tunnel alone would accrue $67,600,000 in average annual equivalent benefits, resulting in excess benefits of $6,800,000.

Spur Tunnel. Subsequent to the optimization of the main tunnel at 39 feet in diameter, an analysis was undertaken to establish the incremental economic feasibility and optimum scale for a second tunnel inlet on the Passaic River. Cost studies demonstrated that the Two Bridges inlet and spur tunnel were more economically efficient than a Beatties Inlet with Passaic River channel modification (see Section 7 of this Appendix). Cost-benefit studies established that the tunnel's second inlet and spur tunnel are incrementally feasible for a range of diameters from approximately 10 to 26 feet (see Table C-72) and that NED excess benefits are maximized for a spur tunnel of 22 feet in diameter (see Table C-72 and Figure C-83). The details of this analysis are presented in the following paragraphs.

As discussed earlier in this Appendix, basin-wide flood events result in a three flood peak phenomena along the main stem Passaic River. For the 100 year storm under without project conditions, the first peak occurs in the Lower Valley within the first 24 hours and is caused by the urban runoff of Lower Valley tributaries in combination with coincidental Central Basin flows entering from Little Falls. The second and largest peak results from the peak flows on the Pompton River. For the 100 year event this peak occurs at hour 34 at the upper Pompton River, hour 59 at Beatties Dam in Little Falls, and at hour 61 at S.U.M. Dam in the Lower Valley. The final peak results from upper Passaic River flows that have been attenuated by Central Basin wetlands. This peak, which reaches Little Falls at about hour 98 for a 100 year storm, does not show as a distinct peak at Little Falls or the Lower Valley, but rather serves to extend the descending limb of the hydrograph for the second peak (see Figure C-19).

The Dual Inlet Plan takes advantage of the difference in timing of the flood flow peaks to make optimum use of tunnel capacity. The optimum operation is based on the upper (Pompton) inlet always having a priority to direct as much flow as possible into the main tunnel. This is because the Pompton

TABLE C-72

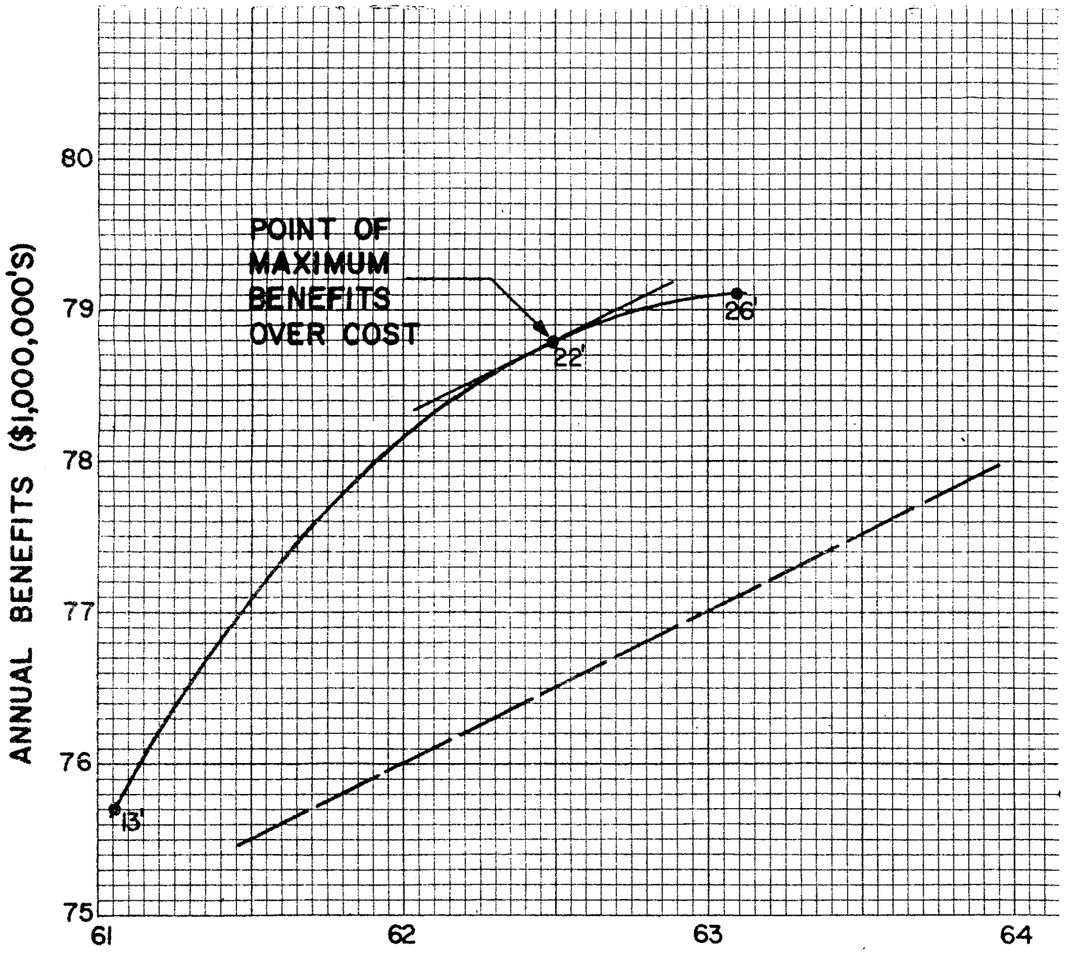
SPUR TUNNEL
OPTIMIZATION ANALYSIS
(Oct. 85 Price Level, 100 Year Project Life, 8-5/8% Interest Rate, $1,000's, Base Year 2000)

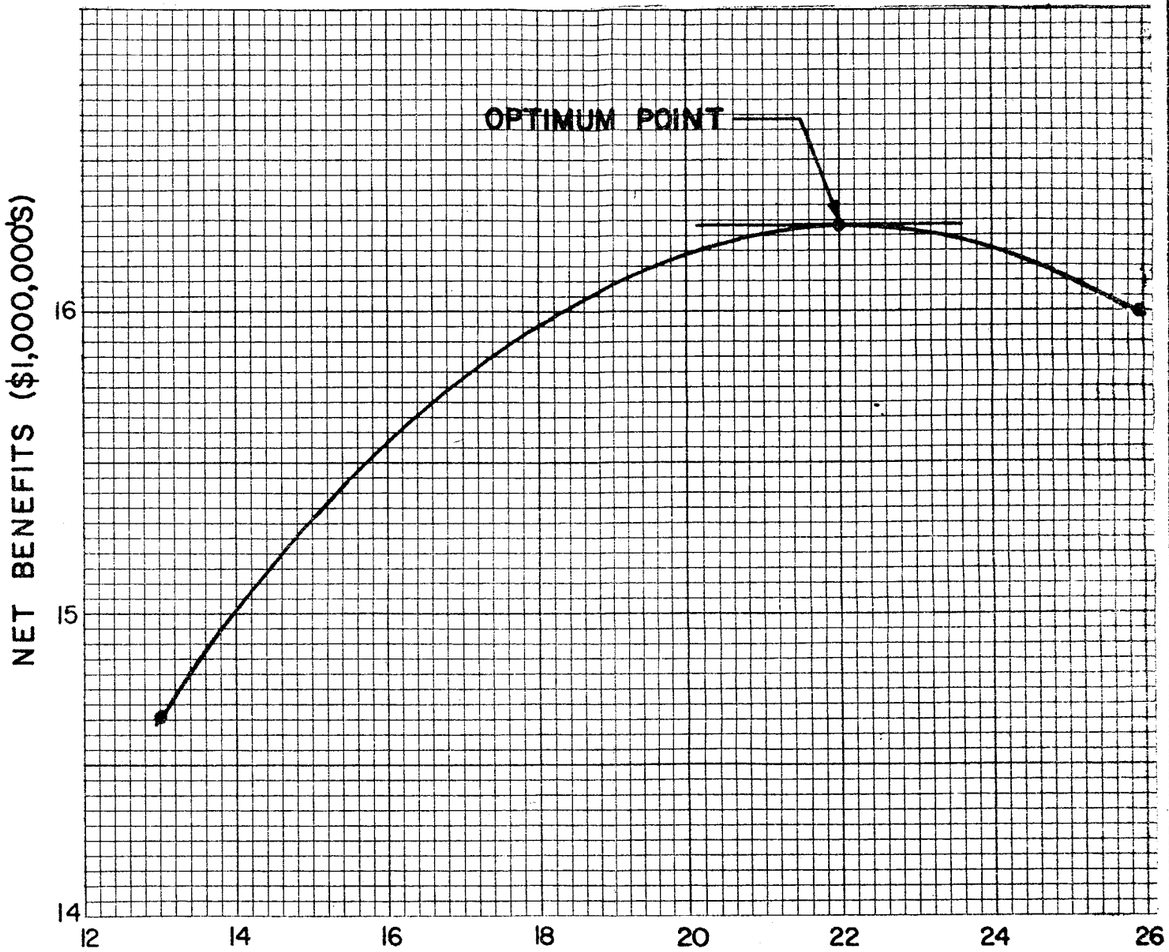
Main Tunnel Diameter	Spur Diameter	First Costs	Investment Costs	Total Annual Costs 1/	Annual Benefits Before Base Year	Annual Benefits After Base Year	Total Annual 2/ Benefits	Net Benefits
39'	13'	595,700	696,300	61,100	3,400	72,300	75,700	14,600
39'	*22'	609,800	713,000	62,500	6,500	72,300	78,800	16,300
39'	26'	618,100	720,100	63,100	6,800	72,300	79,100	16,000

* Optimum Scale.

1/ Operation and Maintenance costs are not included.

2/ Average annual equivalent benefits include inundation reduction, affluence, residential intensification, traffic flow, and FIA cost reduction.





Passaic River Study, N.J. & N.Y.

SPUR TUNNEL
OPTIMIZATION CURVE

River flows constitute the major portion of the critical flood discharges (second peak) at the basin's damage centers. This means that the Two Bridges inlet (and spur tunnel) will operate only when there is excess capacity in the tunnel over and above that needed for Pompton River flows.

Since the main tunnel design is based on the Pompton River flows, when the Pompton River is peaking (for a basin-wide event this would be over an eleven hour period from hours 29-39 for the 100 year flow) the Two Bridges inlet would not operate. Thus, excess tunnel capacity is only available for Passaic River discharges into the Two Bridges inlet prior to hour 29 and subsequent to hour 39. If the Two Bridges inlet and spur did not operate prior to hour 29, the tunnel would not have the effect of reducing the first Lower Valley flood peak and this peak would remain higher than the reduced second (dominant) Lower Valley flood peak resulting from the effective use of the Pompton Inlet. However, by using the Two Bridges inlet to divert as much flow as possible early during the storm, the coincidental Central Basin flow contribution to the first Lower Valley flood peak can be eliminated and this first peak reduced. In this way the Dual Inlet Plan can reduce both the first and second Lower Valley flood peaks.

Likewise, after the Pompton River flood peak has passed (subsequent to hour 39 for the 100 year event) the excess tunnel capacity can be used to reduce the third peak entering from the upper Passaic River. Without this later diversion of flows at the Two Bridges inlet, the third flood peak would approach but not exceed the reduced first two Lower Valley peak discharges for the full range of flood frequencies, thereby extending the peak flood duration. For flows up to the design level, the resulting reduced first two Lower Valley peak discharges would not exceed zero damage levels; so, the fact that the third peak extends this flood duration is not of concern. However, for more infrequent flows approaching the 500 year and SPS events, a reduction of the third peak would reduce the duration of Lower Valley flood peaks at damaging elevations. Therefore, the benefit of the later Passaic River diversion (subsequent to hour 39) is the reduction of the Lower Valley flood peak duration rather than the peak discharge itself (which would be controlled by the first and second peaks).

Examination of the construction schedule (see Supporting Documentation, Part IV - COST ESTIMATES) for the Pompton-Passaic Dual Inlet Tunnel Diversion Plan provides an insight into other advantages of a spur tunnel. The lower leg of the main tunnel (outlet to spur) and the spur tunnel would be operational after 50 months of construction. It would take

another 40 months to complete the rest of the project for the entire tunnel to become operational. During these 40 months, the Two Bridges inlet and spur tunnel would control the amount of water entering the main tunnel, and different size spur tunnels would accrue varying levels of benefits.

As discussed above, the spur tunnel serves three purposes. These are (1) the reduction of the Central Basin flows which contribute to the first peak in the Lower Valley until the Pompton Inlet priority operation, which results in Pompton river flows utilizing the full capacity of the main tunnel, (2) the reduction of flows arriving from the Upper Passaic River which cause the third Lower Valley flood peak, and (3) the reduction of flows entering the Lower Valley prior to the completion of the upper leg of the main tunnel. Quantifiable benefits are associated with only items (1) and (3) above, i.e., the flood damage reductions until the first and second peaks are balanced, and the damage reductions associated with the operation of the lower leg of the tunnel before the base year, prior to completion of the overall project.

A sensitivity analysis indicated that a spur tunnel diameter of 13 feet would reduce the Central Basin flow contribution to the first Lower Valley flood peak to the maximum extent, thus achieving the balancing of the first and second Lower Valley flood peaks during the operation of the Dual Inlet Plan for a basin-wide 100 year event. For the basin-wide 100 year storm, for example, all flows at Two Bridges, excepting a 100 cfs bypass, would be diverted into the spur tunnel up to hour 23. Since a spur tunnel diameter of 13 feet can handle such flows, larger spur tunnel diameters beyond 13 feet do not provide additional benefits as part of the Dual Inlet operation, as shown on Table C-72, by the fact that all three scales produce $72,300,000 in average annual equivalent benefits after the base year. Table II-9 of the Hydraulics Supporting Documentation shows the effects of the tunnel diversion on the flood flows for the duration of a flood event.

A 13-foot diameter spur tunnel would not be able to significantly reduce the third, upper Passaic peak, resulting in the Lower Valley 100 year peak discharge occurring over 100 hours in duration. A larger spur tunnel on the order of 20 to 22 feet in diameter would cut this duration to less than 20 hours. Spur tunnel sizes of 20 feet in diameter and beyond would also provide reductions in the duration of more infrequent flood events. However, although there is a real benefit to this reduction, no tangible monetary benefits could be included in the economic analysis due to limiting factors in the calculation of expected annual damages (EAD's). This is also a contributing factor to the insensitivity of the $72,300,000 in average annual

equivalent benefits for larger spur tunnel sizes. This is because the EAD model operates off stage-damage relationships and does not explicitly reflect flood durations and, therefore, cannot address urban flood control benefits for reduced flood durations of the same peak stage.

A 13-foot diameter spur tunnel would also not have the ability to divert the flow associated with a 100 year storm centered over the upper Passaic River or the Rockaway or Whippany Rivers. This could be accomplished by means of a larger diameter spur tunnel on the order of 20 to 22 feet in diameter. Therefore, a larger spur tunnel has significant operational advantages and thereby reduces the inherent risk and uncertainty in providing protection against a given flood event. Nevertheless, a spur tunnel larger than 13 feet in diameter could not be incrementally justified on NED benefits resulting from the operation of the Dual Inlet Tunnel. As a result, an analysis was undertaken to optimize the size of the spur considering not only its operation as part of the Dual Inlet Tunnel Project, but also its performance before the base year, including the computation of IDC and benefits.

Table C-72 presents the data for incremental benefits and costs for the Two Bridges inlet and various size spur tunnels. The costs include construction costs and IDC, while the benefits include both those in advance of the operation of the entire main tunnel, and those accruing over the life of the Dual Inlet Tunnel Project. Note that the benefits attributed to the operation of the entire Dual Inlet Tunnel Project ($72,300,000) are essentially the same for spur tunnel sizes greater than 13 feet in diameter. The difference in quantifiable NED benefits between the various spur sizes lies essentially in the benefits accrued before the base year. As can be seen from Table C-72 and Figure C-81, the spur tunnel is at its optimum scale at 22 feet in diameter. A spur tunnel of this size would also have the ability to safely divert flows associated with events up to a 100 year storm centered over the Rockaway or upper Passaic Rivers. In addition, it would have the effect of reducing the duration of the peak Lower Valley flows because of its capability to divert upper Passaic River peak flows, occurring late in the storm, to the main tunnel. Although neither of these reductions result in quantifiable NED benefits, they provide considerable operational advantages to the overall Dual Inlet Tunnel Project.

Tunnel Diversion Plan Element Last Added/First Added Summary. Last added/first added incremental analyses of the main and spur tunnels are summarized on Table C-73. Note that this analysis includes the surface works (channel modification, levees and floodwalls) integral to the tunnel diversion plan element. Additional discussions of these features follow this

457

TABLE C-73

FIRST ADDED/LAST ADDED ANALYSES
DUAL INLET DIVERSION TUNNEL ELEMENT

(Oct. 85 Price Level, 8-5/8% Interest Rate, 100 Year Project Life, Base Year 2000, $1,000's)

TUNNEL ELEMENT	TUNNEL DIAMETER (feet)	FIRST COSTS	INVESTMENT COSTS	ANNUAL COSTS 1/	ANNUAL BENEFITS 2/	NET BENEFITS
Dual Inlet Tunnel	39/22	609,800	713,000	62,500	78,800	16,300
Main Tunnel	39	552,400	693,300	60,800	67,600	6,800
Spur Tunnel Last Added	22	57,400	61,800	5,300	11,200	5,900

1/ Operation and maintenance costs are not included.

2/ Average annual equivalent benefits include inundation reduction, affluence, residential intensification, traffic flow, and FIA cost reduction.

section. As shown, the main tunnel was considered on a first added basis with the spur considered as a last added element to arrive at the entire Dual Inlet Tunnel Diversion plan element. An analysis which considered the spur first added and the main tunnel last added was not pursued because the spur tunnel by itself would not serve any purpose as a first added element. Likewise, first and last added analyses which consider the upper leg of the main tunnel separate from the lower leg of the main tunnel and the spur tunnel are not consistent with plan formulation principles. The upper leg of the Main tunnel as a first added element would not serve any purpose, while the lower leg in conjunction with the spur tunnel as a first added element would leave major damage areas unprotected and, as a result, flood flows would not be safely delivered to the tunnel inlet. Therefore, it is only appropriate to separately analyze the upper and lower legs of the main tunnel for the purposes of calculating interest during construction and benefits before the base year.

The Dual Inlet Tunnel Diversion plan element is economically justified on an overall basis with $16,300,000 in net NED benefits. The main tunnel portion of the Tunnel Diversion Plan element (i.e., the main tunnel without the Two Bridges inlet and spur tunnel) is economically justified on a first added basis with $6,800,000 in net NED benefits, and the spur last added to the main tunnel is economically justified with $5,900,000 in excess benefits.

Surface Works Integral To Tunnel.

a. Channel Modification. The channel modifications included in the Dual Inlet Tunnel Plan, located on the Passaic, Pompton, Pequannock, Ramapo and Wanaque Rivers upstream of the tunnel inlets, were scaled to safely deliver flows to the tunnel inlets based on the design level of the tunnel. A strict incremental analysis of these channels is not consistent with plan formulation principles because: (1) these measures are necessary for the diversion tunnel to function; (2) their scales are controlled by the design level of the tunnel; and (3) these features could not be implemented independently from the tunnel project.

Since these channel reaches are within the tunnel backwater, the hydraulic design of the channels is dictated by the design of the inlets. Furthermore, the top widths of the modified channels are limited in most areas by the presence of structures along the riverbanks. The channels are sized to the minimum scale required to direct flows into the tunnel while preventing flood stages from increasing as compared to the without project condition. Except for the Passaic and Pompton Rivers transition

channels to the Two Bridges Inlet, design flows could not be safely conveyed in modified channels. The channels along the Pequannock, Ramapo and Wanaque Rivers were therefore designed in conjunction with levees and floodwalls to deliver design flows to the Pompton Inlet.

Enlarging the channel capacities even further would not eliminate the need for the levee/floodwalls since the flood stages are controlled by the tunnel backwater. Minimizing the extent of channel work along the Pompton tributaries is a fish and wildlife concern and this desire was also reflected in the design.

b. Levees/Floodwalls. Table C-74 presents economic data for those levee/floodwall systems which are integral to the diversion tunnel plan element and are necessary components for the operation of the tunnel. These systems fall into two categories: (1) the Pompton tributaries systems which, in conjunction with channel modification along the Ramapo, Pequannock and Wanaque Rivers, direct the floodwaters to the Pompton Inlet of the main tunnel; and (2) the Lower Valley systems at the tunnel outlet which safely contain flows exiting from the tunnel.

All of the integral systems were included in the Pompton-Passaic Dual Inlet Tunnel Plan at the 100 year design scale of the tunnel plan element, since the elimination of these systems would either result in the tunnel not being able to function as designed (Pompton tributary systems) or would result in the inducement of a significant and unacceptable flood hazard at the tunnel outlet area. Phase II studies will consider the feasibility of increasing the level of protection beyond the 100 year event. For each system, first added and last added incremental feasibility analyses were performed. The levee/floodwall systems were examined separately from the interior flood control facilities. The effects of the integral levee/floodwall systems on preventing flood damages induced by the tunnel operation as well as the additional benefits from preventing tidal and fluvial flooding are presented on a reach basis in Section 10, Table C-91. The first added levee/floodwall benefits were calculated using without project conditions stage-frequency data, while the last added benefits were calculated utilizing the with tunnel stage-frequency data. In each case the benefits were computed as the difference between the total equivalent annual damages and the residual equivalent annual damages at the elevation of the levee. The benefits were then compared to the annual cost of the levee/floodwall system. In general, economic feasibility varied widely for each system based only on the individual areas each levee/floodwall protected.

TABLE C-74
ECONOMIC DATA FOR LEVEE/FLOODWALL SYSTEMS
INTEGRAL TO DUAL INLET TUNNEL PLAN
(Oct. 1985 Price Levels, 8-5/8% Interest Rate,
100 Year Project Life, Base Year 2000, $1000's)

System 1/	Net Benefits First Added	Net Benefits Last Added
LOWER VALLEY		
River Rd. #1	-134.25	-24.85
Main St.	340.65	1,027.25
River Rd. #2	-618.80	-397.00
Riverside Ave. #1	-368.69	269.81
Riverside Ave. #2	-552.95	-256.65
Yantacaw	160.18	709.08
River Drive #1	-282.54	-277.84
River St. - Main Ave.	366.77	879.17
8th Street	-84.40	-193.80
POMPTON TRIBUTARIES		
Pequannock-Ramapo	2,955.48	-141.18
Shore Road	10.44	-207.18
Stiles Court	-20.00	-20.00
Hill Court	-30.00	-30.00
Wanaque Avenue	-95.00	-95.00

1/ All systems provide a 100 year level of protection

The integral Pompton Valley levee/floodwall systems were generally more economically feasible when evaluated on a first added basis rather than on a last added basis. The tunnel and channel modifications upstream of the inlet would reduce the water surface elevations in the vicinity of these systems. Therefore, on a last added basis, the levee/floodwall systems would provide less average annual equivalent benefits. For the integral Lower Valley levee/floodwall systems, the opposite relationship is evident; these systems were more economically feasible when evaluated on a last added basis compared to a first added basis. The tunnel discharge, which outlets in the vicinity of these levees and floodwalls, would cause higher water surface elevations under with project conditions than under without project conditions. Therefore, on a last added basis, the levee/floodwall systems would eliminate more average annual equivalent damages.

Levees/Floodwalls Incremental To Tunnel. Levees and floodwalls were considered on an incremental basis for the tidal reach of the Lower Valley and the Central Basin area upstream of Two Bridges. No levees and floodwalls were found economically feasible on a last added basis for the Pompton River Valley or the Passaic River reach between Two Bridges and Dundee Dam. For these latter reaches the diversion tunnel plan element provides significant flood damage reduction, resulting in no additional protection being needed.

Each independent levee/floodwall system was considered at three scales of development and economic costs and benefits were computed. Of the three scales evaluated, the one with the greatest excess benefits was identified as the approximate NED scale. Phase II GDM studies will focus on refining the optimum levee scales.

The levee/floodwall systems were evaluated separately from the interior flood control facilities. Therefore, the costs and benefits presented in the optimization of levees reflect protection against exterior flooding with the incorporation of minimum facilities for interior drainage. The formulation and evaluation of flood loss reduction measures for interior areas are presented in the Hydraulics Supporting Documentation. The planning procedures and level of detail employed for the analysis of the interior areas are compatible with those for the exterior levee/floodwall systems. However, no benefits were included in the project analysis for the interior flood control protection. The economic optimization of interior facilities will be accomplished as part of the Phase II GDM design.

Table C-75 presents the results of the levee/floodwall optimization studies. As can be seen from this data, the optimum scale for the systems in the Lower Valley reach that are under control of tidal flooding is at the 500 year level of protection, while excess benefits are maximized for the Central Basin levee/floodwall systems at scales ranging from the 100 year to 500 year levels of protection. It is noted that for many of the Central Basin systems the net benefits of the 100 year and 500 year scales are relatively close. Therefore, levels of protection between the 100 year and the 500 year will be carefully evaluated during Phase II studies in order to identify the optimum scale. Tidal and fluvial levee/floodwall systems were included in the Pompton-Passaic Dual Inlet Tunnel Plan at the scales presented in Table C-75. All such systems included in the plan are economically feasible, except for one system along the Rockaway River. This system has been included in the plan at the 100 year scale at the request of the State of New Jersey, the non-Federal sponsor, and is required for an implementable NED plan.

Preservation of Natural Storage. The purpose of this measure is to prevent future increases in damage resulting from loss of flood storage and thereby maintain the design level of the other plan elements over the project life. The preservation plan element was analyzed to determine its optimum scale of development on a first added basis (without the Dual Inlet Tunnel Plan), and its justification with the Dual Inlet Plan was confirmed. The timing for implementation was also examined from a NED viewpoint.

The initial step in the analysis involved projecting what storage areas are likely to be developed, at what rate they would be lost, and the resulting impact on expected annual damages. As previously described in Section 2 - Without Project Conditions, it is expected that natural storage areas will be lost at a rate of approximately 70 acres per year, with 430 acres filled (960 acres developed) between 1984 and 1990, and up to 3,870 acres filled (8,620 acres developed) by the year 2040. Note that, based on the 1978 baseline conditions, a total of 1,630 acres of natural storage would be filled between 1978 and 1990.

The potential impacts of preventing the loss of various portions of the unprotected 8,620 acres were tested by translating each level of development into the corresponding extent of fill that developers would be allowed to place in accordance with NJDEP Flood Hazard Area Regulations. The method of analysis is described in Section 5 - BUILDING BLOCK 20. The resulting impacts of such potential flood storage losses were translated into incremental increases in surface runoff, stream flow, water surface elevations and flood damages.

TABLE C-75
DUAL INLET TUNNEL PLAN SEPARABLE ELEMENTS
INCREMENTAL DEGREE OF PROTECTION
TIDAL AND FLUVIAL LEVEE/FLOODWALL SYSTEMS
(Oct. 85 Price Level, 8 5/8% Interest Rate, 100 Year Project Life, Base Year 2000)

LEVEE/FLOODWALL SYSTEM	Last Added Net Benefits ($1,000's) 50yr	100yr	500yr	Recommended Level of Protection	First Added Net Benefits of Recommended Scale ($1,000's)
LOWER VALLEY-TIDAL					
Kearny Point	250	560	720	500yr	720
Lister Ave.	2,580	2,820	3,090	500yr	3,090
N.J. Turnpike	2,280	2,480	2,680	500yr	2,680
Doremus Ave.	2,070	2,260	2,450	500yr	2,450
South 1st.	430	460	580	500yr	580
CENTRAL BASIN-FLUVIAL					
Passaic #2A	3,600	3,790	3,760	100yr	8,080
Passaic #2C	220	260	250	100yr	820
Passaic #10	70	80	50	100yr	110
Rockaway #1	165	210	195	100yr	320
Rockaway #2	-60	-55	-115	100yr	-50
Rockaway #3	130	250	105	100yr	260
Pinch Brook	1,060	1,180	1,310	500yr	1,310

The levels of future development were analyzed by staging fill encroachments from the outward fringe of the natural storage areas for the desired level to be treated. Although the incremental testing of individual wetlands was cost prohibitive, the analysis indicated that 5,350 acres of the developable natural flood storage areas in Great Piece, Bog and Vly, Troy and Black Meadows, Hatfield Swamp, Canoe Brook and Lower Pompton wetlands provided the more significant portion of the flood storage due to their location and topography. As previously discussed in Section 5 and presented in Table C-50, the preservation of the identified 5,350 acres (which is 62% of the 8,620 acres that remain unprotected) would result in maintaining over 80% of the 100 year flood storage that would otherwise be lost under 2040 conditions. The other 3,270 acres of unprotected natural storage areas, including Passaic Main Stem areas upstream of Chatham and numerous intermittent and fragmented wetlands throughout the Central Basin, did not provide sufficient storage and flood damage reduction benefits to justify a Federal interest.

Real estate studies were performed to determine the cost of protecting natural storage areas through either "in fee" acquisition or permanent easement. Studies revealed that in these areas the land use restriction associated with flood storage easements precluded real estate utility to the extent that the easement cost approached the price of "in fee" acquisition. In addition, the management of these lands would be facilitated by acquisition "in fee." Therefore, the basis for cost studies is "in fee" acquisition of the lands.

The results of this analysis were compiled into relationships of annual costs versus acres acquired, and annual benefits versus acres protected (see Figures C-84 and C-85), which were translated to a net benefit versus acres preserved relationship as shown by Figure C-86. Surface acres were utilized in the optimization of the preservation of natural storage plan element because the aim of the analysis was to identify not only the economically optimum level of flood storage to be preserved, but also the location of such storage. The complexity of the interrelationships between the various routing reaches in the Passaic River Central Basin, compounded by the flow reversal phenomena at the confluences of the Passaic and Pompton Rivers, and Rockaway and Whippany Rivers, resulted in the need to identify one acquisition sequence to serve as the basis for the cost versus acres acquired and benefit versus acres acquired relationships. Determining the impact of first acquiring the areas providing the greatest flood storage versus buying those areas under the most development potential pressure was beyond

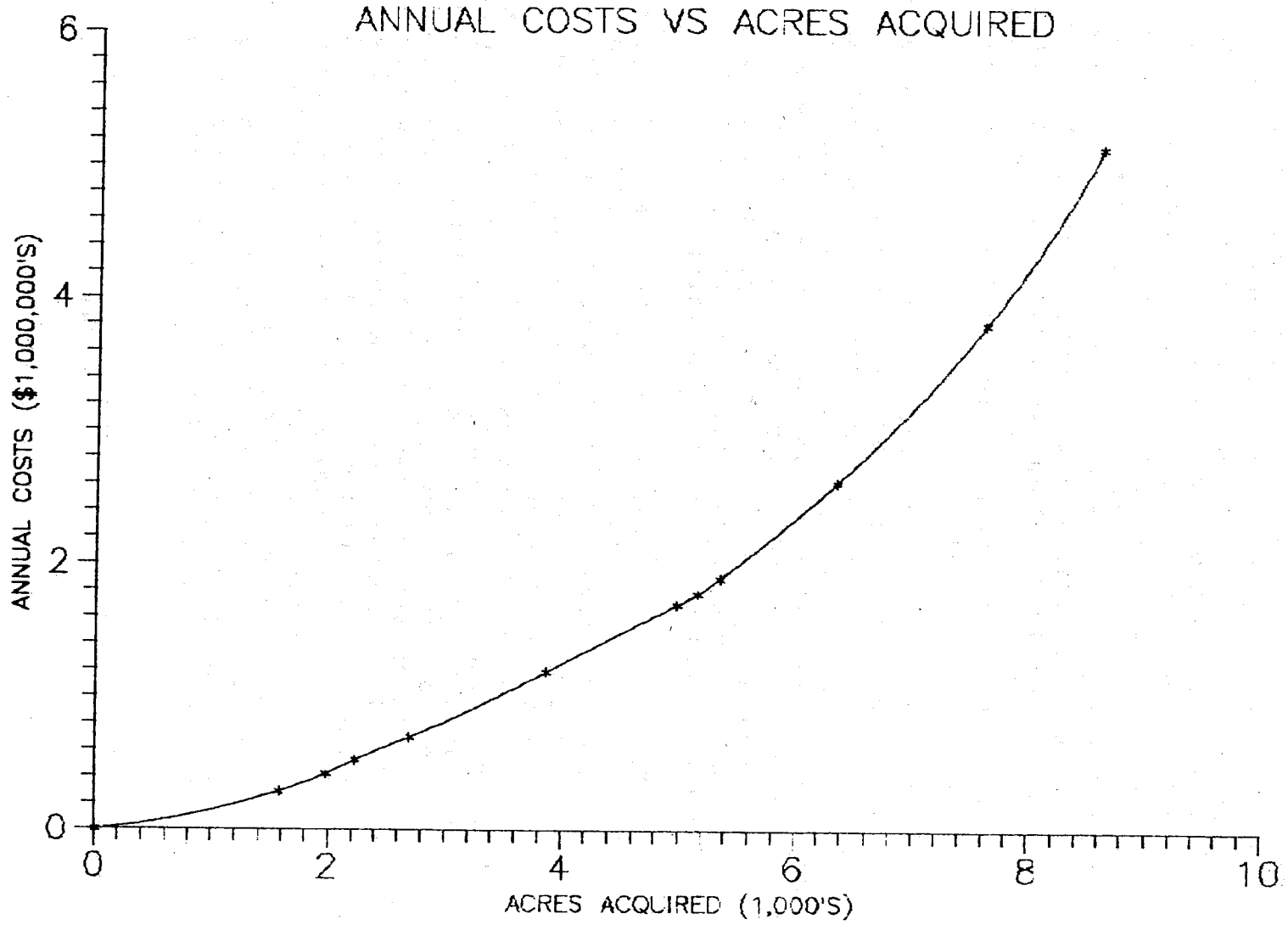

ANNUAL COSTS VS ACRES ACQUIRED
ANNUAL COSTS ($1,000,000'S)
0
2
4
6
0
2
4
6
8
10
ACRES ACQUIRED (1,000'S)

FIGURE C-84

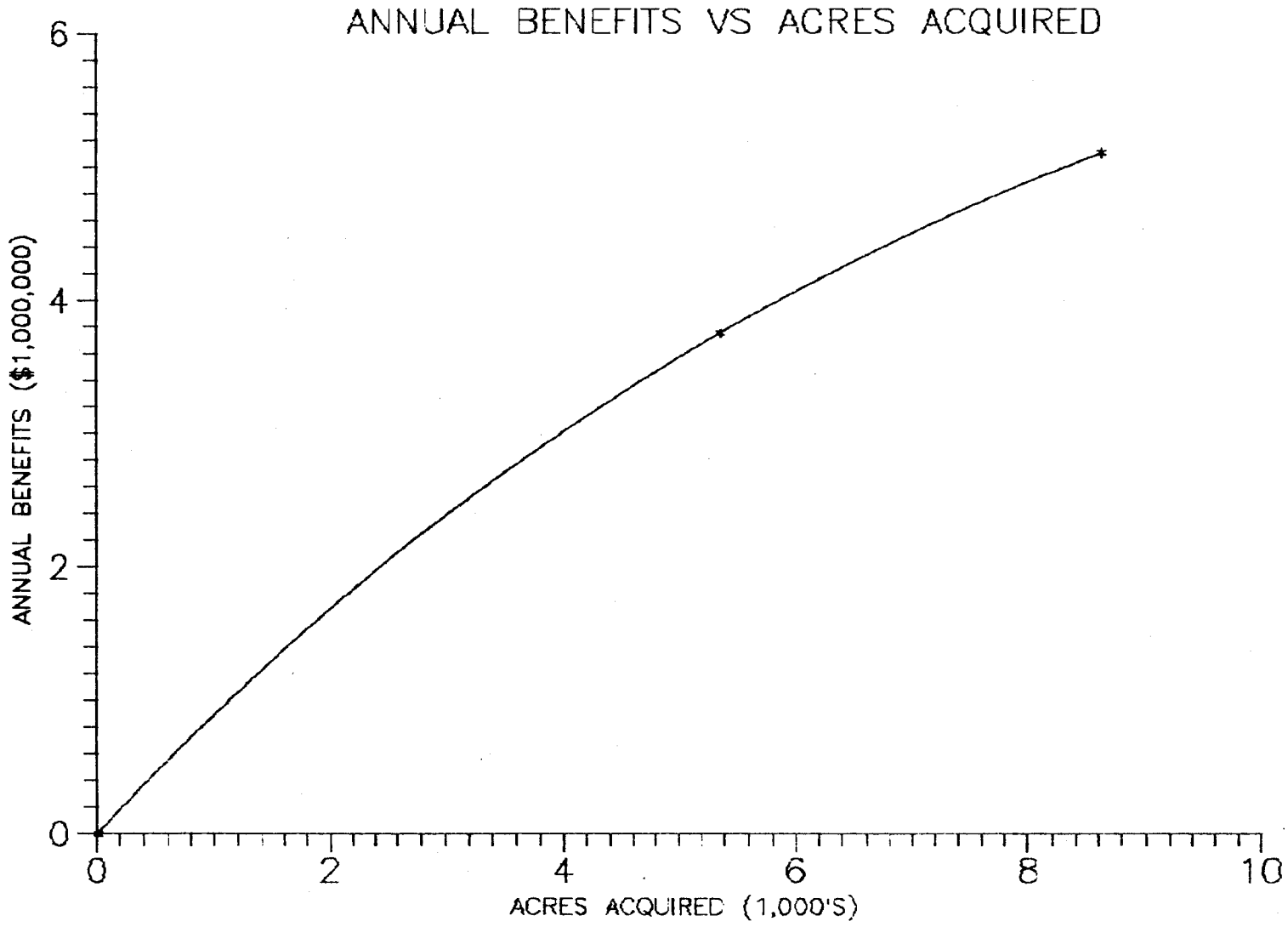

ANNUAL BENEFITS VS ACRES ACQUIRED
ANNUAL BENEFITS ($1,000,000)
0
2
4
6
0
2
4
6
8
10
ACRES ACQUIRED (1,000'S)

FIGURE C-85

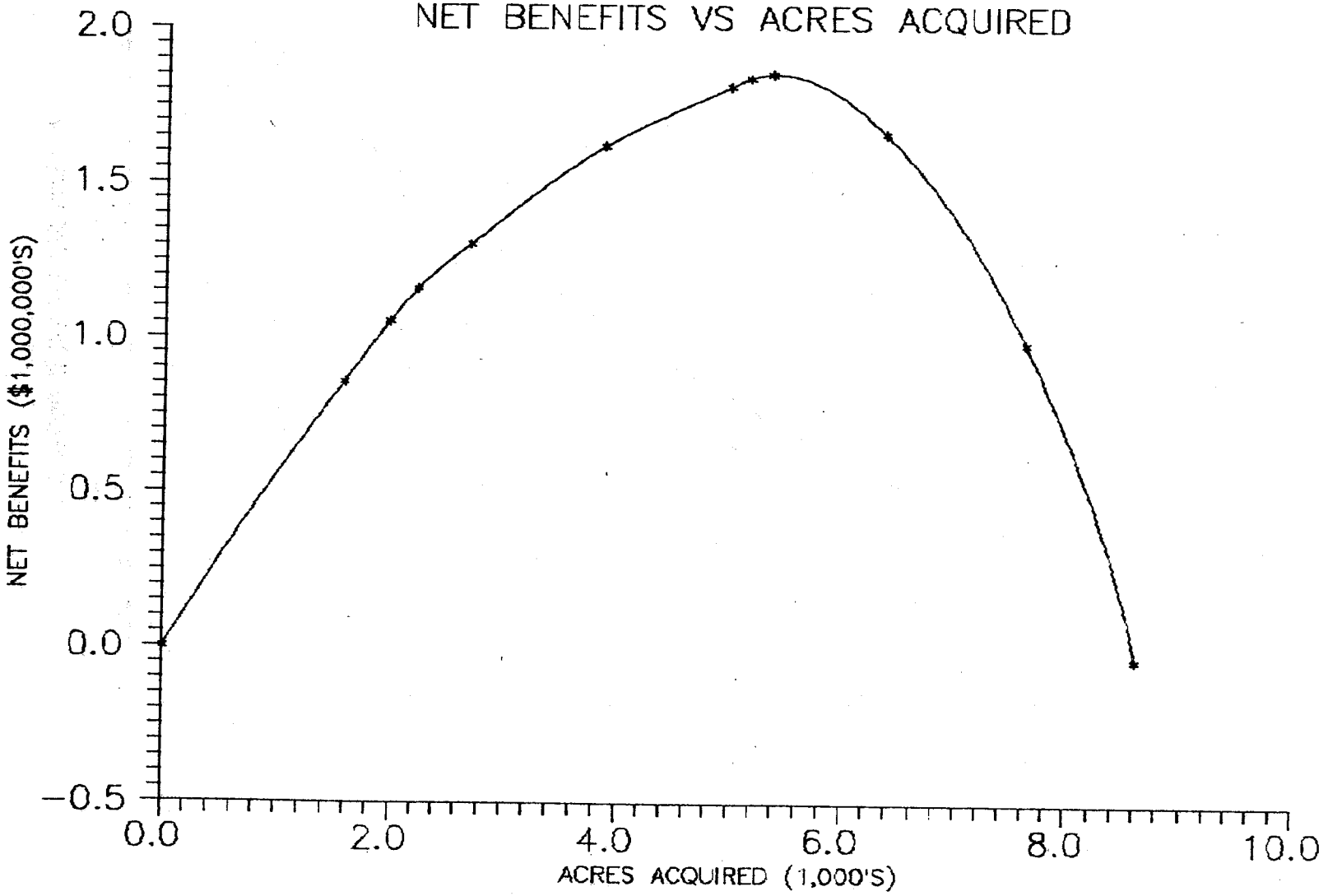

NET BENEFITS VS ACRES ACQUIRED
NET BENEFITS ($1,000,000'S)
2.0
1.5
1.0
0.5
0.0
-0.5
0.0
2.0
4.0
6.0
8.0
10.0
ACRES ACQUIRED (1,000'S)

FIGURE C-86

the scope of the available planning models. The sequence of first acquiring the land which generally is the most inexpensive proved to be the most practical since these lands also generally provided the most flood storage (i.e., lands currently flooded to the greatest depths).

The cost relationship reflects the impact that the flood hazard, access and zoning have on land value. It was anticipated that land closer to the river which is the least accessible and most prone to flooding would be worth the least, with increasing real estate prices proceeding outward from the floodway. Although this was found to be the general rule within an individual community, it was found that the municipality in which the lands lie and, more significantly, the zoning for the property are the predominant factors in determining land values. Real estate costs were found to increase more definitively at the flood fringe and at areas already developed with the ready availability of utility and transportation services.

The benefits derived from this plan element consist of the reduction in future flood damages resulting from the prevention of the loss of natural flood storage. Affluence benefits were not quantified, since the plan relies on benefits accrued as a result of prevented future increases in damages instead of eliminating existing damages. Traffic delay benefits, recreational benefits, reduction in future floodproofing costs and a reduction in flood insurance administration costs, although quantifiable, are not incorporated into the analysis since they are not considered significant. Environmental quality benefits are acknowledged and are especially significant as a result of the proposed project; however, these benefits, though qualitatively discussed (see discussion of environmental effects in Section 10 of this Appendix and in the Environmental Impact Statement in the Main Report), were not quantified and were, therefore, not used in the economic analysis. Intensification benefits, location benefits, NED employment benefits and advance bridge or roadway replacement benefits were not applicable to the evaluation.

The benefit relationship demonstrates the flood storage value of the aforementioned natural storage areas. The topography of the Central Basin wetlands is extremely flat, with the result that there is not a significant variance in flood depths or flood storage for approximately 6,000 acres of the unprotected natural storage, including those areas recommended for acquisition. The natural storage areas lying upstream of Chatham are inundated to lessen depths and provide less storage, as reflected in Section 5 findings previously discussed (see Table C-50). Areas lying

closest to the floodways tend to provide more storage than the fringe areas. The benefit relationship utilized reflects such factors, and is representative of the acquisition sequence utilized in the cost versus acquisition relationship presented in Figure C-84.

Net benefits are optimized at 5,350 acres, as shown in Figure C-86 and Table C-76. This is the level of preservation included in the Dual Inlet Plan. A criteria in the decision of what lands to include was that areas which were contiguous to other (protected or proposed) natural storage areas would be a high priority. Intermittent, fragmented, or relatively small areas of natural storage were not given a high priority for protection compared to the major wetland areas. In this sense, the acres acquired axis for Figure C-86 does not consist of a continuous function, but rather is made up of discrete groups of wetland areas. First and most important, by ensuring that large, contiguous tracts remain undeveloped, the greatest amount of storage would be preserved. It would also preserve significant tracts of wildlife habitat, help protect more sensitive species, maintain a buffer against non-point sources of pollution, and be far easier to manage.

The benefits derived from the preservation of natural storage areas were evaluated by comparing the with and without preservation conditions. The base year for this analysis is 1990, rather than the base year of 2000 for the remainder of the Dual Inlet Plan. The base year of 1990 was identified based on a sensitivity analysis of the timing of implementing the preservation element. This analysis, summarized in Table C-77, highlighted the importance of immediate action regarding land acquisition. Based on the estimated rate of filling for the without project condition, 350 acres of natural storage out of a possible 5,350 acres would be filled (800 acres developed) by 1995 and 700 acres filled (1,600 acres developed) by 2000. Although it can not be projected exactly where this filling and development would occur within the available 8,620 acres of natural storage, it is likely that some, and possibly all, of this filling and development would occur within the 5,350 acres designated for acquisition. Therefore, by delaying acquisition of the critical natural flood storage areas past the year 1990, there would be less of these areas available for preservation with a corresponding decrease in benefits. This analysis clearly demonstrated that more immediate implementation of the protection of natural storage would maximize net benefits and minimize the future increases in the flood hazard.

TABLE C-76
PRESERVATION OF NATURAL STORAGE
INCREMENTAL DEGREE OF PROTECTION
FIRST ADDED ANALYSIS WITHOUT DUAL INLET TUNNEL PLAN

(Oct 86 Price Level, 8-5/8% Interest Rate, 100 Year Project Life, Base Year 1990)

Acres Proctected	First cost ($)	Annual Cost($)	Annual Benefits($) 1/	Net Benefits($)
1,000	2,086,000	180,000	730,000	550,000
2,000	4,926,000	425,000	1,490,000	1,065,000
3,000	9,563,000	825,000	2,200,000	1,375,000
4,000	14,489,000	1,250,000	2,890,000	1,640,000
5,000	19,763,000	1,705,000	3,520,000	1,815,000
5,350*	22,000,000	1,898,000	3,750,000	1,852,000
6,000	27,355,000	2,360,000	4,090,000	1,730,000
7,000	37,324,000	3,220,000	4,540,000	1,320,000
8,000	49,958,000	4,310,000	4,900,000	590,000
8,620	59,463,000	5,132,000	5,100,000	-32,000

* Optimum Scale
1/ Annual benfits do not include municipal benefits.

TABLE C-77 CENTRAL BASIN
NATURAL STORAGE IMPLEMENTATION
TIMING SENSITIVITY
(OCT. 86 PRICE LEVEL, 8-5/8% INTEREST RATE, 100 YEAR PROJECT LIFE)

Year		Without Preservation	With Preservation Base Year 1990	Base Year 1995	Base Year 2000
1990	Acres Filled	0	0	0	0
	Acres Developed	0	0	0	0
	Acres Preserved	0	5,350	0	0
1995	Acres Filled	350	0	350	350
	Acres Developed	800	0	800	800
	Acres Preserved	0	5,350	4,550	0
2000	Acres Filled	700	0	350	700
	Acres Developed	1,600	0	800	1,600
	Acres Preserved	0	5,350	4,550	3,750
2040	Acres Filled	2,410	0	350	700
	Acres Developed	5,350	0	800	1,600
	Acres Preserved	0	5,350	4,550	3,750
	Annual Benefits ($)	-	3,750,000	2,156,000	1,194,000
	Annual Costs ($)	-	1,898,000	1,500,000	1,140,000
	Net Benefits ($)	-	1,852,000	656,000	54,000
	B/C Ratio	-	1.98	1.4	1.05

Benefit and cost data for the economic analyses of preserving natural flood storage with and without the remaining elements of the Dual Inlet Tunnel Plan are presented in Table C-78. Both analyses reflect acquiring 5,350 acres of natural storage by the year 1990. Based on the sensitivity analysis results of the timing of implementing preservation, a 1990 implementation date would maximize net benefits and minimize future increases in flood damages.

In Table C-78, data for analysis of the preservation element without the tunnel element are presented under both 1990 and 2000 base year scenarios. The base year 2000 data for preservation without the tunnel allows for a direct comparison with the data for the preservation with the tunnel analysis. Since the structural elements of the comprehensive Dual Inlet Tunnel Plan would not be fully operational until the year 2000, the benefits generated by the preservation element between 1990 and 2000 are the same for both the with and without Dual Inlet Tunnel analyses. The difference between the preservation benefits presented in Table C-78 without the tunnel element ($8,770,000) versus with the tunnel element ($3,170,000) occurs after the year 2000 when the tunnel project element would become operational. The data indicate that preservation of natural flood storage areas is economically feasible with or without implementation of the remaining elements of the Dual Inlet Tunnel Diversion Plan. The preservation benefits with the Dual Inlet Tunnel Plan ($3,170,000) were utilized in determining the overall benefits for the comprehensive plan.

With the diversion plan in place, the preservation of natural flood storage serves to maintain the level of protection of the project over its life. If such natural storage was not preserved, the design level of the project would diminish and the benefits realized would be reduced. As shown on the improved conditions profiles in the Supporting Documentation, Part II - Hydraulics, the range in Central Basin water surface elevations for flood events between the 10 year and the 100 year is limited. Therefore, the design levels of the Central Basin levees are sensitive to changes in the stage-frequency relationship. Without preservation, the peak flow from the Central Passaic River would arrive at Two Bridges earlier in the storm and would have a greater magnitude than under the with preservation condition. Therefore, the water surface elevations would be higher in the Central Basin. As a result, the 100 year design level of the majority of the Central Basin levees would be reduced to a level varying between a 25-year and a 50-year event without the preservation of natural storage. In addition, since more water would arrive at the spur tunnel inlet, the discharges entering the Lower Valley would be greater, also resulting in higher water surface elevations in the Lower Valley in the vicinity of the tunnel outlet.

TABLE C-78

PRESERVATION OF NATURAL STORAGE
ANALYSES WITH AND WITHOUT DUAL INLET TUNNEL PLAN
(Oct. 86 Price Level, 8-5/8% Interest Rate,
100 Year Project Life)

	WITHOUT TUNNEL		WITH TUNNEL
	BASE YEAR 1990	BASE YEAR 2000	BASE YEAR 2000
ACRES PROTECTED	5,350	5,350	5,350
FIRST COST ($)	22,000,000	22,000,000	22,000,000
ANNUAL COSTS ($)	1,898,000	1,898,000	1,898,000
ANNUAL BENEFITS ($)	3,750,000	8,770,000	3,170,000
NET BENEFITS ($)	1,852,000	6,872,000	1,272,000
INCREMENTAL B/C RATIO	1.98	4.6	1.7

The alternative to preserving natural storage areas in order to maintain the design level of the project consists of increasing the extent and height of levee/floodwall systems in the Central Basin and in the vicinity of the tunnel outlet. This structural alternative would cost $33,300,000, an increase of $11,300,000 over the cost of preserving natural storage areas. This analysis confirms that the early implementation of natural storage preservation is warranted when analyzed in conjunction with the implementation of the Dual Inlet Project. However, it is recognized that the number of acres recommended for acquisition may change during future studies upon determination of the effect of New Jersey's new Freshwater Wetlands Protection Act on the without project conditions.

Fish and Wildlife Mitigation. Three separable fish and wildlife mitigation measures have been included in the Pompton-Passaic Dual Inlet Tunnel Plan: (1) instream habitat structures for mitigation of aquatic habitat losses; (2) wetland reclamation and planting for mitigation of wetland losses; (3) nest boxes for the mitigation of terrestrial habitat losses. A full description of these measures is included in Section 10 of this Appendix. Each of these measures was fully coordinated with the U.S. Fish and Wildlife Service and NJDEP Division of Fish and Game. The measures were included in the plan to the extent each was incrementally justified. This analysis took both monetary and nonmonetary values into account in accordance with EC 1105-2-50, Change 3, dated 1 August 1984. The incremental justification of these measures is presented in Section 9, Appendix B - Natural Resources. Numerous other measures which fall into the category of standard engineering practice were also incorporated into the plan to accommodate fish and wildlife resources. These measures are also presented in Section 10 of this Appendix.

Nonstructural Measures. Studies found that the last added inclusion of nonstructural measures to the Dual Inlet Plan at areas not receiving full protection from either the tunnel or levees and floodwalls against the 100 year design flood is not incrementally feasible on a reach basis, although buyout of a limited number of structures may be feasible when considered on an individual basis. However, this would be more appropriately treated as an interim project, as authorized in Section 1148 of the Water Resources Development Act of 1986 (PL 99-662). Furthermore, nonstructural measures were not found to be as economically efficient as levees and floodwalls at those areas for which levee/floodwall local protection measures were

incrementally feasible. No further consideration was given to nonstructural measures on a reach basis for flood damage reduction, although a limited number of structures were further considered for permanent evacuation as part of fish and wildlife mitigation.

The construction of a weir at the downstream terminus of the Great Piece Meadows to allow for maintenance of existing wetland habitat requires the removal of structures on Camp Lane in Fairfield. It is projected that these structures will be acquired by other agencies prior to construction of the weir. If these structures are not purchased and removed by others, it would be necessary to include their acquisition in the Dual Inlet Tunnel Plan.

SECTION 9 - EVALUATION AND COMPARISON OF DETAILED STAGE ALTERNATIVES

GENERAL

Based on the detailed planning stage studies described in Sections 7 and 8 of this Appendix, Plans 16A, 30A and 30E were refined to be more economically efficient and responsive to the problem and opportunity statements. The final iteration of these plans, which reflects the screening and optimization analyses, is described in the following paragraphs:

PLAN 30E

Plan 30E, the Pompton River/Passaic River Dual Inlet Tunnel Diversion Plan, is the NED plan and was selected as the preferred plan by the State of New Jersey. This plan would take 90 months to construct.

The key feature of this plan is a 13.5 mile-long, 39-foot diameter tunnel from the Pompton River down to the lower Passaic River. The upper tunnel inlet and diversion works would be located in Wayne on the upper Pompton River below its confluence with the Pequannock, Wanaque and Ramapo Rivers. A second inlet would be provided by means of a 1.2 mile long, 22-foot diameter spur tunnel from Two Bridges to the main tunnel. The tunnel would divert floodwaters from the upper Pompton River and from the central Passaic River area to an outlet near the Third River/Passaic River confluence at the Clifton-Nutley border.

The crown of the underground tunnel would be about 125 feet below grade level at the Pompton River Inlet, about 130 feet below the Passaic River Inlet, and about 155 feet below the outlet. The intersection of the main and spur tunnels would be about 150 feet below ground level. At its deepest point, under the Watchung Mountains in the area of the Little Falls-Clifton border, the tunnel would be 450 feet underground.

This plan, which is illustrated in Figure C-87, was developed to make more efficient use of the Pompton Tunnel with the expectation that flows could be further reduced by a second inlet at Two Bridges, while operating the tunnel with a priority diversion at the Pompton River inlet. The double inlet takes advantage of the difference in timing, approximately 2 days, of the flood flow peaks to make more effective use of the tunnel. The objective is to direct as much flow as possible into the Pompton River inlet and then, if the tunnel flow is operating at a level less than capacity, allow additional flow to enter the tunnel at Two Bridges by manipulating gates in the Two Bridges gated diversion spillway. The diversion tunnels and associated surface works are designed to protect against a 100 year flood event.

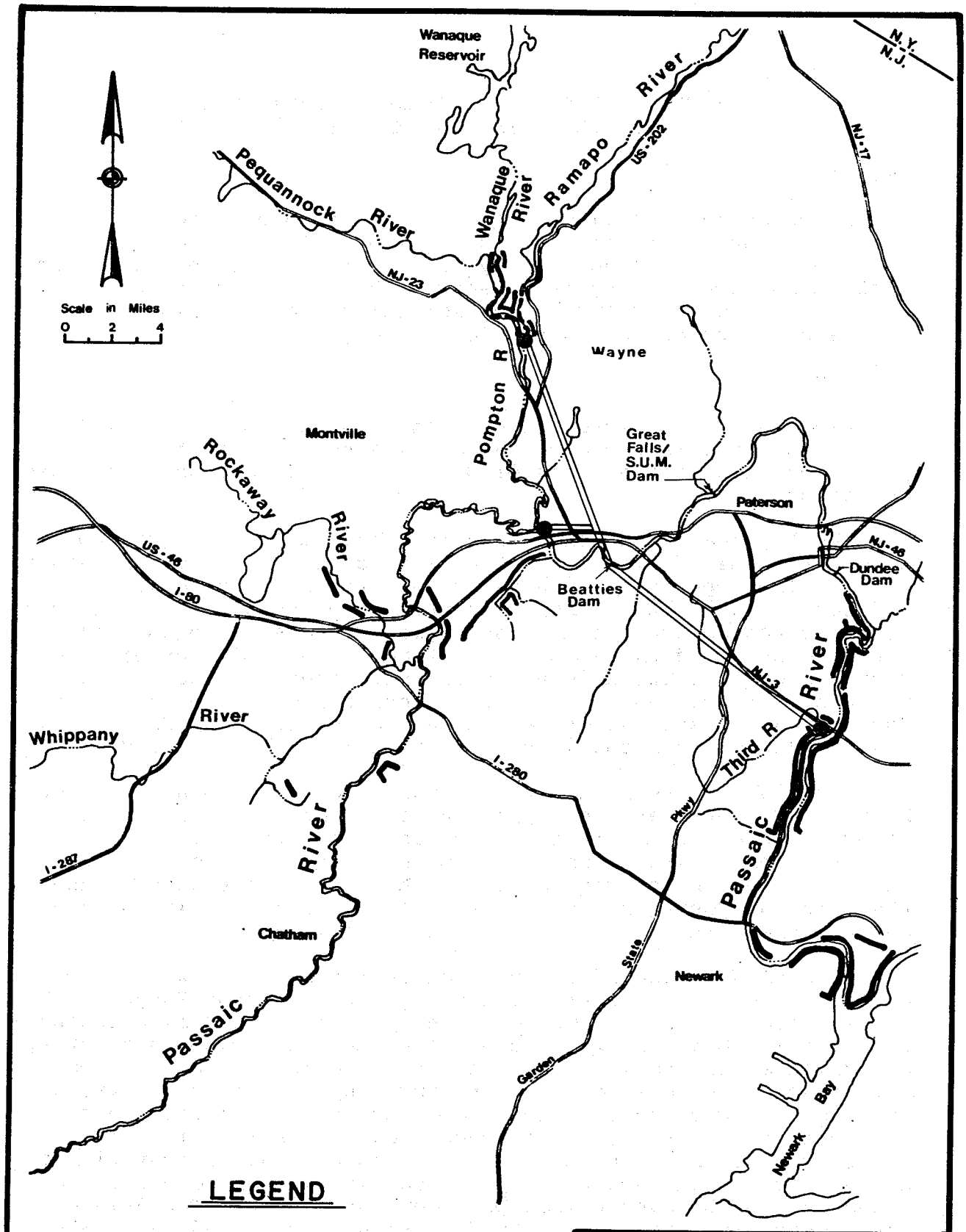

Wanaque Reservoir
N.Y.
N.J.
Pequannock River
Wanaque River
Ramapo River
US-202
NJ-17
NJ-23
Scale in Miles
0 2 4
Wayne
Pompton R
Montville
Great Falls/ S.U.M. Dam
Rockaway River
Paterson
US-46
I-80
NJ-46
Dundee Dam
Beatties Dam
NJ-3
Passaic River
Whippany River
I-280
Third R
Pkwy
I-287
Passaic River
Chatham
State
Newark
Garden
Newark Bay
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
DIVERSION TUNNEL
Passaic River Study N.J. & N.Y.
DETAILED
PLAN 30 E
POMPTON-PASSAIC RIVERS DUAL
INLET TUNNEL DIVERSION

FIGURE C-87

In addition to the main and spur tunnels, this plan includes 5.9 miles of channel modification and 26 levee/floodwall systems consisting of 23.7 miles of levees and 14.0 miles of floodwall. The physical features of these plan elements are summarized in Tables C-79 and C-80. Of the 5.9 miles of channel modification, 4.8 miles would be required upstream of the Pompton Inlet to direct floodflows into the tunnel, and to protect upstream areas. The Pequannock, Wanaque and Ramapo Rivers would be deepened an average of 7 feet, 6 feet, and 4 feet, respectively. The remaining 1.1 miles of channel modification would occur along the Passaic River and lower Pompton River. The Passaic River channel would be deepened for a total of 0.8 miles, extending from upstream of Two Bridges to the Route 46 crossing to divert flood flows into the spur tunnel. A transition channel would extend along the Pompton River from Two Bridges upstream for 0.3 miles.

No other structural remedies would be needed along the Pompton River or along the Passaic River between the Two Bridges inlet and Dundee Dam, because the tunnels would divert flood flows away from these areas.

Levees and floodwalls along the Pompton River tributaries include 3.5 miles of levees and 0.7 miles of floodwalls which are integral to the design of the Pompton Inlet and provide 100 year flood protection along the Ramapo, Wanaque and Pequannock Rivers.

The 37.7 miles of levees and floodwalls also include flood protection in the Central Basin upstream of Two Bridges along the Main Stem Passaic and Rockaway Rivers and Deepavaal and Pinch Brooks. Protection against floods, ranging from a 100 year up to a 500 year event, would be provided intermittently where needed by 9.0 miles of setback levees and 0.5 miles of floodwall.

Within the Lower Valley from the Saddle River down to Newark Bay, the plan calls for 14 levee/floodwall systems including about 11.2 miles of levees and 12.8 miles of floodwalls. From the Saddle River downstream to the Second River, 5.7 miles of levees and 7.8 miles of floodwalls are required to protect against the combined tidal/fluvial effects and tunnel discharges. They would provide protection against a 100 year flood. A tunnel diversion plan could not be constructed without the implementation of these flood control measures. Along the lower Passaic River from the Second River to the mouth at Newark Bay, 5.5 miles of levees and 5.0 miles of floodwalls are required to protect against flooding from tidal events. They would provide protection against a 500 year flood.

TABLE C-79. PLAN 30 E - DUAL INLET TUNNEL PLAN
CHANNEL MODIFICATION PHYSICAL FEATURES TABLE

REACH	COMMUNITY	Average Depth of Cut (Ft)	Averarge Depth Top of Banks to Invert (Ft)	Average Base Width (Ft)	Average Top Width (Ft)
Passaic River Rt. 46 to Two Bridges 0.8 miles	Wayne	4	15	175	235
Pompton River Two Bridges upstream 0.3 miles	Wayne Lincoln	4	7	150	205
Pequannock River Confluence with the Pompton River upstream 2.6 miles	Wayne Pequannock Pompton Lakes Riverdale	7	15	74-100	135-160
Ramapo River Confluence with the Pompton River upstream 1.2 miles	Wayne Pompton Lakes	4	17	60-100	130-170
Wanague River Confluence with the Pequannock River upstream 1 mile	Pompton Lakes	6	12	74	125

TABLE C-80
PLAN 30E - DUAL INLET TUNNEL PLAN - LEVEE/FLOODWALL PHYSICAL FEATURES

System	Municipality	Bank	River	LEVEE Avg. Ht. (Ft.)	LEVEE Avg. Base Width (Ft.)	LEVEE Length (Ft.)	FLOODWALL Avg. Ht. (Ft.)	FLOODWALL Length (Ft.)	Approximate Station Start	Approximate Station End	Level of Protection
LOWER VALLEY											
Tidal Systems											
Kearny Point	Kearny	Right Left	Hackensack Passaic	8.8	62.8	16,600	8.0	17,920	Mouth	150+00	500
Doremus Ave.	Newark	Right	Passaic	8.0	58.0	2,400	10.2	1,910	Mouth	76+00	500
N.J. Turnpike	Newark	Right	Passaic	7.4	54.4	2,030	7.5	590	84+00	114+00	500
Lister Ave.	Newark	Right	Passaic	7.4	54.4	4,930	10.5	2,910	114+00	198+00	500
South 1st. St.	Harrison, E. Newark	Left	Passaic	7.9	57.4	3,130	8.3	2,800	222+00	288+00	500
Systems Integral to Tunnel											
Main St.	Belleville	Left Right	Second Passaic	4.5	37.0	560	7.5	6,580	419+00	490+00	100
River Road #1	N. Arlington, Kearny	Left	Passaic	7.3	53.8	4,710	6.0	830	442+00	496+00	100
Riverside Ave. #1	Lyndhurst, N. Arlington, Rutherford	Left	Passaic	12.6	85.6	8,570	9.3	2,460	496+00	610+00	100
River Road #2	Belleville, Clifton, Nutley	Right	Passaic	8.0	58.0	2,650	9.0	7,720	492+00	587+00	100

TABLE C-80 (CONT)
PLAN 30E - DUAL INLET TUNNEL PLAN - LEVEE/FLOODWALL PHYSICAL FEATURES

System	Municipality	Bank	River	LEVEE Avg. Ht. (Ft.)	LEVEE Avg. Base Width (Ft.)	LEVEE Length (Ft.)	FLOODWALL Avg. Ht. (Ft.)	FLOODWALL Length (Ft.)	Approximate Station Start	Approximate Station End	Level of Protection
Yantacaw	Clifton	Left	Third	11.5	79.0	1,540	9.9	1,120	Mouth	30+00	100
River Drive #1	City of Passaic	Right	Passaic	9.2	65.2	1,920	7.8	3,760	655+00	750+00	100
Riverside Ave. #2	Rutherford	Left	Passaic	9.2	65.2	1,570	11.6	4,990	610+00	676+00	100
River St.-Main Ave.	Rutherford, Wallington, E. Rutherford	Left	Passaic	8.2	59.2	5,860	10.1	4,160	685+00	794+00	100
8th St.	City of Passaic	Right	Passaic	10.0	70.0	2,580	10.8	9,780	750+00	854+00	100

SUMMARY OF LOWER VALLEY

	Levee Length	Levee Avg. Ht.	Floodwall Length	Floodwall Avg. Ht.
Tidal	29,090 Ft. (5.51 mi.)	8.3 Ft.	26,130 Ft. (4.95 mi.)	8.5 Ft.
Mitigation	29,960 Ft. (5.67 mi.)	9.7 Ft.	41,400 Ft. (7.84 mi.)	9.6 Ft.
TOTAL	59,050 Ft. (11.18 mi.)	9.0 Ft.	67,530 Ft. (12.79 mi.)	9.2 Ft.

TABLE C-80 (CONT)
PLAN 30E - DUAL INLET TUNNEL PLAN - LEVEE/FLOODWALL PHYSICAL FEATURES

System	Municipality	Bank	River	LEVEE Avg. Ht. (Ft.)	LEVEE Avg. Base Width (Ft.)	LEVEE Length (Ft.)	FLOODWALL Avg. Ht. (Ft.)	FLOODWALL Length (Ft.)	Approximate Station Start	Approximate Station End	Level of Protection
CENTRAL BASIN											
Fluvial Systems											
Passaic 2A	Fairfield, West Caldwell	Left Right	Deepavaal Brook Passaic	8.6	61.6	19,430	9.0	1,230	70+00 2,310+00	182+00 2,400+00	100
Passaic 2C	West Caldwell	Right	Deepavaal Brook	7.0	52.0	4,860	8.5	950	130+00	145+00	100
Passaic 10	Livingston	Right	Passaic	8.4	60.4	4,500	-	-	2,590+00	2,635+00	100
Rockaway 1	Parsippany-Troy Hills	Right	Rockaway	8.7	62.2	3,640	-	-	105+00	210+00	100
Rockaway 2	Montville	Left	Rockaway	8.3	59.8	5,340	-	-	140+00	200+00	100
Rockaway 3	Parsippany-Troy Hills	Right	Rockaway	10.3	71.8	6,320	-	-	218+00	282+00	100
Pinch Brook	East Hanover	Right	Pinch Brook	6.6	49.6	3,380	12.0	200	Pinch Brook 500 Trib. to Whippany		

SUMMARY OF CENTRAL BASIN

	Levee Length	Levee Avg. Ht.	Floodwall Length	Floodwall Avg. Ht.
TOTAL	47,470 Ft. (8.99 mi.)	8.41 Ft.	2,380 Ft. (0.45 mi.)	9.05 Ft.

TABLE C-80 (CONT)
PLAN 30E - DUAL INLET TUNNEL PLAN - LEVEE/FLOODWALL PHYSICAL FEATURES

System	Municipality	Bank	River	LEVEE Avg. Ht. (Ft.)	LEVEE Avg. Base Width (Ft.)	LEVEE Length (Ft.)	FLOODWALL Avg. Ht. (Ft.)	FLOODWALL Length (Ft.)	Approximate Station Start	Approximate Station End	Level of Protection
PEQUANNOCK-WANAQUE-RAMAPO											
Systems Integral to Tunnel											
Pequannock-Ramapo	Pompton Lakes	Right Left	Ramapo Pequannock	9.4	66.4	9,230	10.8	1,500	98+00 on Ramapo	104+00 on Pequannock	100
Shore Road	Wayne	Left	Ramapo	8.0	58.0	4,500	8.2	1,200	Mouth	56+00	100
Stiles Court	Pompton Lakes	Left	Pequannock	3.3	29.8	1,760	-	-	155+00	173+00	100
Hill Court	Pompton Lakes	Right	Wanaque	8.7	62.2	1,350	8.0	600	60+00	73+00	100
Wanaque Avenue	Pompton Lakes	Left	Wanaque	9.9	69.4	1,540	10.5	680	75+00	80+00	100

SUMMARY

	Levee Length	Levee Avg. Ht.	Floodwall Length	Floodwall Avg. Ht.
TOTAL	18,380 Ft. (3.48 mi.)	8.5 Ft.	3,980 Ft. (.75 mi.)	9.5 Ft.

Recreational features, such as hiking/biking paths, park benches, overlooks, drinking fountains and vest pocket parks, are included in the levee/floodwall design for those structures on the east bank between the Saddle and Second Rivers as part of the beautification and planting features in accordance with the desire of the non-Federal sponsor.

In the Central Passaic Basin the preservation of 5,350 acres of natural storage areas is included as a key feature of the plan. The acquisition of these lands insures the future integrity design scale of the project by preventing increases in floodflows due to placing of fill and development in these natural storage areas. This acquisition, in conjunction with the protection of 15,865 acres under other Federal/State programs including FIA floodways, County and Federal parks/preserves, and State funded Green Acres open spaces, would preserve the flood storage and environmental character of the Central Basin wetlands.

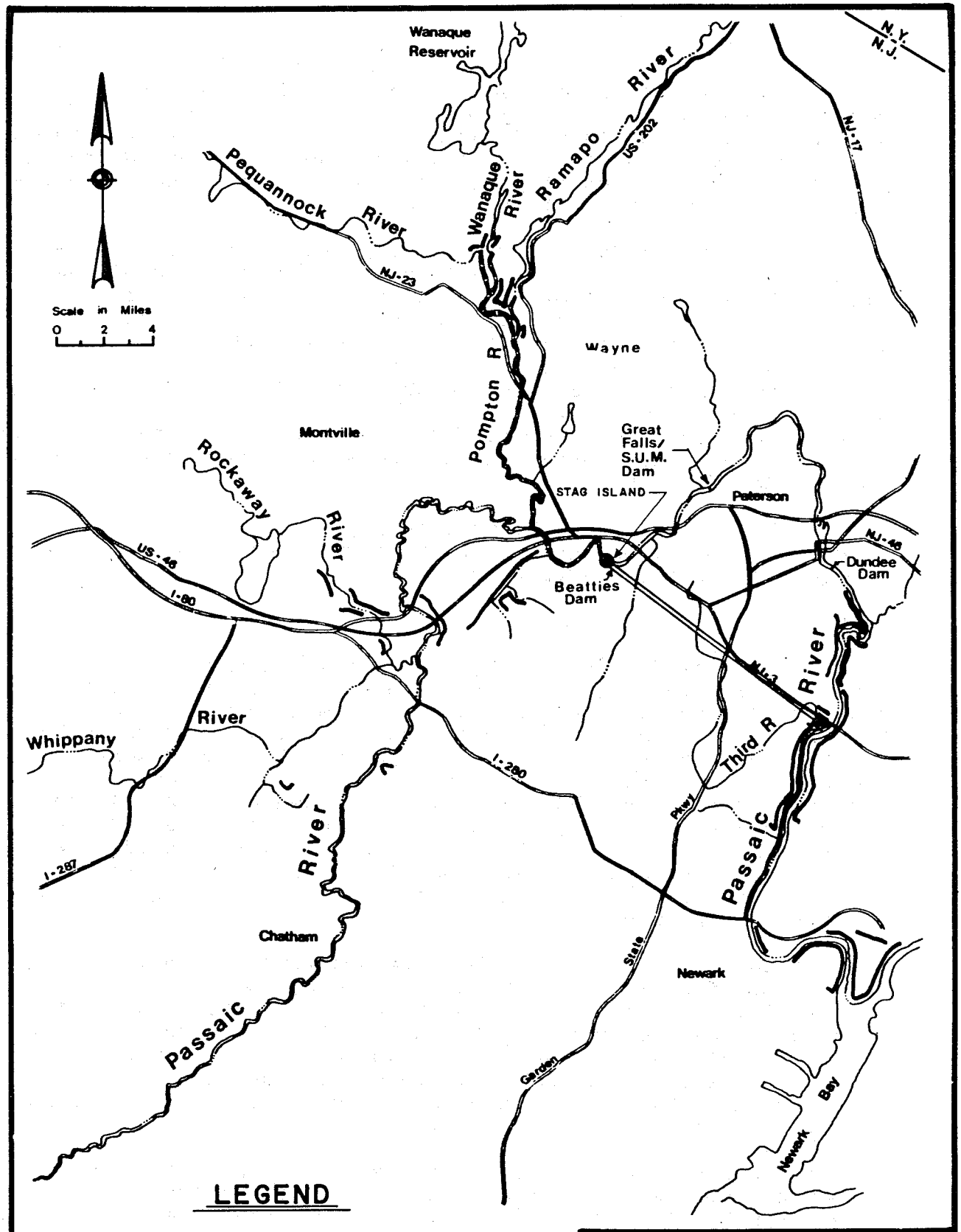
The Floodwarning and Forecasting System for the Passaic River Basin would be integral to proper operation of the tunnel components and gated structures.

PLAN 30A

The central feature of the single inlet tunnel diversion plan is a 7 mile-long, 35-foot-diameter tunnel that extends from about 2,000 feet upstream of Beatties Dam down to the lower Passaic River. The tunnel inlet and diversion works would be located on Stag Island in Wayne. The tunnel would divert floodwaters from the central Passaic River area to an outlet near the Third River/ Passaic River confluence at the Clifton-Nutley border. The underground tunnel would be about 90 feet below ground level at the inlet and about 155 feet below the outlet. At its deepest point, under the Watchung Mountains in the area of the Little Falls-Clifton border, the tunnel would be 450 feet underground.

The tunnel element would be combined with 14.7 miles of channel modification, 23.7 miles of levees, and 14.0 miles of floodwalls to provide protection up to a 100 year event in the Pompton Valley and up to a 500 year event in the Central Basin and Lower Valley. Plan 30A, which would take 145 months to construct, is illustrated in Figure C-88. Tables C-81 and C-82 summarize the physical features of the channel modifications and levee/floodwall systems, respectively.

The channel modification elements of this plan include deepening the Passaic River for an average of 15 feet for 3.0 miles from Two Bridges downstream to the tunnel inlet in order to divert flood flows into the tunnel.



485

FIGURE C-88

TABLE C-81 PLAN 30A - SINGLE INLET TUNNEL PLAN
CHANNEL MODIFICATION PHYSICAL FEATURES

REACH	COMMUNITY	Average Depth of Cut (Ft)	Average Depth Top of Banks to Invert (Ft)	Average Base Width (Ft)	Average Top Width (Ft)
Passaic River					
Stag Island to Two Bridges 3.0 miles	Wayne	15	26	160	290
Pompton River					
Two Bridges to Pompton Plains 6.8 miles	Wayne (61 Structures Required to be Removed) Lincoln Park Pequannock	12	23	95	190
Pequannock River					
Confluence with the Pompton River upstream 2.6 miles	Wayne Pequannock Pompton Lakes Riverdale	14	24	75	170
Ramapo River					
Confluence with the Pompton River upstream 1.3 miles	Wayne Pompton Lakes	6	24	55	150
Wanaque River					
Confluence with the Pequannock River upstream 1 mile	Pompton Lakes	6	18	75	150

TABLE C-82
PLAN 30A - SINGLE INLET TUNNEL PLAN - LEVEE/FLOODWALL PHYSICAL FEATURES

System	Municipality	Bank	River	LEVEE Avg. Ht. (Ft.)	LEVEE Avg. Base Width (Ft.)	LEVEE Length (Ft.)	FLOODWALL Avg. Ht. (Ft.)	FLOODWALL Length (Ft.)
LOWER VALLEY								
Tidal Systems								
Kearny Point	Kearny	Right Left	Hackensack Passaic	8.8	62.8	16,600	8.0	17,920
Doremus Ave.	Newark	Right	Passaic	8.0	58.0	2,400	10.2	1,910
N.J. Turnpike	Newark	Right	Passaic	7.4	54.4	2,030	7.5	590
Lister Ave.	Newark	Right	Passaic	7.4	54.4	4,930	10.5	2,910
South 1st St.	Harrison, E. Newark	Left	Passaic	7.9	57.4	3,130	8.3	2,800
Systems Integral to Tunnel								
Main St.	Belleville	Left Right	Second Passaic	4.5	37.0	560	7.5	6,580
River Road #1	N. Arlington, Kearny	Left	Passaic	7.3	53.8	4,710	6.0	830
Riverside Ave. #1	Lyndhurst, N. Arlington, Rutherford	Left	Passaic	12.6	85.6	8,570	9.3	2,460
River Road #2	Belleville, Clifton, Nutley	Right	Passaic	8.0	58.0	2,650	9.0	7,720
Yantacaw	Clifton	Left	Third	11.5	79.0	1,540	9.9	1,120
River Drive #1	City of Passaic	Right	Passaic	9.2	65.2	1,920	8.0	3,760
Riverside Ave. #2	Rutherford	Left	Passaic	9.2	65.2	1,570	11.6	4,990
River St.-Main Ave.	Rutherford, Wallington, E. Rutherford	Left	Passaic	8.2	59.2	5,860	10.1	4,160
8th St.	City of Passaic	Right	Passaic	10.0	70.0	2,580	10.8	9,780

TABLE C-82 (CONT.)
PLAN 30A - SINGLE INLET TUNNEL PLAN - LEVEE/FLOODWALL PHYSICAL FEATURES

System	Municipality	Bank	River	LEVEE Avg. Ht. (Ft.)	LEVEE Avg. Base Width (Ft.)	LEVEE Length (Ft.)	FLOODWALL Avg. Ht. (Ft.)	FLOODWALL Length (Ft.)
CENTRAL BASIN								
Fluvial Systems								
Passaic 2A	Fairfield, West Caldwell	Left Right	Deepavaal Brook Passaic	8.6	61.6	19,430	9.0	1,230
Passaic 2C	West Caldwell	Right	Deepavaal Brook	7.0	52.0	4,860	8.5	950
Passaic 10	Livingston	Rightq	Passaic	8.4	60.4	4,500	-	-
Rockaway 1	Parsippany-Troy Hills	Right	Rockaway	8.7	62.2	3,640	-	-
Rockaway 2	Montville	Left	Rockaway	8.3	59.8	5,340	-	-
Rockaway 3	Parsippany-Troy Hills	Right	Rockaway	10.3	71.8	6,320	-	-
Pinch Brook	East Hanover	Right	Pinch Brook	6.6	49.6	3,380	12.0	200
PEQUANNOCK-WANAQUE-RAMAPO								
Fluvial Systems								
Pequannock-Ramapo	Pompton Lakes	Right	Ramapo	11.9	81.4	9,230	13.3	1,500
Shore Road	Wayne	Left	Ramapo	10.5	73.0	4,500	10.7	1,200
Stiles Court	Pompton Lakes	Left	Pequannock	3.3	29.8	1,760	-	-
Hill Court	Pompton Lakes	Right	Wanaque	8.7	62.2	1,350	8.0	600
Wanaque Avenue	Pompton Lakes	Left	Wanaque	9.9	69.4	1,540	10.5	680

Channel modifications, averaging 12 feet in depth, would be required along the Pompton River from Two Bridges upstream for 6.8 miles. As part of the Pompton River channel modification, it would be necessary to acquire 61 structures located either on islands in the channel or along the river banks.

The lower Pequannock, Wanaque and Ramapo Rivers would require a total of 4.9 miles of channel modifications. The average channel deepening of the three tributaries would be 14 feet, 6 feet and 6 feet, respectively. In addition to the channel modifications on the Pequannock, Wanaque and Ramapo Rivers, approximately 3.5 miles of levees and 0.7 miles of floodwalls would be required. The systems along the lower reaches of the three tributaries would average approximately 2.5 feet higher than those in Plan 30E. The levee/floodwall elements in the Central Basin and Lower Valley would be identical to those of the Dual Inlet Tunnel Plan. The preservation of 5,350 acres of natural storage areas would also be implemented as part of this plan. As in Plan 30E the Floodwarning and Preparedness System for the Passaic River Basin would be integral to the proper operation of Plan 30A.

PLAN 16A

This alternative is a combination of levees, floodwalls, channel modifications and nonstructural measures which would provide levels of protection ranging from a 10 year to a 500 year flood. Plan 16A, which is illustrated in Figure C-89, would take 72 months to construct.

The key feature is the 16.4 mile-long channel modification proposed for the Lower Valley. This channel modification would provide a 100 year level of protection between Route 3 in Rutherford and Beatties Dam. The channel modification is summarized in Table C-83 and is described below.

The proposed channel modification scheme for the lower Passaic River would start just downstream of the N.J. Route 3 Bridge, and extend upstream to a point near Fleishers Brook in Garfield, a distance of approximately 5.4 miles. The bottom width of the modified channel would be 135 feet for a distance of 4.8 miles. The alignment and top width of the modified channel would be confined to those of the existing channel for almost its entire length. The proposed channel would include two sections of semi-trapezoidal channel and two sections of trapezoidal channel, with 2.5:1 side slopes. The channel would be deepened an average of 8 feet. There would be 0.3 miles of transition channel at both the downstream and upstream limits.

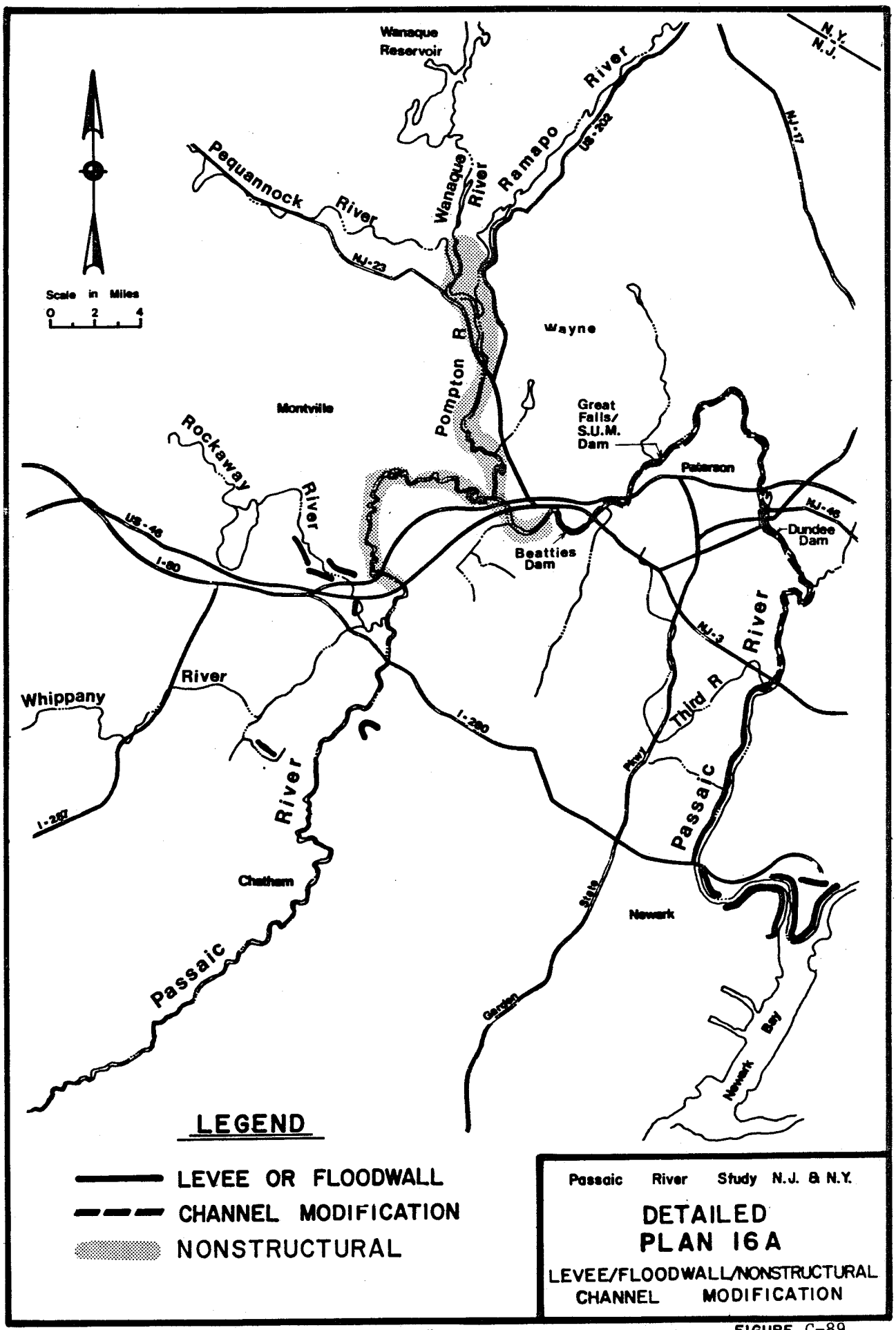

Wanaque Reservoir
Pequannock River
Wanaque River
Ramapo River
N.Y.
N.J.
NJ-17
US-202
NJ-23
Scale in Miles
0 2 4
Wayne
Pompton R.
Montville
Great Falls/ S.U.M. Dam
Paterson
Rockaway River
US-46
I-80
Beatties Dam
NJ-46
Dundee Dam
NJ-3
Third R.
Passaic River
Whippany River
I-280
I-287
Chatham
Passaic River
State
Garden
Newark
Newark Bay
LEGEND
LEVEE OR FLOODWALL
CHANNEL MODIFICATION
NONSTRUCTURAL
Passaic River Study N.J. & N.Y.
DETAILED
PLAN 16A
LEVEE/FLOODWALL/NONSTRUCTURAL
CHANNEL MODIFICATION

FIGURE C-89

TABLE C-83
PLAN 16A - NONSTRUCTURAL MEASURES AND CHANNEL MODIFICATION PHYSICAL FEATURES

NONSTRUCTURAL MEASURES

Subbasin	Total Number of Structures		
	Floodproofing	Raising	Evacuation
CENTRAL BASIN			
Residential	1176	46	12
Non-residential	81	4	6
POMPTON VALLEY			
Residential	3004	516	10
Non-residential	196	12	15

Total 5078 structures involved in non-structural measures.

CHANNEL MODIFICATION PHYSICAL FEATURES

Reach	Length (ft)	Approximate Depth of Cut (ft)	Average Depth, Top of Banks to Invert (ft)	Average Base Width (ft)
Passaic River Route 3 to Dundee Dam	2,000	dredged		
	2,600	5	30	135
	12,850	5	30	135
	1,734	5	30	135
	7,916	15	30	135
	2,000	dredged		
Dundee Dam to Great Falls	4,515	5	25	540
	2,450	12	25	340
	3,350	5	25	280
	8,200	5	25	270
	13,200	15	25	210
	3,500	10	25	115
	4,400	10	25	95
Great Falls to Beatties Dam	10,460	<5	20	184
	9,280	10	20	115

Between Dundee Dam and the Great Falls, the proposed channel would be a trapezoidal channel with a bottom width ranging from 540 feet at Dundee Dam to 95 feet at the upstream limit. The length of the modified channel would be approximately 7.3 miles. The proposed thalweg would be lowered an average of 10 feet.

Between the Great Falls and Beatties Dam, there would be 3.7 miles of trapezoidal channel with bottom widths ranging from 184 feet at the S.U.M. Dam to 115 feet at Beatties Dam. The channel would be deepened an average of 6 feet. This plan also calls for lowering the crest of the S.U.M. Dam 1.6 feet, to an elevation of 113.0 feet NGVD.

Plan 16A contains a total of 10.5 miles of levees and 5.0 miles of floodwalls. The five levee/floodwall systems located in the Lower Valley, between the mouth of the Passaic River upstream to the I-280 Bridge, would protect against a 500 year tidal flood. These Lower Valley systems are identical to those included in Plans 30E and 30A. The six intermittent systems located in the Central Basin along the Passaic and Rockaway Rivers and Pinch Brook would protect against floods ranging from the 100 year event to the 500 year event. Table C-84 summarizes the physical features of the levees and floodwalls. In conjunction with the levee/floodwall systems, ponding areas, pressure interceptors and pumping stations would be provided to protect against interior flooding.

Nonstructural measures included in Plan 16A would provide a 10 year level of protection to the Pompton Valley and the central Passaic River between Beatties Dam and the upstream limit of Deepavaal Brook. The number of structures protected by the nonstructural measures of floodproofing, raising and evacuation are detailed in Table C-83. The Floodwarning and Forecasting System would provide advance warning if flooding is expected to exceed the design level of the nonstructural measures.

Plan 16A also includes the preservation of 5,350 acres of natural storage areas that are included in Plans 30E and 30A.

EVALUATION OF DETAILED PLANS

National Economic Development. Economic data for the three detailed plans are presented in Table C-85. Plan 30E ranked first in terms of NED efficiency with $35,200,000 in excess benefits. Plan 30A ranked second with excess benefits of $25,800,000 while Plan 16A ranked last with $21,200,000 in excess benefits.

TABLE C-84

PLAN 16A
LEVEE/FLOODWALL PHYSICAL FEATURES

System	Municipality	Bank	River	LEVEE Avg. Ht. (Ft.)	LEVEE Avg. Base Width (Ft.)	LEVEE Length (Ft.)	FLOODWALL Avg. Ht. (Ft.)	FLOODWALL Length (Ft.)
LOWER VALLEY								
Kearny Point	Kearny	Left Right	Passaic Hackensack	8.8	62.8	16,600	8.0	17,920
Doremus Ave.	Newark	Right	Passaic	8.0	58.0	2,400	10.2	1,910
Turnpike	Newark	Right	Passaic	7.4	54.4	2,030	7.5	590
Lister Ave.	Newark	Right	Passaic	7.4	54.4	4,930	10.5	2,910
South 1st St.	Harrison, E. Newark	Left	Passaic	7.9	57.4	3,130	8.3	2,800
CENTRAL BASIN								
Passaic R. #3B	Fairfield	Right	Passaic	15.5	103.0	3,660	-	-
Passaic R. #10	Livingston	Right	Passaic	10.8	74.8	4,500	-	-
Rockaway R. #1	Parsippany	Right	Rockaway	10.4	72.4	3,640	-	-
Rockaway R. #2	Montville	Left	Rockaway	9.0	64.0	5,340	-	-
Rockaway R. #3	Parsippany	Right	Rockaway	10.9	75.4	5,940	-	-
Pinch Brook	E. Hanover	Right	Pinch	7.1	52.6	3,380	12.5	200

TABLE C-85 SUMMARY OF DETAILED PLAN EVALUATION
(October 1985 price level, 8-5/8% Interest Rate)

EVALUATION CRITERIA	WITHOUT PROJECT	PLAN 30E	PLAN 30A	PLAN 16A
Excess Annual Benefits ($1,000'S)	0	35,200	25,800	21,200
Average Annual Equivalent Benefits ($1,000's) 1/	0	118,200	105,700	59,800
Residual Average Annual Equivalent Damages ($1,000's) 2/	102,600	17,200	25,200	56,600
Residual 500yr Stage Damage ($1,000's)2/	2,700,000	1,343,000	1,409,100	2,219,700
B/C Ratio	N/A	1.4	1.3	1.6
First Cost ($1,000's)	N/A	814,100	728,200	385,300
Construction Duration (Months)	N/A	90	145	72
Investment Cost ($1,000's)	N/A	927,100	892,200	433,800
Annual O&M ($1,000's)	N/A	2,090	1,990	1,050
Total Annual Cost	N/A	83,000	79,900	38,600
Prevent Loss of Life	N/A	VERY HIGH	HIGH	MODERATE
Preserve Transportation Facilities	N/A	VERY HIGH	HIGH	MODERATE
Level of Protection Provided	N/A	100-500	50-500	10-500
Efficiency	N/A	Very High	Moderate	Moderate
Acceptability				
Non-Federal Sponsor	NONE	Very High	High	Low
Public	NONE	High	Moderate	Moderate
Completeness	N/A	Complete	Complete	Complete
Effectiveness	N/A	High	Moderate	Low

1/ Includes benefits due to inundation reduction, affluence, residential intensification, PATH delay, traffic flow, industrial content growth and FIA cost reduction.

2/ Excludes Upper Passaic Basin

Of the three detailed plans, Plan 30E was estimated to be the most expensive to construct and would have the highest annual operation and maintenance (O&M) costs. Plan 30E has a first cost of $814,100,000 and annual O&M costs of $2,090,000. Plan 30A was the second most expensive with a first cost of $728,200,000 and annual O&M costs of $1,990,000. Plan 16A would be the least expensive with a first cost of $385,300,000 and annual O&M costs of $1,050,000.

The average annual equivalent benefits of Plans 30E, 30A and 16A were estimated to be $118,200,000, $105,700,000, and $59,800,000, respectively.

The residual flood damages associated with the detailed plans were highest for Plan 16A. This plan would have residual average annual equivalent damages equal to $56,600,000 and residual damages of $2,219,700,000 for the 500 year event. Plan 30A would have $25,200,000 in residual average annual equivalent damages and $1,409,100,000 residual damages at the 500 year event. The residual damages corresponding to Plan 30E are the least of the three detailed plans. Plan 30E would have residual average annual equivalent damages of $17,200,000 and residual damages equal to $1,343,000,000 at the 500 year event. The residual damages for both Plans 30A and 30E include damages associated with the operation of the tunnel.

Response to Problem and Opportunity Statements. Table C-86 presents the responses of the three detailed plans to each of the problem and opportunity statements developed for this study. The following discussion highlights the responses to the more significant problem and opportunity statements.

Plan 30E, the Dual Inlet Tunnel plan, achieves the flood damage reduction objective of the study by providing levels of protection ranging from the 100 year to the 500 year flood event in the major damage reaches. As discussed earlier in this Appendix, the optimum operation for Plan 30E during a basin-wide flood event is based on the Pompton inlet always having a priority to direct as much flow as possible into the main tunnel. The Passaic inlet at Two Bridges would operate only when there is excess capacity over that needed for Pompton River flows. However, having the Passaic River inlet also allows for the ability to reduce flood damages in the event of a storm centered over the Central Basin.

Plan 30A, the Single Inlet Tunnel plan, would provide a 50 year level of protection in the major damage reaches along the Pompton River and up to 100 year level of protection along the Pequannock, Wanaque and Ramapo Rivers. The Lower Valley and Central Basin damage areas would receive protection ranging from a 100 year up to a 500 year event.

TABLE C-86

RESPONSES OF DETAILED PLANS TO PROBLEM AND OPPORTUNITY STATEMENTS

PROBLEMS AND OPPORTUNITIES	RESPONSES OF DETAILED PLANS		
	Plan 30 E	Plan 30 A	Plan 16 A
1. Reduce flood damages.	Provides 100-500 year level of protection.	Provides 50-500 year level of protection.	Provides 10-100 year level of protection.
2. Preserve water supply potential.	Water supply would be unaffected.	Same as Plan 30 E.	Same as Plan 30 E.
3. Preserve and/or enhance fish and wildlife habitat.	Fish and wildlife habitat would be adversely impacted by the elimination or alteration of wetlands, and and channel modifications. To compensate for these impacts, aquatic habitat structures, nest boxes, the Great Piece Weir, preservation of natural storage areas, planting flora in ponding areas and other environmental features would be included.	This plan would have a more severe impact on fish and wildlife habitat than Plan 30E. The types of environmental features that would be included are the same as Plan 30 E.	Habitat would be maintained in areas acquired for natural storage. Property where structures are evacuated as part of the nonstructural measure would be planted with vegetation.
4. Preserve and/or enhance low head hydropower generation potential.	Hydropower potential would be unaffected.	Same as Plan 30 E.	Same as Plan 30 E.

4/96

TABLE C-86 (CONT)

RESPONSES OF DETAILED PLANS TO PROBLEMS AND OPPORTUNITY STATEMENTS

PROBLEMS AND OPPORTUNITIES	RESPONSES OF DETAILED PLANS		
	Plan 30 E	Plan 30 A	Plan 16 A
5. Preserve and/or enhance the Basin's remaining wetlands.	905 acres of wetlands would be eliminated or altered. 4860 acres of wetlands would be preserved intact through the acquistion of natural storage areas.	945 acres of wetlands would be eliminated or altered. 4860 acres of wetlands would be preserved intact through the acquisition of natural storage areas.	250 acres of wetlands would be eliminated or altered. 5200 acres of wetlands would be preserved intact through the acquistion of natural storage areas.
6. Protect and improve surface and groundwater quality.	Temporary degradation of surface water quality during construction and maintenance activities. Drawdown of groundwater table in vicinity of modified channels. No impact on acquifers including the buried valley aquifer.	Same as Plan 30 E, except possible impact on aquifers other than the buried valley aquifer.	Same as Plan 30 E.
7. Preserve outdoor recreational opportunities and open space.	Recreational features would be included as part of the beautification and planting measures associated with the Lower Valley tidal and integral levees.	Same as Plan 30 E.	Same as Plan 30 E in the Lower Valley tidal area.

TABLE C-86 (CONT)

RESPONSES OF DETAILED PLANS TO PROBLEM AND OPPORTUNITY AND STATEMENTS

PROBLEMS AND OPPORTUNITIES	RESPONSES OF DETAILED PLANS		
	Plan 30 E	Plan 30 A	Plan 16 A
8. Preserve commercial and recreational navigation opportunities along the lower Passaic River.	Navigation opportunites would be unaffected.	Same as Plan 30 E.	Same as Plan 30 E.
9. Preserve and protect endangered and threatened species and their habitats.	Existing habitat would be maintained in areas acquired for natural storage and in Great Piece Meadows through the use of the weir structure.	Same as Plan 30 E.	Same as Plan 30 E, except Great Piece Meadows would be unaffected.
10. Reduce streambank erosion along the Passaic River and tributaries.	In the modified channel reaches, riprap would be used where needed to prevent erosion.	Same as Plan 30 E.	Same as Plan 30 E.
11. Preserve significant archaeological, cultural and historic resources.	Cultural survey would be performed during the post-authorization, pre-construction phase in order to identify resources.	Same as Plan 30 E.	Same as Plan 30 E.

4198

TABLE C-86 (CONT)

RESPONSES OF DETAILED PLANS TO PROBLEM AND OPPORTUNITY AND STATEMENTS

PROBLEMS AND OPPORTUNITIES	RESPONSES OF DETAILED PLANS		
	Plan 30 E	Plan 30 A	Plan 16 A
12. Prevent the disturbance of known toxic waste sites and protect them from flooding.	Toxic waste sites in the Lower Valley and Central Basin would be protected within the 100-500 year floodplains. Sites that could be affected by construction activities are projected to be cleaned up by other agencies prior to construction.	Same as Plan 30 E, except toxic waste sites in the Lower Valley and Central Basin would be protected within the 50-500 year floodplains.	Same as Plan 30 E, except only toxic waste sites in the Lower Valley would be protected within the 100-500 year floodplains.
13. Improve aesthetics and preserve scenic or unique sites.	Heights of levees and floodwalls would affect views in Central Basin and Lower Valley. Central Basin wetland views would be maintained through preservation of natural storage areas.	Same as Plan 30 E.	Same as Plan 30 E, except no levees and floodwalls in the Central Basin.
14. Protect and enhance 3 river reaches that are included in the Nation-wide Rivers Inventory and are potential National Wild and Scenic Rivers.	Only Two Bridges to I-80 reach would be affected by this plan. The inclusion of the Great Piece Weir would maintain the integrity of the wetlands in this reach.	Same as Plan 30 E.	Plan 16 A would not affect these river reaches.

Plan 16A would provide levels of protection ranging from the 100 year up to the 500 year event in the Lower Valley and the Central Basin above the upstream limit of Deepavaal Brook. The Pompton Valley and Central Basin between Beatties Dam and upper Deepavaal Brook, however, would only receive a 10 year level of protection. Since this area contains major damage reaches, this plan was not considered to be fully responsive to the flood damage reduction objective.

The implementation of preservation of natural storage areas in conjunction with any of the three detailed plans would be responsive to the objective of preserving the Basin's remaining wetlands.

Plans 30E, 30A and 16A would also be responsive to the objective of preserving and providing recreational opportunities and open space by incorporating recreation features as part of beautification and planting measures in the Lower Valley as desired by the non-Federal sponsor. In addition, the plan elements were formulated to avoid conflict with existing recreational facilities.

Evaluation Criteria. The final array of plans was evaluated based on completeness, effectiveness, efficiency and acceptability. Table C-86 summarizes the response of each plan to the evaluation criteria.

Each of the three detailed plans were determined to be complete alternatives since each provides and accounts for all investments or actions required to ensure the planned effects.

Plan 30E, the Dual Inlet Tunnel plan, was determined to be the most effective since it most fully achieves the primary objective of flood damage reduction. Plan 30A was ranked second in terms of effectiveness since it would provide less protection along the Pompton River than Plan 30E. Plan 16A was ranked last in effectiveness since it would provide only a very low level of protection to many of the major damage reaches.

Based on NED efficiency, the detailed plans were ranked in descending order as follows: Plan 30E, Plan 30A and Plan 16A.

Plan 30E was selected as the preferred plan by the non-Federal sponsor and is strongly supported by a portion of the basin's interests. Plan 30A is not acceptable to the basin's environmental interests because of the extensive channel modifications included in this plan. Furthermore, since it does not provide a 100 year level of protection along the Pompton

River, it is not as acceptable as Plan 30E to the non-Federal sponsor and the public. Plan 16A is supported by environmental groups and some Lower Valley municipalities. However, it is not acceptable to the Pompton Valley/Central Basin because of the low level of protection provided to these areas.

Environmental Quality. The comparative impacts of the three detailed plans on the Basin's significant environmental resources are detailed in Tables C-87 and C-88 and are highlighted in the following paragraphs.

a. Terrestrial Resources. Plan 30E would impact on 905 acres of wetlands, of which 630 acres are compensated for through wetland planting in ponding areas, and 185 acres would be mitigated through wetland reclamation or management measures in the Central Basin project lands. An additional 90 acres of forested wetlands would be converted to scrub-shrub cover type due to tree removal upstream of the Pompton River tunnel inlet.

Plan 30A would impact on 945 acres of wetlands, of which 630 arces are compensated for through wetland planting in ponding areas and 235 acres would be mitigated through wetland reclamation or management measures in the Central Basin project lands. As in Plan 30E, 90 acres of forested wetlands would be converted to scrub-shrub cover type as part of Plan 30A due to tree removal near the confluence of the Ramapo and Pequannock Rivers.

Plan 16A would impact on 250 acres of wetlands, of which, 189 acres are compensated for through wetland planting (174 in ponding areas and 15 acres in nonstructural buyout land) and 61 acres would be mitigated through wetland reclamation or management measures in the Central Basin project lands.

b. Aquatic Resources. Plans 30E and 30A would both result in the loss of two acres of anadromous fish habitat in the Lower Valley due to shoreline modifications. Plan 16A would produce the most adverse impacts on anadromous fish habitat. This plan would result in the loss of 84 acres of habitat due to the extensive channel modifications in the Lower Valley. Furthermore, Plan 16A would adversely affect 325 acres of aquatic habitat in the Lower Valley between Dundee and Beatties Dams.

501

TABLE C-87
COMPARATIVE IMPACTS OF ALTERNATIVES
(1 of 6)

CATEGORIES SIGNIFICANT RESOURCES	BASE CONDITION (Today)	FUTURE WITHOUT ACTION (2040)	DUAL INLET PLAN	SINGLE INLET PLAN	NO-TUNNEL PLAN
ANADROMOUS FISH, LOWER VALLEY MOUTH TO DUNDEE DAM (REACH 1)	Downstream of Dundee Dam: 130 acres of tidal flats; some spawning by anadromous fish.	AT BEST, NO CHANGE	ADVERSE - Loss of 2 acres of anadromous fish habitat.	ADVERSE - Same as Dual Inlet Plan.	ADVERSE - Loss of 84 acres of riverine habitat due to channel modifications.
			BENEFICIAL - Creation of 4 acres of anadromous habitat as part of the project.	BENEFICIAL - Same as Dual Inlet Plan.	BENEFICIAL - 21 acres of riverine habitat re-created.
FRESHWATER FISHERY LOWER VALLEY (REACH 2)	Above Dundee Dam Upstream to Beatties Dam: 325 acres of riverine/lacustrine habitat.	NO CHANGE	NO ADVERSE EFFECT	NO ADVERSE EFFECT	ADVERSE - 325 acres of riverine habitat adversely affected.
WETLANDS - DOWNSTREAM OF DUNDEE DAM, LOWER VALLEY (REACH 1)	45 acres of wetlands.	NO CHANGE	ADVERSE - Loss of 10 acres of riparian/ wetland habitat.	ADVERSE - Same as the Dual Inlet Plan.	ADVERSE - Loss of 6 acres of riparian wetland.
			BENEFICIAL - Creation of 10 acres in Reach 4 or 5.	BENEFICIAL - Same as Dual Inlet Plan.	BENEFICIAL - Creation of 6 acres of wetland in Reach 4, or 5.
WETLANDS - ABOVE DUNDEE DAM UPSTREAM TO BEATTIES DAM, LOWER VALLEY (REACH 2)	40 acres of wetlands	NO CHANGE - Unless washed out due to large storm event.	ADVERSE - Loss of 5 acres of adverse forested wetland from scattered remnants downstream of Little Falls.	ADVERSE - Same as Dual Inlet Plan.	ADVERSE - Loss of 40 acres of riparian wetlands to channel widening.
			BENEFICIAL - 5 acres recreated/upgraded in Reach 5 to offset loss.	BENEFICIAL - Same as Dual Inlet Plan.	BENEFICIAL - Upgrade/re-create 30 acres of wetland in Reach 5 and 10 acres in Reach 4 to offset loss.

TABLE C-87

COMPARATIVE IMPACTS OF ALTERNATIVES
(2 of 6)

CATEGORIES SIGNIFICANT RESOURCES	BASE CONDITION (Today)	FUTURE WITHOUT ACTION (2040)	DUAL INLET PLAN	SINGLE INLET PLAN	NO-TUNNEL PLAN
ENDANGERED AND THREATENED SPECIES, LOWER VALLEY (REACH 1)	Federal: None NJ Threatened: American Shad.	NO CHANGE	NO EFFECT	NO EFFECT	NO EFFECT
WATER QUALITY, LOWER VALLEY (REACHES 1 AND 2)	Poor	Remain the same or worsen due to increased development.	NO EFFECT	NO EFFECT	ADVERSE - Water quality would degrade temporarily during maintenance dredging occasionally necessary.
CULTURAL RESOURCES, LOWER VALLEY (REACHES 1 AND 2)	2 National Historic Districts.	More nominations to National Register may occur.	NO ADVERSE EFFECT	NO ADVERSE EFFECT	ADVERSE EFFECT - Bank slope work likely to affect sites.
			BENEFICIAL - Prevention of flood damages.	BENEFICIAL - Same as Dual Inlet Plan.	BENEFICIAL - Same as Dual Inlet Plan.
HAZARDOUS SUBSTANCE SITES, LOWER VALLEY (REACHES 1 AND 2)	There are 2 Superfund and 26 CERCLA, hazardous substance sites within the 100-year floodplain.	Flooding could spread substances into living areas, fish and wildlife habitats.	BENEFICIAL - Protecting all sites from flooding within the 500 year floodplain up to Second River, and within the 100 year from the Second River to Beatties Dam.	BENEFICIAL - Same protection as Dual Inlet Plan.	BENEFICIAL - Same protection as Dual Inlet Plan.

TABLE C-87

COMPARATIVE IMPACTS OF ALTERNATIVES
(3 of 6)

CATEGORIES SIGNIFICANT RESOURCES	BASE CONDITION (Today)	FUTURE WITHOUT ACTION (2040)	DUAL INLET PLAN	SINGLE INLET PLAN	NO-TUNNEL PLAN
FISHERIES, CENTRAL BASIN - INCLUDING POMPTON VALLEY AND TRIBUTARIES (REACH 4) AND BEATTIES DAM TO TWO BRIDGES (REACH 3) AND TWO BRIDGES TO GREAT PIECE MEADOWS (REACH 5)	Angler use is high in some areas with active NJDEP fish stocking program. Demand for fisheries exceeds the supply of 250 acres of habitat	Water quality remains about same - Point Source pollution lessens.Non-Point source pollution inreases.	ADVERSE - Impact on 45 acres of riverine habitat, due to construction of channel modifications. Habitat restoration techniques would help restore fishery.	ADVERSE - 120 acres impacted, otherwise the same as the Dual Inlet Plan.	NO ADVERSE EFFECT
WETLANDS, CENTRAL BASIN BEATTIES DAM TO TWO BRIDGES (REACH 3)	5 acres of wetlands.	AT BEST NO CHANGE	ADVERSE - 5 acres of forested wetland lost to tunnel inlet structures.	ADVERSE - Same as Dual Inlet Plan.	NO ADVERSE EFFECT
WETLANDS, CENTRAL BASIN - UPSTREAM TO LOWER ROCKAWAY, WHIPPANY (REACH 5) AND POMPTON VALLEY AND TRIBUTARIES (REACH 4)	13,000 acres in the Central Basin study area providing habitat for numerous plant and animal communities, including State endangered species: and acting as flood storage areas. 8,620 acres are unprotected by public ownership or regulations.	High degree of risk and uncertainty regarding development. Increased pressure to allow development as upland alternative sites become unavailable. Up to 3,870 acres expected to be lost by 2040.	ADVERSE - With plan 815 acres of mostly forested wetland lost, 90 acres of forested altered. BENEFICIAL - With plan 905 acres lost and adversely affected wetland would be replanted, created, managed to offset loss. BENEFICIAL - Preservation 4,860 acres of wetland saved from risk of development 2,190 acres are saved from risk of filling.	ADVERSE - With plan 945 acres of mostly forested affected adversely or lost. BENEFICIAL - With plan 945 acres of adverse effect offset/gained. Same as Dual Inlet Plan. BENEFICIAL - Same as Dual Inlet Plan.	NO ADVERSE EFFECTS BENEFICIAL - Preservation of about 5,200 acres saved from risk of development 2,340 acres are saved from risk of filling.

505

TABLE C-87

COMPARATIVE IMPACTS OF ALTERNATIVES
(4 of 6)

CATEGORIES SIGNIFICANT RESOURCES	BASE CONDITION (Today)	FUTURE WITHOUT ACTION (2040)	DUAL INLET PLAN	SINGLE INLET PLAN	NO-TUNNEL PLAN
NATIONAL NATURAL LANDMARK - TROY MEADOWS (REACH 5)	2,390 acre wetland area.	Increased threat of development especially at periphery of the meadows.	BENEFICIAL - 1,175 would be preserved for posterity with this plan.	BENEFICIAL - Same as Dual Inlet Plan.	BENEFICIAL - Same as Dual Inlet Plan.
WILD AND SCENIC RIVERS (REACH 5)	8-mile reach of Passaic River in Great Piece Meadows is recognized as having wild and scenic river values based on its botanical characteristics.	Progressive botanical changes in adjacent wetlands due to increased frequency and magnitude of inundation caused by development-related hydrologic changes in watershed. Also, reduction of wild and scenic values due to progressive development of the wetland fringe bordering the immediate floodway.	ADVERSE - For about five days each year, free-flowing characteristics of the Passaic River upstream of Two Bridges would be altered by use of a low weir. BENEFICIAL - Preservation intact of 1,240 acres of natural setting of the remaining river reach through acquisition of flood storage areas in Great Piece Meadows.	ADVERSE - Same as Dual Inlet Plan. BENEFICIAL - Protection of habitat. Same as Dual Inlet Plan.	NO ADVERSE IMPACT BENEFICIAL - Same as Dual Inlet Plan.

TABLE C-87

COMPARATIVE IMPACTS OF ALTERNATIVES
(5 of 6)

CATEGORIES SIGNIFICANT RESOURCES	BASE CONDITION (Today)	FUTURE WITHOUT ACTION (2040)	DUAL INLET PLAN	SINGLE INLET PLAN	NO-TUNNEL PLAN
ENDANGERED AND THREATENED SPECIES, CENTRAL BASIN (REACH 5)	No Federal. Six NJ endangered species, 7 threatened species.	Reduction of wetland habitat; subsequent elimination.	BENEFICIAL - Protection of 4,200 acres of wetland habitat.	BENEFICIAL - Same as the Dual Inlet Plan.	BENEFICIAL - Protection of 4,540 acres of wetland habitat.
WATER QUALITY, CENTRAL BASIN (REACHES 4 AND 5)	Poor to fair on Passaic River (Reach 5). Good in Pompton Valley (Reach 4).	Degradation from increased non-point-source runoff especially during floods.	ADVERSE - Short term impacts during construction. Possible temperature increase due to river bank clearing. BENEFICIAL - Project would reduce contaminents entering the river during flood events.	ADVERSE - Same as Dual Inlet Plan, except in Pompton Valley where channel work would cause increased temporary degradation. BENEFICIAL - Same as Dual Inlet Plan.	NO EFFECT - No degradation.
GROUNDWATER RESOURCES (REACHES 4 AND 5)	Generally good. Quality decreasing due to increased development.	Continued degradation of quality.	NO EFFECT	BENEFICIAL - Recharge of the aquifer.	NO EFFECT
CULTURAL RESOURCES, CENTRAL BASIN (REACHES 4 AND 5)	2 National Historic Districts.	Possibly more nominations to National Register of Historic Places.	BENEFICIAL - Possible discovery of new prehistoric sites. Protection from floods.	BENEFICIAL - Same as Dual Inlet Plan.	NO EFFECT - Same as future without project.

TABLE C-87

COMPARATIVE IMPACTS OF ALTERNATIVES
(6 of 6)

CATEGORIES SIGNIFICANT RESOURCES	BASE CONDITION (Today)	FUTURE WITHOUT ACTION (2040)	DUAL INLET PLAN	SINGLE INLET PLAN	NO-TUNNEL PLAN
HAZARDOUS SUBSTANCE SITES, CENTRAL BASIN (REACHES 3-5)	There are 2 Superfund and 20 CERCLA hzardous substances sites in the 100 year floodplain.	Flooding could spread hazardous substances into living areas, fish and wildlife habitats.	Protection of all sites within the 100 year floodplain in the Pompton Valley, within the 100 to 500 year floodplain in the Passaic.	Sames as with Dual Inlet Plan, but only 50 year protection on Pompton River.	No site protection in the Pompton River Valley or the Passaic River upstram from Beatties Dam to Pine Brook.
RECREATION, FISHING (REACHES 1-5)	Limited due to lack of shoreline access and water quality, except in the Pompton Valley and its upstream tributaries where there is shoreline and trout stocking fishing.	Continued limitations and reduction in use.	ADVERSE - Access only at selected points. Fisheries affected during construction and maintenance.	ADVERSE - Same as Dual Inlet Plan.	BENEFICIAL - No adverse effects. Additional parkland or open space from evacuated home sites.
BOATING AND SWIMMING	Severe peak demand day deficits occur in basin for all water-related recreational activities.	Deficits projected to increase with more people using fixed amount of resources.	BENEFICIAL - Preservation of natural storage, along with recreational/beautification areas as part of plan components, would decrease projected deficits.	BENEFICIAL - Same as Dual Inlet Plan.	BENEFICIAL - Similar to Dual Inlet Plan but benefit less extensive in Lower Valley.

TABLE C-88 (Page 1 of 11)

DUAL INLET PLAN

{1}
EFFECTS OF STAGE III PLANS ON AQUATIC AND WETLAND AREAS, AND MITIGATION, AND OTHER TECHNIQUES TO OFFSET EFFECTS

	AQUATIC HABITAT	WETLAND (ACRES) HABITAT			
	(ACRES)	FORESTED	SCRUB-SHRUB	EMERGENT	TOTAL
REACH 1 MOUTH TO DUNDEE DAM					
Aquatic Habitat in Project Area	930	-	-	-	-
Wetland Habitat in Project Area	-	4	1	40	45
Effects of Levees (Without Mitigation) {2}					
Direct Effect - Loss	0	-1	-1	-8	-10
Direct Effect - Habitat Change	0	0	0	0	0
Indirect Effect - Loss	0	0	0	0	0
Indirect Effect - Habitat Change	0	0	0	0	0
Mitigation for Levee Effects	0	+1	+1	+8	+10{3}
Effects of Tunnel (Without Mitigation)					
Direct Effect - Habitat Change	-2	0	0	0	0
Mitigation For Tunnel Effects	+4	0	0	0	0
NET EFFECT OF PLAN - REACH 1	+2	0	0	0	0{4}
REACH 2 DUNDEE DAM TO BEATTIES DAM					
Aquatic Habitat in Project Area	325	-	-	-	-
Wetland Habitat in Project Area	-	30	10	0	40
Effect of Tunnel (Without Mitigation)					
Indirect Effect - Loss	0	-5	0	0	-5
Mitigation For Tunnel Effects	0	+5{5}	0	0	+5{3}
NET EFFECT - REACH 2	0	0	0	0	0{4}
REACH 3 BEATTIES DAM TO TWO BRIDGES					
Aquatic Habitat in Project Area	80	-	-	-	-
Wetland Habitat in Project Area	-	5	0	0	5
Effect of Tunnel Inlet Structure (Without Mitigation)					
Direct Effect - Loss	0	-5	0	0	-5
Mitigation For Tunnel Inlet Structure	0	+5{5}	0	0	+5{3}

TABLE C-88 (Page 2 of 11)

DUAL INLET PLAN

{1}
EFFECTS OF STAGE III PLANS ON AQUATIC AND WETLAND AREAS, AND MITIGATION, AND OTHER TECHNIQUES TO OFFSET EFFECTS

	AQUATIC HABITAT	WETLAND (ACRES) HABITAT			
	(ACRES)	FORESTED	SCRUB-SHRUB	EMERGENT	TOTAL
Effects of Channel Modifications {6} (Without Mitigation)					
Direct Effect - Habitat Change	-20	-	-	-	-
Mitigation For Channel Modification/ Effects	+20	-	-	-	-
NET EFFECTS OF CHANNEL MODIFICATION REACH 3	0{4}	-	-	-	-
NET EFFECT - REACH 3	0	0	0	0	0{4}
REACH 4 POMPTON VALLEY					
Aquatic Habitat in Project Area	40	-	-	-	-
Wetland Habitat in Project Area	-	1260	220	200	1680
Effects of Levees (Without Mitigation)					
Direct Effect - Loss	0	-20	0	0	-20
Mitigation For Levee Effects	0	+20{5}	0	0	+20
NET EFFECTS OF LEVEES - REACH 4	0	0	0	0	0{4}
Effects of Ponding Areas (Without Mitigation)					
Direct Effect - Loss	0	-30	0	0	-30
Wetland Planting For Ponding Areas	0	0	0	+30	+30
NET EFFECT OF PONDING AREAS - REACH 4	0	-30	0	+30	0{4}
Effects of Channel Modifications - Sideslopes, and Tunnel Works (Without Mitigation) Pequannock, Ramapo and Wanaque Rivers					
Direct Effect - Loss	0	-40	0	0	-40
Direct Effect - Habitat Change	-25	0	0	0	0
Mitigation For Channel Modifications Effects	+25	0	0	+40	+40{7}
NET EFFECTS OF CHANNEL MODIFICATION - REACH 4	0{4}	-40	0	+40	0{4}
Effects of Tunnel and Channel Modifications (including Engineering and Environmental Design) on Flow Regime {8}					
Direct Effect - Habitat Change	0	-90	+90	0	0{9}

509

TABLE C-88 (Page 3 of 11)

DUAL INLET PLAN

{1}
EFFECTS OF STAGE III PLANS ON AQUATIC AND WETLAND AREAS, AND MITIGATION, AND OTHER TECHNIQUES TO OFFSET EFFECTS

	AQUATIC HABITAT	WETLAND (ACRES) HABITAT			
	(ACRES)	FORESTED	SCRUB-SHRUB	EMERGENT	TOTAL
NET EFFECT OF TUNNEL AND CHANNEL MODIFICATION ON FLOW REGIME - REACH 4	0	-90	+90	0	0{4}
NET EFFECT TOTAL - REACH 4	0	-160	+90	+70	0{4}
REACH 5 TWO BRIDGES UPSTREAM ON THE PASSAIC RIVER					
Aquatic Habitat in Project Area	50	-	-	-	-
Wetland Habitat in Project Area	-	6935	1310	3075	11320
Effects of Levees (Without Mitigation)					
Direct Effect - Loss	0	-30	-10	-5	-45
Mitigation For Levee Effects	0	+30{5}	+10	+5	+45
NET EFFECT OF LEVEES - REACH 5	0	0	0	0	0{4}
Effects of Ponding Areas (Without Mitigation)					
Direct Effect - Loss	0	-480	0	-80	-560
Wetland Planting For Ponding Effects	0	0	0	+560	+560
NET EFFECT OF PONDING AREAS - REACH 5	0	-480	0	+480	0{4}
NET EFFECT OF CHANNEL MODIFICATIONS - REACH 5	0{4}	-	-	-	-
Effects of Tunnel (including Engineering and Enviornmental Design) on Flow Regime {10}					
Direct Effect - Loss	0	-85	-15	0	-100
Mitigation Tunnel Effects	0	+85{5}	+15	0	+100
NET EFFECT OF TUNNEL - REACH 5	0	0	0	0	0{4}
NET EFFECT OF TOTAL - REACH 5	0	-480	0	+480	0{4}
NET EFFECT TOTAL PROJECT	+2	-640	+90	+550	0{4}

TABLE C-88 (Page 4 of 11)

DUAL INLET PLAN

{1}
EFFECTS OF STAGE III PLANS ON AQUATIC AND WETLAND AREAS, AND MITIGATION, AND OTHER TECHNIQUES TO OFFSET EFFECTS

{1} Direct effects include modifications and losses resulting from construction of project components such as tunnel inlets, levees and floodwalls and excavation of ponding areas. Indirect effects include modifications and losses resulting from changes in the flow regime (i.e. changes to flood elevations and durations). Secondary effects (i.e. encroachment of development of natural areas) will not occur as a result of project in Reaches 1-3 since virtually all areas are developed, or dedicated parkland. In Reaches 4 and 5, floodways contiguous to acquisition areas will be maintained according to the New Jersey State - Corps agreement in Items of Local Cooperation.

{2} The categories (eg. Direct Effect - Loss, etc.) are fully arrayed only once, in subsequent iterations only the pertinent category(s) are displayed.

{3} Mitigation would be carried out in Reach 4 and 5, on project (acquisition) lands.

{4} The Net Effect (eg. 0) does not necessarily imply full compensation, (eg. in kind, in place) but rather the maximum mitigation attainable with the plan as proposed.

{5} Areas of replacement (forested cover type wetland) would succeed to this cover type with time.

{6} The 20 acres include portions of Reaches 3, 4 and 5.

{7} This forty acres of emergent wetland is being created in Reach 4 ponding areas, which at present are not wetlands.

{8} Engineering and Environmental Design Features in Reach 4 include the 1 year bypass rule, and operation of the Pequannock Weir in conjunction with the retainage of the existing U.S.G.S. Weir to maintain existing water surface and groundwater levels upstream of the Pompton Inlet.

{9} The plan as currently developed calls for the removal of trees to prevent damage to structural elements of the project. The Pequannock Weir would maintain water surface elevations, therefore, wetland would remain, but would change from forested to scrub-shrub.

{10} Engineering and Environmental Design Features in Reach 5 include the 1 year bypass rule, and operation of the Great Piece Meadows Weir.

511

TABLE C-88 (Page 5 of 11)

SINGLE INLET PLAN

{1}
EFFECTS OF STAGE III PLANS ON AQUATIC AND WETLAND AREAS, AND MITIGATION, AND OTHER TECHNIQUES TO OFFSET EFFECTS

	AQUATIC (ACRES)	WETLAND (ACRES)			
		FORESTED	SCRUB-SHRUB	EMERGENT	TOTAL
REACH 1 MOUTH TO DUNDEE DAM					
Aquatic Habitat in Project Area	930	-	-	-	-
Wetland Habitat in Project Area	-	4	1	40	45
Effects of Levees (Without Mitigation) {2}					
Direct Effect - Loss	0	-1	-1	-8	-10
Direct Effect - Habitat Change	0	0	0	0	0
Indirect Effect Loss	0	0	0	0	0
Indirect Effect Habitat Change	0	0	0	0	0
Mitigation For Levee Effects	0	+1	+1	+8	+10{3}
Effects of Tunnel (Without Mitigation)					
Direct Effect - Habitat Change	-2	0	0	0	0
Mitigation For Levee-Tunnel Effects	+4	0	0	0	0
NET EFFECT OF PLAN - REACH 1	+2	0	0	0	0{4}
REACH 2 DUNDEE DAM TO BEATTIES DAM					
Aquatic Habitat in Project Area	325	-	-	-	-
Wetland Habitat in Project Area	-	30	10	0	40
Effects of Tunnel of Water Surface Elevation Change (Without Mitigation					
Indirect Effect - Habitat Change	0	-5	0	0	-5
Mitigation For Tunnel Effect	0	+5 {3}{5}	0	0	+5
NET EFFECT OF PLAN - REACH 2	0	0	0	0	0{4}
REACH 3 BEATTIES DAM TO TWO BRIDGES					
Aquatic Habitat in Project Area	80	-	-	-	-
Wetland Habitat in Project Area	-	5	0	0	5
Effects of Tunnel Inlet Structure (Without Mitigation)					
Direct Effect - Loss	0	-5	0	0	-5
Mitigation For Tunnel Inlet Structure	0	+5 {3}{5}	0	0	+5

512

TABLE C-88 (Page 6 of 11)

SINGLE INLET PLAN

{1}
EFFECTS OF STAGE III PLANS ON AQUATIC AND WETLAND AREAS, AND MITIGATION, AND OTHER TECHNIQUES TO OFFSET EFFECTS

	AQUATIC (ACRES)	WETLAND (ACRES)			
		FORESTED	SCRUB-SHRUB	EMERGENT	TOTAL
NET EFFECT OF PLAN - REACH 3	0	0	0	0	0{4}
Effects of Channel Modifications {6} (Without Mitigation)					
Direct Effect - Habitat Change	-55	-	-	-	-
Mitigation for Channel Modification/ Effects	+55	-	-	-	-
NET EFFECTS OF CHANNEL MODIFICATION REACH 3	0{4}	-	-	-	-
NET EFFECT OF PLAN - REACH 3	0	0	0	0	0{4}
REACH 4 POMPTON VALLEY					
Aquatic Habitat in Project Area	120	-	-	-	120
Wetland Habitat in Project Area	-	1260	220	200	1680
Effects of Levees (Without Mitigation)					
Direct Effect - Loss	0	-20	0	0	-20
Mitigation For Levee Effects	0	+20	0	0	+20
NET EFFECT OF LEVEES - REACH 4	0	0	0	0	0{4}
Effects of Ponding (Without Mitigation)					
Direct Effect - Loss	0	-30	0	0	-30
Mitigation For Ponding Effect	0	0	0	+30	+30
NET EFFECTS OF PONDING AREA - REACH 4	0	-30	0	+30	0{4}
Effects of Channel Modification - Sideslopes, etc. (Without Mitigation) Pequannock, Ramapo, Wanaque and Pompton Rivers					
Direct Effect - Loss		-80	0	0	-80
Direct Effect - Habitat Change	-120	0	0	0	0
Mitigation For Channel Modification	+120	0	+40	+40{7}	+80
NET EFFECTS OF CHANNEL MODIFICATIONS - REACH 4	0	-80	+40	+40	0{4}

513

TABLE C-88 (Page 7 of 11)

SINGLE INLET PLAN

{1}
EFFECTS OF STAGE III PLANS ON AQUATIC AND WETLAND AREAS, AND MITIGATION, AND OTHER TECHNIQUES TO OFFSET EFFECTS

	AQUATIC (ACRES)	WETLAND (ACRES) FORESTED	SCRUB-SHRUB	EMERGENT	TOTAL
REACH 4					
Effects of Tunnel and Channel Modifications on Flow Regime {8}					
Direct Effect - Habitat Change	0	-90{9}	+90	0	0
NET EFFECT OF TUNNEL AND CHANNEL MODIFICIATION ON FLOW REGIME - REACH 4	0	-90	+90	0	0{4}
REACH 5 TWO BRIDGES UPSTREAM ON THE PASSAIC RIVER					
Aquatic Habitat in Project Area	50	-	-	-	-
Wetland Habitat in Project Area	-	6935	1310	3075	11320
Effects of Levees (Without Mitigation)					
Direct Effect - Loss	0	-30	-10	-5	-45
Mitigation For Levee Effects					
Levee Effects With Mitigation	0	+30{5}	+10	+5	+45
NET EFFECT OF LEVEES - REACH 5	0	0	0	0	0{4}
Effects of Ponding Areas (Without Mitigation)					
Direct Effect - Loss	0	-480	0	-80	-560
Mitigation For Ponding Effects	0	0	0	+560	+560
NET EFFECT OF PONDING AREAS - REACH 5	0	-480	0	+480	0{4}
NET EFFECT OF TUNNEL DOWNSTREAM - REACH 5	0{4}	-	-	-	-
Effects of Tunnel Downstream of Weir (Without Mitigation)					
Direct Effect - Loss	0	-85	-15	0	-100
Direct Effect - Habitat Change		-	-	-	-
Effects of Tunnel Downstream of Weir {10}					
Direct Effect - Loss	0	+85{5}	+15	0	+100
Direct Effect - Habitat Change		-	-	-	-
NET EFFECT OF TUNNEL DOWNSTREAM OF WEIR - REACH 5	0	0	0	0	0{4}
NET EFFECT - TOTAL PROJECT	+2	-700	+130	+570	0{4}

SINGLE INLET PLAN

{1}
EFFECTS OF STAGE III PLANS ON AQUATIC AND WETLAND AREAS, AND MITIGATION, AND OTHER TECHNIQUES TO OFFSET EFFECTS

FOOTNOTES:

{1} Direct effects include modifications and losses resulting from construction of project components such as tunnel inlets, levees and floodwalls and excavation of ponding areas. Indirect effects include modifications and losses resulting from changes in the flow regime (i.e. changes to flood elevations and durations). Secondary effects (i.e. encroachment of development of natural areas) will not occur as a result of project in Reaches 1-3 since virtually all areas are developed, or dedicated parkland. In Reaches 4 and 5, floodways contiguous to acquisition areas will be maintained according to the New Jersey State - Corps agreement in Items of Local Cooperation.

{2} The categories (eg. Direct Effect - Loss, etc.) are fully arrayed only once, in subsequent iterations only the pertinent category(s) are displayed.

{3} Mitigation would be carried out in Reach 4 and 5, on project (acquisition) lands.

{4} The Net Effect (eg. 0) does not necessarily imply full compensation (eg. in kind, in place), but rather the maximum mitigation attainable with the plan as proposed.

{5} Areas of replacement (forested cover type wetland) would succeed to this cover type with time.

{6} The 20 acres include portions of Reaches 3, 4 and 5.

{7} This forty acres of emergent wetland is being created in Reach 4 ponding areas. which at present are not wetlands.

{8} Engineering and Environmental Design Features in Reach 4 include the 1 year bypass rule, and operation of the Pequannock Weir in conjunction with the retainage of the existing U.S.G.S. Weir to maintain existing water surface and groundwater levels upstream of the Pompton Inlet.

{9} The plan as currently developed calls for the removal of trees to prevent damage to structural elements of the project. The Pequannock Weir would maintain water surface elevations, therefore, wetland would remain, but would change from forested to scrub-shrub.

{10} Engineering and Environmental Design Features in Reach 5 include the 1 year bypass rule, and operation of the Great Piece Meadows Weir.

515

TABLE C-88 (Page 9 of 11)

LEVEE/FLOODWALL/NONSTRUCTURAL/CHANNEL MODIFICATION PLAN

(1)
EFFECTS OF STAGE III PLANS ON AQUATIC AND WETLAND AREAS, AND MITIGATION, AND OTHER TECHNIQUES TO OFFSET EFFECTS

	AQUATIC (ACRES)	WETLAND (ACRES)			
		FORESTED	SCRUB-SHRUB	EMERGENT	TOTAL
REACH 1 MOUTH TO DUNDEE DAM					
Aquatic Habitat in Project Area	930	-	-	-	-
Wetland Habitat in Project Area	-	4	1	40	45
Effects of Levees (Without Mitigation)(2)					
Direct Effect - Loss	0	-1	-1	-4	-6
Direct Effect - Habitat Change	0	0	0	0	0
Indirect Effect Loss	0	0	0	0	0
Indirect Effect Habitat Change	0	0	0	0	0
Mitigation For Levee Effects	0	+1	+1	+4	+6(3)
NET EFFECT OF PLAN - REACH 1	0	0	0	0	0(4)
Effects of Channel Modification (Without Mitigation)					
Direct Effect - Habitat Change	-84	-	-	-	0
Mitigation For Channel Modification	+21	0	0	0	0
NET EFFECT OF PLAN - REACH 1	-63	0	0	0	0
REACH 2 DUNDEE DAM TO BEATTIES DAM					
Aquatic Habitat in Project Area	325	-	-	-	-
Wetland Habitat in Project Area	-	30	10	0	40
Effects of Channel Modification (Without Mitigation) Direct Effect - Habitat Change	-325	-30	-10	0	-40
Mitigation For Channel Modification	+80	+30(5)	0	0	+30(3)
NET EFFECT OF PLAN - REACH 2	-245	0	-10	0	-10(4)

TABLE C-88 (Page 10 of 11)

LEVEE/FLOODWALL/NONSTRUCTURAL/CHANNEL MODIFICATION PLAN

(1)
EFFECTS OF STAGE III PLANS ON AQUATIC AND WETLAND AREAS, AND MITIGATION, AND OTHER TECHNIQUES TO OFFSET EFFECTS

	AQUATIC (ACRES)	WETLAND (ACRES)			
		FORESTED	SCRUB-SHRUB	EMERGENT	TOTAL
REACH 3 BEATTIES DAM TO TWO BRIDGES					
Aquatic Habitat in Project Area	80	-	-	-	-
Wetland Habitat in Project Area	-	5	0	0	5
Effects of Structure Buyout Without Mitigation					
Direct Effect -	0	0	0	0	0
Mitigation Applied to Nonstructural Plan For Ponding Areas	0	0	0	+5	+5
NET EFFECT OF STRUCTURE BUYOUT - REACH 4	0	0	0	+5	+5
REACH 4 POMPTON VALLEY					
Aquatic Habitat in Project Area	40	-	-	-	-
Wetland Habitat in Project Area	-	1260	220	200	1680
Effects of Nonstructural Plan (Without Mitigation)	0	0	0	0	0
Mitigation Applied to Nonstructural Plan For Ponding Areas	0	0	0	+10	+10
NET EFFECT OF NONSTRUCTURAL PLAN - REACH 4	0	0	0	+10	+10
REACH 5 TWO BRIDGES UPSTREAM ON THE PASSAIC RIVER					
Aquatic Habitat in Project Area	50	-	-	-	60
Wetland Habitat in Project Area	-	6935	1310	3075	11320
Effects of Levees (Without Mitigation)					
Direct Effect - Loss	0	-20	-5	-5	-30
Mitgiation For Levee Effects	0	+20(5)	0	+5	+25
NET EFFECT OF LEVEES - REACH 5	0	0	-5	0	-5(4)

517

TABLE C-88 (Page 11 of 11)

LEVEE/FLOODWALL/NONSTRUCTURAL/CHANNEL MODIFICATION PLAN

{1}
EFFECTS OF STAGE III PLANS ON AQUATIC AND WETLAND AREAS, AND MITIGATION, AND OTHER TECHNIQUES TO OFFSET EFFECTS

	AQUATIC (ACRES)	(WETLAND ACRES) FORESTED	SCRUB-SHRUB	EMERGENT	TOTAL
Effects of Ponds (Without Mitigation) Direct Effect - Loss	0	-164	-10	0	-174
Mitigation For Pond Effects	0	0	0	+174	+174
NET EFFECT OF PONDING AREAS - REACH 5	0	-164	-10	+174	0{4}
NET EFFECT - TOTAL PROJECT	-308	-164	-25	+189	0{4}

FOOTNOTES:

{1} Direct effects include modifications and losses resulting from construction of project components such as tunnel inlets, levees and floodwalls and excavation of ponding areas. Indirect effects include modifications and losses resulting from changes in the flow regime (i.e. changes to flood elevations and durations). Secondary effects (i.e. encroachment of development of natural areas) will not occur as a result of project in Reaches 1-3 since virtually all areas are developed, or dedicated parkland. In Reaches 4 and 5, floodways contiguous to acquisition areas will be maintained according to the New Jersey State - Corps agreement in Items of Local Cooperation.

{2} The categories (eg. Direct Effect - Loss, etc.) are fully arrayed only once, in subsequent iterations only the pertinent category(s) are displayed.

{3} Mitigation would be carried out in Reach 4 and 5, on project (acquisition) lands.

{4} The Net Effect (eg. 0) does not necessarily imply full compensation (eg. in kind, in place), but rather the maximum mitigation attainable with the plan as proposed.

{5} Areas of replacement (forested cover type wetland) would succeed to this cover type with time.

However, in the Central Basin, Plan 16A may result in the maintenance of fishery due to maintenance of water quality. The tunnel plans would cause a reduction of aquatic habitat in the Central Basin during construction. Plan 30A would adversely impact three times as much aquatic habitat as Plan 30E. Use of habitat mitigation measures as part of Plans 30E and 30A would help restore the fishery after construction. However, temporary adverse impacts would occur during periodic maintenance of the modified channels.

c. Water Quality. Adverse water quality impacts resulting from the three detailed plans would be of a short-term nature, occurring during construction and maintenance activities. Plan 16A would impact water quality only in the Lower Valley, where the water quality is already severely degraded. Plans 30A and 30E would adversely impact the higher water quality in the Central Basin. Plan 30A, the Single Inlet Tunnel Plan, would have the most significant impacts of the three detailed plans.

d. Other Significant Resources. The impacts of the three detailed plans would be approximately the same on other significant resources including recreation, hazardous and toxic waste sites, endangered and threatened species, transportation, and cultural resources.

COMPARISON AND TRADE-OFF SUMMARY

A comparison and trade-off analysis is used to provide a basis for plan selection. The process used to compare the detailed plans consists of a trade-off analysis of the plan characteristics discussed above, including contributions to the planning objectives, the beneficial and adverse effects of each alternative and the responses to specific evaluation criteria. Table C-89 presents the rankings of the plans based on criteria significant to the comparison and trade-off analysis.

Plan 30E is ranked first based on NED criteria since it maximizes benefits over costs. It was, therefore, designated the NED plan. Plan 30E also provides the highest level of protection. In the major damage reaches along the Pompton River, Plan 30E provides a 100 year level of protection while Plans 30A and 16A provide 50 year and 10 year protection, respectively. Based on environmental quality criteria, Plan 30E ranks first. As such, it was designated the least environmentally damaging plan. Additionally, Plan 30E, which has the least amount of channel modification, would have the least impact on aquatic resources. Plan 30A would have more extensive

519

TABLE C-89

SUMMARY EVALUATION OF DETAILED PLANS

SIGNIFICANT CRITERIA RANKING 1/

Plan	NED	EQ	NON-FED SPONSOR	PUBLIC ACCEPTABILITY	COMPLETENESS	TOTAL RAW SCORE	OVERALL RANKING
30E	1	1	1	1	1	5	1
30A	2	3	2	3	1	11	2
16A	3	2	3	2	3	13	3

1/ Most desirable plan = 1 .... least desirable = 3

and deeper channel modifications than Plan 30E and would, therefore, have substantially greater adverse impacts on aquatic resources. Plan 16A would have extensive channel modification in the Lower Valley which would adversely impact anadromous fish.

RATIONALE FOR SELECTION

Plan 30E was selected as the recommended plan for the following reasons:

- It is the NED plan, the plan which reasonably maximizes net excess benefits consistent with protecting the Nation's environment.
- It is accepted by the public and is the plan supported by the non-Federal sponsor.
- It efficiently and effectively addresses the problem and opportunity statement of reducing the flood hazard and associated urban flood damages along the Main Stem Passaic River and its major tributaries.
- It reduces average annual equivalent flood damages by 83%.
- It provides the highest level of protection of the detailed planning stage alternatives.
- It is the least environmentally damaging of the detailed planning stage alternatives.

DIFFERENCES FROM PLAN SELECTED BY STATE

The Pompton/Passaic Rivers Dual Inlet Tunnel Diversion Plan, the revised Plan 30E, is detailed in Section 10. However, the major differences between this plan and the preferred plan selected by the State of New Jersey are summarized below. The revisions to the plan were made either to improve the economic efficiency of the plan or in response to requests from the State of New Jersey.

- The tunnel inlet on the Passaic River was relocated to the Two Bridges area.
- The tunnel outlet was relocated to the Passaic River upstream of its Third River confluence.
- The main tunnel diameter was reduced by one foot to 39 feet.

521

- A 22-foot diameter, 1.2 mile-long spur tunnel was incorporated into the plan.

- The preservation of 5,350 acres of Central Basin natural storage areas was incorporated into the plan.

- The channel modification on the Passaic River was reduced in length by 2.8 miles and in depth by 5 feet.

- The channel modifications on the Ramapo, Pequannock and Wanaque Rivers were reduced in depths and widths.

- The tidal levee/floodwall systems were reduced in length by 1.6 miles. The levels of protection of the remaining systems were increased to a 500-year event.

- The Lower Valley levee/floodwall systems integral to the tunnel were increased in length by 1.6 miles.

- The 5.0 miles of Lower Valley fluvial levees and floodwalls were eliminated.

- The Central Basin fluvial levee/floodwall systems were reduced in length by 12.1 miles. The level of protection of one system was increased to a 500 year event.

- The levee/floodwall systems integral to the Pompton River tunnel inlet were reduced in length by 1.9 miles.

- Environmental and fish and wildlife mitigation measures were incorporated into the plan.

- Project planning addressed needs for river access and local recreation plans.

SECTION 10 - RECOMMENDED PLAN

GENERAL

The Pompton/Passaic Dual Inlet Tunnel Diversion Plan combines large underground diversion tunnels with levees, floodwalls, channel modifications and natural flood storage to provide flood protection to major damage areas in the Pompton River Valley, the Central Passaic Basin and the lower Passaic River. The plan is depicted on Figure C-90. (All figures contained in Section 10, C-90 to C-136 can be found at the end of the text.)

The major elements of this flood control proposal are the two tunnels, with the key being the 13.5-mile long, 39- foot diameter main tunnel, which would carry floodwaters from an inlet at the upper Pompton River down to an outlet on the lower Passaic River. A 1.2-mile long, 22-foot diameter spur tunnel would convey Central Basin area floodwaters from an inlet just downstream of Two Bridges on the Passaic River, to an underground connection with the main diversion tunnel. The two inlets would be located in Wayne Township while the outlet would rise on the west bank of the Passaic River at its confluence with the Third River in Clifton. The diversion tunnels and associated surface works are designed to protect against a 100 year flood event.

The tunnels would be entirely underground, some 125 feet below the surface at the Pompton Inlet, about 130 feet below the Passaic Inlet, and approximately 155 feet below the outlet. The intersection of the main and spur tunnels would be about 150 feet below ground level. At its deepest point, under the Watchung Mountains in the vicinity of the Little Falls-Clifton border, the main tunnel would be some 450 feet underground.

The Dual Inlet Plan was developed to make more efficient use of the main tunnel with the expectation that flows could be further reduced by a second inlet at Two Bridges, while operating the tunnel with a priority diversion at the Pompton River Inlet. The double inlet takes advantage of the approximate two-day difference in timing of the flood peaks to make more effective use of the tunnel. The objective is to direct as much flow as possible into the Pompton River Inlet and then, if the tunnel flow is less than capacity, allow additional flow to enter the tunnel by the operation of gates in the Two Bridges diversion spillway. The Floodwarning and Forecasting System for the Passaic River Basin, which is currently being enhanced by the Corps of Engineers in cooperation with the State of New Jersey, will be an integral element in carrying out the established operating rules for the tunnel.

A total of 5.9 miles of channel modifications would be required to direct the flows into the inlets. The diversion tunnels will be augmented by 26 levee/floodwall systems, comprising 23.7 miles of levees and 14.0 miles of floodwall. The levees and floodwalls will be situated along the Passaic River and tributaries throughout the damage areas. Except for a transition channel at the Passaic River confluence, no other structural remedies will be needed along the Pompton River because the tunnel will divert most of the Pompton Valley flood flows.

In the Lower Valley, no works are proposed from Beatties Dam downstream to just above the Saddle River because the tunnel would divert most of the damaging flood flows away from this area.

From just above the Saddle River down to Newark Bay, the plan calls for 14 levee/floodwall systems with about 11.2 miles of levee and almost 12.8 miles of floodwall. The levee/floodwall systems between the Saddle River vicinity and the Second River are required to protect against the combined tidal and fluvial effects, including the tunnel discharges. These systems would provide protection against a 100-year flood. A tunnel diversion plan could not be constructed without the implementation of these flood control measures. From the Second River downstream to Newark Bay, intermittent levees and floodwalls are required to protect against flooding from tidal events. They would provide protection against a 500-year flood.

Upstream of the Pompton Inlet, 3.5 miles of levees, 0.7 miles of floodwalls, and 4.8 miles of channel modifications would be required to direct flood flows into the tunnel, and to protect upstream areas. The lower Pequannock, Wanaque and Ramapo Rivers would be deepened an average of 7, 6, and 4 feet, respectively. The Pompton Valley would be protected against a 100-year flood event. The Passaic River channel would be deepened for a distance of 0.8 miles from upstream of Two Bridges to the Route 46 crossing to divert flood flows into the spur tunnel's Passaic River Inlet. A 0.3 mile transition channel would extend up the Pompton River from the Passaic River confluence.

Along the Passaic River, upstream of Two Bridges, levels of protection ranging from 100 to 500 years would be provided at intermittent locations by setback levees and floodwalls. These systems include about 9 miles of levees and 1/2 mile of floodwall.

Channel modification and levee/floodwall plan elements are detailed in Tables C-79 and C-80.

Each levee/floodwall system includes interior drainage facilities, such as ponding areas and pumping stations, which would handle the interior runoff generated behind the line of protection.

The planning of levees and floodwalls includes provisions for required river access. Recreational beautification features have been included on the Passaic River east bank between the Saddle and Second Rivers at the request of the non-Federal sponsor. These include hiking/biking paths, overlooks, benches, water fountains, and pocket parks.

The plan requires a total of 810 acres of real estate as permanent easements for structural features and operation and maintenance activities. During construction, an additional 193 acres of property would be required as temporary easements. The surface works of the tunnel elements would require 16 acres to be acquired "in fee." Subsurface easements would be required from over 340 parcels of properties along the tunnel routes. Table C-90 presents a summary of real estate requirements for each affected municipality. It is essential that the tunnel inlet, outlet and work shaft sites be acquired early in the process in order to preclude development at these locations.

The preservation of 5,350 acres of natural storage areas in the Central Passaic Basin is also a major feature of the plan. The acquisition of these lands would insure the future integrity of the design scale of the project by preventing increases in flood flows which might be caused by the loss of these areas to development. This acquisition, in conjunction with the 15,865 acres already protected under existing Federal and State programs, would preserve the flood storage and environmental characteristics of the Central Basin wetlands. Therefore, as part of this plan, it is required that the existing floodways in the areas of acquisition be maintained.

Figures C-91 to C-122 present the layout of the selected plan along with improved floodplain delineations, hydraulic profiles and typical sections.

TUNNEL ELEMENTS

The function of the tunnel elements of the plan is to divert flood flows from the upper Pompton River and from the Central Passaic River and reintroduce them into the estuarine portion of the Passaic River, bypassing highly developed areas along the Pompton and lower Passaic Rivers. Figures C-123 to C-127 present details regarding the tunnel design.

TABLE C-90

DUAL INLET TUNNEL PLAN
REAL ESTATE REQUIREMENTS

LEVEE/FLOODWALL AND CHANNEL ELEMENTS

COMMUNITY	EASEMENTS		
	PERMANENT, UPLAND (ACRE)	PERMANENT, RIVER (ACRE)	TEMPORARY (ACRE)
BERGEN COUNTY:			
E. RUTHERFORD BORO.	3.54	-	1.64
LYNDHURST TWP.	17.71	-	5.57
N. ARLINGTON BORO.	14.37	-	5.92
RUTHERFORD BORO.	10.33	-	5.77
WALLINGTON BORO.	8.77	-	3.47
ESSEX COUNTY:			
BELLEVILLE TOWN	6.42	-	5.71
FAIRFIELD BORO.	82.95	13.77	18.85
LIVINGSTON TWP.	27.41	-	3.11
NEWARK CITY	44.50	-	9.84
NUTLEY TOWN	4.89	-	3.29
W. CALDWELL BORO.	15.51	-	3.44
HUDSON COUNTY:			
HARRISON TOWN	8.09	-	3.60
KEARNY TOWN	94.96	-	21.12

TABLE C-90 (CONT)

DUAL INLET TUNNEL PLAN
REAL ESTATE REQUIREMENTS

LEVEE/FLOODWALL AND CHANNEL ELEMENTS

COMMUNITY	EASEMENTS		
	PERMANENT, UPLAND (ACRE)	PERMANENT, RIVER (ACRE)	TEMPORARY (ACRE)
MORRIS COUNTY:			
E. HANOVER TWP.	13.45	-	2.33
LINCOLN PARK BORO.	1.14	10.33	1.65
MONTVILLE TWP.	47.92	-	3.68
PARSIP-TROY HILLS	128.05	-	6.86
PEQUANNOCK TWP.	1.93	15.43	11.47
RIVERDALE BORO.	1.17	9.37	2.18
PASSAIC COUNTY:			
CLIFTON CITY	6.35	-	2.43
PASSAIC CITY	17.00	-	9.99
POMPTON LAKES BORO.	86.25	50.81	30.24
WAYNE TWP.	35.35	32.87	17.91
TOTAL LEVEE/ FLOODWALL AND CHANNEL ELEMENTS	678.06	132.58	180.07

TABLE C-90 (CONT)

TUNNEL ELEMENT

COMMUNITY	SURFACE RIGHTS		SUBSURFACE EASEMENTS
	FEE TAKING (ACRE)	TEMPORARY EASEMENT (ACRE)	NUMBER OF PARCELS AFFECTED BY TUNNEL
PASSAIC COUNTY:			
CLIFTON CITY	3.50	3.50	106
LITTLE FALLS TWP.	1.50	2.50	86
TOTOWA BORO.	-	-	5
WAYNE TWP.	11.00	7.00	147
TOTAL TUNNEL	16.00	13.00	344

Pompton River Inlet. The proposed location of the inlet portal is upstream of the Pompton Plains Cross Road (Jackson Avenue) Bridge in Wayne Township on the east bank of the Pompton River immediately downstream of the confluence of the Ramapo and Pequannock Rivers (see Figure C-125). The site is currently part of a sand and gravel mining operation with these material stockpiled on and adjacent to the site. The area around the site is generally an undeveloped low-lying floodplain to the west and north, and agricultural to the east. Stream slopes in the area are very flat. The necessary structures consist of a river flow restrictor, a river diversion spillway, and a morning glory tunnel inlet. The inlet would be located in a basin that is approximately 400 feet in diameter and excavated to a depth of 8 feet.

Two Bridges Inlet and Spur Tunnel. The proposed inlet is located on the east bank of the Passaic River, about 500 feet upstream of the Route 80 bridge, adjacent to Fairfield Road in Wayne (see Figure C-126). To utilize this site, a bridge for Fairfield Road would be built over the inlet structure. The surrounding area is lightly developed for residential use and mostly consists of undeveloped low-lying wetlands. The inlet structure, which is similar to the Pompton River tunnel inlet, would consist of a gated diversion spillway and morning glory tunnel inlet. The diversion spillway would consist of gates to control the floodwaters which enter the basin containing the morning glory inlet. The morning glory inlet is contained in a basin similar to the Pompton Inlet. This inlet leads to a 22-foot diameter, 1.2-mile long spur tunnel which connects to the main tunnel route.

Tunnel Outlet. The outlet location is on the west bank of the Passaic River at its confluence with the Third River (see Figure C-125). The diverted flows would exit the tunnel through an upshaft to the surface at sea level (greatly reducing water velocity) and then flow out into the Passaic River. Levees and floodwalls would be constructed on both banks of the Third River to protect nearby areas from increased river stages estimated to be 15.4 feet N.G.V.D., as compared to 11.3 feet that would occur under without project conditions for the 100-year design flows. Because the tunnel outlet is in the tidal portion of the Passaic River, levees and floodwalls are the only suitable measure for mitigating the increased flood stages. To protect against hurricane surges and to mitigate for increased flood stages, a total of 5.7 miles of levees averaging 9.7 feet in height and 7.8 miles of floodwalls averaging 9.6 feet in height would be required between the Second River and the Monroe Street Bridge, a distance of 8.2 miles. These additional flows, however, would have negligible effects on river stages downstream of the Rutgers Avenue Bridge because of the large flow capacity of the navigation channel below this location.

Alternate Outlet Locations. Relocating the tunnel outlet to Newark Bay would eliminate the need for the nine integral levee/floodwall systems, totalling 13.5 miles, along the Passaic River from the Second River to upstream of the Saddle River. The Newark Bay outlet would require the main tunnel to be 35,000 feet longer and one-foot larger in diameter in order to maintain the same level of protection upstream of Dundee Dam. The additional tunnel work would extend the construction period by at least 18 months. The Newark Bay outlet option would add up to $300 million to the investment cost of the Dual Inlet Tunnel Plan, resulting in a total annual cost of $110,400,000. The average annual equivalent benefits of the plan would be reduced by $5,500,000 to $117,000,000 (October 1986 price level). With a Newark Bay outlet, the Dual Inlet Plan would have a benefit-cost ratio of 1.1.

A tunnel outlet in the vicinity of the Second River would eliminate the need for three integral levee/floodwall systems (Eighth Street, River St.-Main Ave., and River Drive 1 systems), totalling 5.0 miles. The remaining six systems integral to the tunnel outlet would be one to 3.5 feet lower in height than required with the outlet in the Third River vicinity. The Second River outlet would add almost 10,000 feet to the tunnel length and extend the construction period by about one year. The investment cost of the Dual Inlet Tunnel Plan would increase by about $100 million, resulting in total annual cost of $93,900,000. The benefits of the plan with a Second River outlet would be approximately the same as with the outlet in the Third River vicinity. The benefit-cost ratio of the Dual Inlet Tunnel Plan with a Second River outlet would be 1.3.

CHANNEL MODIFICATIONS INTEGRAL TO THE TUNNEL ELEMENT

Channel modifications included as part of this plan along the Passaic, Pompton, Pequannock, Wanaque and Ramapo Rivers are required to direct flood flows into the tunnel inlets. The modifications along the latter three rivers are also required to provide protection to the areas upstream of the Pompton River tunnel inlet.

Passaic and Pompton Rivers. Transition channels, which would direct flows into the inlet to the spur tunnel on the Passaic River, would involve about 0.8 miles of the Passaic River, from upstream of Two Bridges down to the Route 46 Bridge, and about 0.3 miles of the Pompton River, extending upstream from its confluence with the Passaic (See Figure C-102). This channel would have an average base width of 175 feet and would be deepened an average of 4 to 5 feet. The resulting top width of the channel would be approximately 235 feet. The top width of the existing channel averages approximately 220 feet.

Pequannock River. The channel modifications along the Pequannock River would extend from the location of the Pompton River tunnel inlet, just upstream of Pompton Plains Cross Road, upstream for 2.6 miles, as shown on Figure C-114. The modification would consist of deepening the existing channel by 7 feet and increasing the channel's bottom width to an average of 74 to 100 feet. The top width of the modified channel would range from 135 to 160 feet. The top width of the existing channel is approximately 100 feet.

Wanaque River. The channel modifications along the Wanaque River would extend from the Wanaque River-Pequannock River confluence to the Paterson-Hamburg Turnpike, about 1 mile upstream (see Figure C-115). The proposed modifications consist of deepening the existing channel approximately 6 feet and increasing the channel bottom width to an average 74 feet. The resulting average top width would be approximately 125 feet. The top width of the existing channel averages about 90 feet.

Ramapo River. The channel modifications along the Ramapo River extend from the Ramapo River-Pequannock River confluence, upstream for 1.2 miles, to the Paterson-Hamburg Turnpike Road (see Figure C-116). Ramapo River modifications consist of deepening the existing channel 4 feet and increasing the channel's bottom width to between 60 and 100 feet. The average top width of the modified channel would be approximately 150 feet. The top width of the existing channel is approximately 110 feet.

LEVEE/FLOODWALL SYSTEMS INTEGRAL TO THE TUNNEL ELEMENT

Levee/floodwall systems between the Saddle River and the Second River, and upstream of the Pompton River tunnel inlet are integral to the operation of the tunnel. Table C-80 provides data on the physical features of the levee/floodwall systems. Figures C-93 to C-96 and C-114 to C-116 present the layout of the systems. The descriptions below contain components such as walking paths, overlooks, etc. included in the project under beautification.

Induced Damages. The economic effects of the integral levee/floodwall systems are detailed by damage reach in Table C-91. These systems eliminate 76% of the average annual equivalent damages induced by the operation of the tunnel. The induced damages not eliminated by the integral levees and floodwalls were considered as a project cost. The integral systems, which are scaled at the 100 year level of protection, also provide additional benefits of almost $4,700,000 resulting from a reduction in without project conditions damages. Phase II studies will consider the feasibility of increasing the level of protection beyond the 100 year event for those damages reaches that have significant residual induced damages.

TABLE C-91

INDUCED DAMAGES
(Oct. 1986 Price Level, 8-5/8% Interest Rate, Base Year 2000,
Average Annual Equivalent Dollars, $1,000's)

	WITHOUT PROJECT	WITH TUNNEL/ PRESERVATION		WITH INTEGRAL LEVEE/FLOODWALL SYSTEMS			
DAMAGE REACH	ANNUAL DAMAGES	ANNUAL DAMAGES	INDUCED DAMAGES	ANNUAL DAMAGES	INDUCED DAMAGES ELIMINATED	ADDITIONAL BENEFITS	INDUCED DAMAGES NOT ELIMINATED
010031	1.4	5.3	3.9	5.3	.0	.0	3.9
010032	685.0	1,097.2	412.2	91.6	320.6	685.0	91.6
010041	99.9	264.4	164.5	53.5	111.0	99.9	53.5
011042	333.8	896.5	562.7	186.4	376.3	333.8	186.4
010051	76.5	236.6	160.1	35.6	124.5	76.5	35.6
010052	223.8	495.5	271.7	46.6	225.1	223.8	46.6
010061	232.5	504.9	272.4	36.2	236.2	232.5	36.2
010071	389.2	1,098.8	709.6	134.5	575.1	389.2	134.5
010072	367.9	1,019.0	651.1	93.9	557.2	367.9	93.9
010081	26.0	44.1	18.1	4.9	13.2	26.0	4.9
010091	522.3	1,257.1	734.8	272.4	496.6	488.1	238.2
010092	11.9	21.7	9.8	7.4	4.8	9.5	5.0
010101	988.4	1,011.9	23.5	305.2	23.5	683.2	.0
010102 a/	1,111.4	1,104.6	.0	211.2	.0	804.9	.0
010107	14.1	15.7	1.6	15.7	.0	.0	1.6
010109	10.9	11.4	0.5	11.4	.0	.0	0.5
010112 a/	524.7	455.9	.0	240.5	.0	245.4	.0
010118	950.6	953.0	2.4	953.0	.0	.0	2.4
010119	36.7	40.2	3.5	40.2	.0	.0	3.5
670031 b/	22.2	26.5	6.6	5.5	1.8	19.2	2.5
670032 b/	13.7	14.9	1.7	1.5	0.2	12.9	0.7
670040 c/	53.5	61.9	8.1	61.6	.0	.0	8.1
TOTAL	6,696.4	10,637.1	4018.8	2814.1	3066.1	4697.8	949.6

a/ Although there is an overall reduction in average annual equivalent damages for this reach with the tunnel and preservation compared to the without project conditions, there would be an increase in damages for some storm events. Therefore, an integral levee/floodwall system was included in this reach.

b/ The integral levees and floodwalls in this reach, required to direct floodwaters to the Pompton inlet, reduce the available floodplain storage and thereby cause an increase in damages for storm events that overtop the levee/floodwall system.

c/ Induced flooding is caused by downstream integral levee/floodwall systems which increase flood stages upstream as a result of reducing floodplain storage.

Descriptions of Levee/Floodwall Systems. There are a total of 14 integral levee/floodwall systems; nine systems are located in the vicinity of the tunnel outlet and five are located upstream of the Pompton tunnel inlet. The integral levee/floodwall systems are described below.

In the Borough of North Arlington and the Town of Kearny, commercial and industrial structures along the left bank of the Passaic River within the area bounded by the Passaic River, Baltimore Avenue, and Belleville Turnpike would be protected against tidal and fluvial flooding, including the tunnel discharges, by 4,710 feet of levee with an average height of 7.3 feet and resulting base width of 53.8 feet, and 830 feet of floodwall averaging 6.0 feet in height. The River Road levee/floodwall system #1 (Figure C-94) would also require the raising of 110 feet of Passaic Avenue and inclusion of a gated structure across the Belleville Turnpike bridge. Recreational/beautification features would include a walking/bike path on top of the levee and a river overlook near the upstream end of the levee. Runoff from the 35 acre drainage area behind the system would be removed by 299 cfs and 319 cfs capacity pumping stations.

The Riverside Avenue #1 levee/floodwall system (see Figure C-94), located on the left bank of the Passaic River in North Arlington, Lyndhurst, and Rutherford, consists of 8,570 feet of levee and 2,460 feet of floodwall. It protects the residential, commercial, and industrial structures bounded by the Passaic River, Route 3, and Baltimore Avenue from tidal and fluvial flooding, including the tunnel discharges. The levee in this area would have an average height of 12.6 feet and base width of 85.6 feet. The floodwalls would be 9.3 feet high. Gated structures would be required for river access and across the Kingsland Avenue Bridge. The recreational/beautification features would include a walking/bike path on the levee, alignment of the levee to form an amphitheater, a public boating facility in Lyndhurst and a strip park at the upstream end of the system. Runoff from the 577 acre drainage area behind the system would be handled by 263, 311, 318, 401 and 429 cfs capacity pumping stations.

The right bank of the Passaic River, in the communities of Belleville, Nutley and Clifton, would be protected from tidal and fluvial flooding, including the tunnel discharges, from the Second River to the Third River by two levee/floodwall systems, the Main Street and River Road #2 systems (Figures C-93 and C-94). The length of levee required for the Main Street system would be 560 feet at an average height of 4.5 feet and base width of 37.0 feet. The floodwall would average 7.5 feet high for its 6,580 foot length. The River Road #2 system would have 2,650 feet of levee and 7,720 feet of floodwall. The average

heights would be 8.0 feet and 9.0 feet, respectively. The levee base width would average 58.0 feet. Gated structures would be placed at the McCarter Highway, Rutgers Street, Route 21 and Kingsland Avenue bridges. Access to the river for boating and a boat shelter would also be provided. Interior drainage would be handled by 228, 253, 255, and 337 cfs capacity pumping stations for the Main Street System, and by 217, 237, 297, and 345 cfs capacity pumping stations for the River Road #2 system.

Along the left bank of the Third River approximately 1,540 feet of levees and 1,120 feet of floodwalls would be required to protect against tidal and fluvial floods, including tunnel discharges. The levees and floodwalls would average 11.5 feet and 9.9 feet in height, respectively, with the base width of the levee averaging 79.0 feet. The levees and floodwalls, known as the Yantacaw levee/floodwall system, would extend from Route 21 to Route 3 on the Third River, as shown on Figure C-94. A 100 foot section of River Road would require raising in order to provide a continuous line of protection. In addition, a Passaic Valley Sewerage Commission's pumping station would be replaced. Runoff from behind the system would be handled by a 299 cfs capacity pumping station.

On the left bank of the Passaic River in the Borough of Rutherford, the Riverside Avenue levee/floodwall system #2 would provide tidal and fluvial flood protection, including protection against backwater from the tunnel discharge, to the area from the Route 3 Bridge upstream almost to the Union Avenue Bridge (see Figures C-94 and C-95). To protect this area, 1,570 feet of 9.2 foot high levees with an average base width of 65.2 feet, and 4,990 feet of floodwalls averaging 11.6 feet in height would be required. Gated structures would allow river access. A walking path on the levee, a strip park, two pocket parks and a public boat launching ramp would be part of the recreational/ beautification features in this system. Runoff from the system would be handled by 222, 228, two 239 and a 355 cfs capacity pumping stations.

Along the right bank of the Passaic River in the City of Passaic, structures within the area bounded by the Passaic River and Route 21 would be protected from tidal and fluvial flooding, including tunnel discharge backwater, by 1,920 feet of levee and 3,760 feet of floodwall (see Figure C-95). In the River Drive levee/floodwall system #1, levees would have an average height of 9.2 feet and a base width of 65.2 feet. The floodwalls would have an average height of 8.0 feet. Concrete capping along Route 21 would also be provided to prevent flooding of the highway. A gated structure on the Main Avenue bridge and under

Route 21 near Wayside Court would be required in order to ensure a continuous line of protection. Gated structures would also be required for river access. Runoff from the 36 acre drainage area would be handled by 358 and 400 cfs capacity pumping stations.

The River Street - Main Avenue levee/floodwall system would be located on the left bank of the Passaic River in the Boroughs of Rutherford, East Rutherford and Wallington, as shown on Figure C-95. The system would extend from Washington Avenue in Rutherford upstream to Alden Street in Wallington. The system would consist of 5,860 feet of levee with an average height and base width of 8.2 feet and 59.2 feet, respectively, and 4,160 feet of floodwall with an average height of 10.1 feet. Gated structures would be located on the Main Avenue and 8th Street bridges in order to ensure a continuous line of protection. Protection would be provided against tidal and fluvial flooding, including backwater flooding from the tunnel discharge. Access would also be provided to dock facilities on the river. Recreational/beautification features would be provided in the form of a walking/bike path on the levee, a public boat ramp and two parks. A third park would be located further upstream in Garfield below Dundee Dam. Runoff from the 522.5 acre drainage area behind the levee/floodwall system would be handled by two pumping stations, having 325 cfs and 62 cfs capacities.

On the right bank of the Passaic River, in the City of Passaic, the area bounded by the Passaic River, Weasel Brook, and Monroe Street would be protected by 2,580 feet of levee and 9,780 feet of floodwall (see Figures C-95 and C-96). In the 8th Street levee/floodwall system, levees would have an average height of 10.0 feet and a resultant base width of 70.0 feet. The floodwalls would have an average height of 10.8 feet. Protection would be provided against tidal and fluvial flooding, including backwater flooding from the tunnel discharge.

Closures in the form of gates would be required across an industrial access road over Weasel Brook and the 8th Street, Wall Street, Conrail Railroad and Monroe Street bridges. A 211 cfs pumping station would handle the runoff from the 207.5 acre drainage area.

The Pequannock - Ramapo levee/floodwall system is located on the left bank of the Pequannock River and on the right bank of the Ramapo River in the Borough of Pompton Lakes, as presented on Figures C-114 and C-116. This system would provide protection to structures within the area bounded on the south and west by the Pequannock River, on the east by the Ramapo

River and on the north by Riverview Road. To protect against flooding, 9,230 feet of levees and 1,500 feet of floodwalls would be required. The levees would have an average height of 9.4 feet and base width of 66.4 feet. The floodwalls would have an average height of 10.8 feet.

It would be necessary to raise portions of Riverview Road and Willow Avenue in order to maintain the line of protection. To collect runoff from the 348 acre drainage area behind the system, three ponding areas would be required. The ponding areas would consist of an 11.8 acre pond, 4 feet deep; a 25.8 acre pond, 3 feet deep; and a 8.0 acre pond, 4 feet deep.

The Shore Road levee/floodwall system would consist of 4,500 feet of levees and 1200 feet of floodwalls located on the left bank of the Ramapo River in the Township of Wayne (see Figure C-116). Protection would be provided to structures within the area bounded by the Ramapo River and Black Oakridge Road. The levees would have an average height of 8.0 feet, with a base width of 58.0 feet. The floodwalls would have an average height of 8.2 feet.

The levees and floodwalls would be located along the river due to the close proximity of structures to the bank. Runoff from the 230 acre drainage area behind the levee/floodwall system would be collected by 3 ponding areas. These consist of an 8.4 acre pond, 5 feet deep; a 4.9 acre pond, 5 feet deep; and an 8.2 acre pond, 4 feet deep.

The Stiles Court levee system is located on the left bank of the Pequannock River in the Borough of Pompton Lakes (see Figure C-114). This system would provide protection to the structures in the area bounded by the New York Susquehanna and Western Railroad (NYSWRR) on the north, Ringwood Avenue to the east and Hamburg Turnpike to the south. To protect against flooding, 1,760 feet of levees would be required. The levees would have an average height of 3.3 feet and base width of 29.8 feet. A 2.1 acre pond, 4 feet deep, would be required to collect the runoff from behind the levee.

The Hill Court levee/floodwall system is located on the right bank of the Wanaque River in the Borough of Pompton Lakes, as shown on Figure C-115. The system provides protection to the structures along Henderson and Hill Courts.

To protect this area against flooding, 1,350 feet of levees and 600 feet of floodwall would be required. The levees would have an average height of 8.7 feet and a base width of about 62.2 feet. The floodwalls would have an average height of 8 feet. A 1.6 acre pond, 4.5 feet deep, would be required to collect runoff from behind the system.

The Wanaque Avenue levee/floodwall system is located on the left bank of the Wanaque River in the Borough of Pompton Lakes, as shown in Figure C-115. This system would provide protection to the structures bounded by the Wanaque River and Wanaque Avenue between the NYSWRR and Pompton Avenue.

To protect this area against flooding, 1,540 feet of levee and 680 feet of floodwall would be required. The average height of the levees would be 9.9 feet and the average base width would be 69.4 feet. The floodwall would have an average height of 10.5 feet. Runoff would be collected by a 217 cfs capacity pumping station.

INCREMENTAL LEVEE/FLOODWALL ELEMENTS OF THE DUAL INLET TUNNEL DIVERSION PLAN

Table C-80 provides data on the physical features of the incremental levee/floodwall systems, along with the approximate station locations of each system. The descriptions below include project components, such as walking paths, overlooks, etc., which are categorized as beautification measures.

The most downstream area to be protected is located at Kearny Point at the mouth of the Passaic River, as shown on Figures C-91 and C-92. The Kearny Point levee/floodwall system consists of 16,600 feet of earthen levees and 17,920 feet of concrete floodwalls, protecting industrial structures on the left bank of the Passaic River, around Kearny Point and upstream along the right bank of the lower reaches of the Hackensack River in the Town of Kearny. The damages incurred in this area are predominantly the results of tidal flooding. The levees in this area average 8.8 feet in height and 62.8 feet in base width. The floodwalls are approximately 8 feet high. In order to provide a continuous line of protection, a gated structure would be required across Fish House Road and across three sections of railroad tracks. Access through the levees and floodwalls to the river and dock sites would be provided by gated structures. Runoff from the 1,011 acre drainage area behind the system, which would normally drain into the river by gravity, would be discharged by 335 cfs and 349 cfs capacity pumping stations, as well as collected by four ponding areas, 4 feet deep, totaling 50.4 acres.

Proceeding upstream along the Passaic River, the Doremus Avenue levee/floodwall system (see Figure C-91) would protect industrial structures against tidal flooding. These structures are located on the right bank of the Passaic River in the City of Newark, within the area bounded by the Passaic River, Lincoln Highway and the Central Railroad of New Jersey.

This system consists of 2,400 feet of levees with an average height of 8.0 feet and base width of 58.0 feet, and 1,910 feet of floodwalls with an average height of 10.2 feet. Gated structures would be provided at two openings underneath the Central Railroad of New Jersey in order to ensure the line of protection. Access would also be provided to the river through gated structures. Runoff from the 329 acre drainage area would be removed by two 253 cfs capacity pumping stations.

The area protected by the Turnpike levee/floodwall system, is bounded by the Passaic River, the NJ Turnpike, and Routes 1 and 9 in the City of Newark on the right bank of the Passaic River, as shown on Figure C-91. This system would protect industrial structures against tidal flooding. This system consists of 2,030 feet of levees and 590 feet of floodwalls. The levee averages 7.4 feet in height and 54.4 feet in width at the base. A 500 foot section of road would be realigned to accommodate a section of the levee. The floodwall is 7.5 feet high. Runoff from the 135 acre drainage area behind the system would be collected by three ponding areas, 4 feet deep, covering a total of 23.0 acres.

The Lister Avenue levee/floodwall system, shown on Figures C-91 and C-92, lies on the right bank of the Passaic River and consists of 4,930 feet of levees and 2,910 feet of floodwalls. The levee averages 7.4 feet in height and 54.4 feet in width at the base. The floodwall is 10.5 feet high. This system protects industrial, commercial, and residential structures within the area bounded by the Passaic River, NJ Turnpike, Ferry Street and Freeman Street in the City of Newark. Access would be provided to dock facilities through gated structures. A park would also be provided at the upstream end of the levee for recreational/beautification purposes. Runoff from the 395 acres of drainage area behind the system would be discharged by several pumping stations. The capacities of the pumping stations would be 255, 270 and 349 cfs.

The South 1st Street levee/floodwall system (see Figures C-92 and C-93) on the left bank of the Passaic River in the communities of East Newark and Harrison would provide protection from tidal floods between the South 4th Street Bridge and Route 280 upstream. A total of 3,130 feet of levees with an average height of 7.9 feet and base width of 57.4 feet, and 2,800 feet of floodwalls averaging 8.3 feet high would be required. In order to provide a continuous line of protection, gated structures would be required on the Harrison Avenue bridge and across Passaic Avenue. Access to the river would be provided through gated structures. A park would be located at the upstream end of the system as a recreational/beautification feature. Runoff from the drainage area behind the system would be handled by 200 cfs and 257 cfs capacity pumping stations.

The Passaic River levee/floodwall system #2A (see Figures C-103, C-104, C-107, C-119, and C-120) consists of 19,440 feet of earthen levees and 1,230 feet of floodwalls which protect residential, commercial and industrial structures in the Boroughs of Fairfield and West Caldwell within the area bounded by the right bank of the Passaic River, I-80, Bloomfield Avenue and the left bank of Deepavaal Brook. The levees would have an average height of 8.6 feet with a base width of 61.6 feet, while the floodwalls would have an average height of 9.0 feet. As part of this system, one road raising and the installation of flap valves on eleven culverts are required.

The runoff from the drainage area behind the system would be collected in six ponding areas, each 4 feet deep, ranging in size from 20.7 acres to 133.4 acres.

The Passaic River levee/floodwall system #2C is located along the right bank of the Deepavaal Brook in the Boroughs of Fairfield and West Caldwell (see Figure C-120). This system would provide protection to the structures along Fairfield Place.

To protect this area, 4,860 feet of levees and 950 feet of floodwalls would be required. The levees and floodwalls would have an average height of 7.0 feet and 8.5 feet, respectively. The average base width of the levees would be 52.0 feet. The runoff from the 67 acre drainage area would be collected by a 6.8 acre pond, 4 feet deep.

The Passaic River levee system #10 consists of 4,500 feet of levees located on the right bank of the Passaic River in the Township of Livingston, as shown on Figure C-109. Protection would be provided to structures within the area bounded on the west by the Passaic River and on the east by Eisenhower Parkway.

The levees would be set back approximately 800 feet from the river to protect the existing wetlands in this area. The average height of the levees would be 8.4 feet and the base width would be 60.4 feet. Runoff from the 302.7 acre drainage area behind the levee would be collected by two ponding areas, each 4 feet deep. The ponds would have areas of 8.6 and 10.4 acres.

The Rockaway River levee system #1 would consist of 3,640 feet of levees located on the right bank of the Rockaway River in the Township of Parsippany-Troy Hills (see Figures C-117 and C-118). Protection would be provided to structures within the area bounded by the Rockaway River, New Road, Edwards Road and Vail Road.

The portion of the levee system that is upstream of Route 80 would be set back approximately 1,100 feet from the river. The levees downstream of Route 80 would only be set back approximately 200 feet from the river since structures are located closer to the bank in this area. The average height of the levees would be 8.7 feet and the base width would be 62.2 feet.

In order to maintain the line of protection, it would be necessary to install gated structures on four culverts under I-280 and two culverts under I-80. Runoff from the 900 acre drainage area behind the system would be collected by six ponding areas. The ponding areas would vary in depth from 2 feet to 6 feet and their sizes would range from 3.3 acres to 28.1 acres.

The Rockaway River levee system #2 is located on the left bank of the Rockaway River in the Township of Montville, as shown on Figures C-117 and C-118. This system is designed to protect structures in the area bounded by the Rockaway River, Barnet Road, Walnut Drive, Konner Avenue, Dogwood Circle and Change Bridge Road.

To protect this area from flooding from the Rockaway River, 5,340 feet of levees would be aligned along the river. The levees would have an average height of 8.3 feet with a base width of 59.8 feet. It would also be necessary to raise a portion of Barnet Road, and two areas of Change Bridge Road.

A 27.5 acre ponding area, 4 feet deep, and a 10.5 acre pond, 5 feet deep, along with four pressure interceptors and a 148 cfs capacity pumping station would be required to collect surface runoff from the drainage area behind the levee.

The Rockaway River levee system #3 would consist of 6,320 feet of levees located on the right bank of the Rockaway River in the Township of Parsippany-Troy Hills (see Figure C-118). Protection would be provided to structures within the area bounded by the Rockaway River on the east, River Drive, Mohawk Avenue and Sandalwood Drive on the west, Vail Road on the south and Tioga Avenue on the north.

Due to the close proximity of structures to the bank, it would be necessary to align the levee along the stream and realign a portion of the channel. The average height of the levee would be approximately 10.3 feet. The average base width of the levee would be 71.8 feet.

Runoff from the 870 acre drainage area would be collected by a ponding area, a pressure interceptor, and a pumping station. The ponding area would consist of a 26 acre pond, 4 feet deep. The pressure interceptor would consist of a 72 inch diameter pipe. The pumping station would utilize a 188 cfs capacity pump.

The Pinch Brook levee/floodwall system is located on the right bank of Pinch Brook in the Township of East Hanover (see Figure C-122). This system is bounded by Pinch Brook, Great Meadow Lane and Brentwood Drive. In order to protect against backwater flooding from the Whippany River in this area, 3,380 feet of levees would be required. The levees, which would be aligned along the brook, would have an average height of 6.6 feet and a base width of 49.6 feet. There would be 200 feet of floodwall with an average height of 12 feet. A 7.2 acre pond, 5.5 feet deep, would be required to collect runoff from the 96.4 acre drainage area behind the system.

PRESERVATION OF NATURAL STORAGE UNDER THE DUAL INLET TUNNEL PLAN

In order to minimize the impact of future development within the basin, the acquisition of significant portions of the remaining natural storage areas within the Central Passaic Basin is recommended as part of the selected plan. Developmental pressures, as described in Section 2 - WITHOUT PROJECT CONDITIONS and Section 8 - OPTIMIZATION, indicate the necessity of maintaining the design integrity of the tunnel diversion by preventing the filling and development of these lands. In light of the rate at which natural storage loss is proceeding in the Central Passaic Basin, Federal preservation is recommended as an "Early Action" element of the overall plan in order to minimize future increases in flood flows.

In the Draft Feasibility Report, the NJDEP was strongly urged to pursue halting development through the use of State permitting procedures until a Federal "Early Action" project could be implemented. The State permitting procedures were considered more appropriate than Federal permitting procedures for the prevention of additional filling and development before a Federal preservation project can be implemented. This is because the State's program is aimed specifically at preventing increased flood damages while the Federal program is intended to maintain water quality.

Subsequent to the completion of the Draft Feasibility Report and Draft Environmental Impact Statement, the State of New Jersey passed a moratorium on wetland development and then enacted the Freshwater Wetlands Act. The extent to which this new law will further limit the loss of natural storage cannot be

determined until State regulations are developed and implemented. Therefore, it is recognized that the acreage of natural storage areas recommended for acquisition may change during the design phase for this project in order to reflect the interpretation of the State law.

The current recommendation is for a total of 5,350 acres to be acquired, all within the following eight major wetland areas: Great Piece Meadows; Bog and Vly Meadows; the lower Pompton Valley; Hatfield Swamp; Hatfield Swamp South; Troy Meadows; Black Meadows; and Canoe Brook. Tables C-92 and C-93 list the acres proposed for acquisition by major wetland and by municipality. The Recommended Plan Figures C-103 to C-113, C-117, C-121, and C-122 show the areas to be acquired in relation to location of the other plan elements. Figures C-128 to C-136 show the specific locations of the major natural storage areas as well as the areas to be acquired in the Central Passaic Basin.

As can be seen on Figures C-130 and C-131, which show natural storage areas within the Great Piece Meadows, areas south of I-80 in Fairfield are proposed for acquisition even though they would be behind the Passaic River levee/floodwall system #2A. This acreage would remain as natural storage prior to construction of the levee system. It would then be utilized as ponding areas for the interior runoff behind the levee. This is also the case for the natural storage areas behind the Pinch Brook and the Passaic River #10 levee systems. These areas could be included with other areas which may possibly be managed by the U.S. Department of the Interior Fish and Wildlife Service as wildlife habitat.

Vital considerations in the preservation of natural storage, as proposed under this plan, involve: (1) the retention by the State of New Jersey of existing approved FIA Floodways at their current limits in the areas of acquisition; (2) a realistic determination, based on NJDEP estimates for final delineations, of floodways in communities where they have not yet been adopted, without attempting to take this plan into account; and (3) the retention of current State fill and storm water management regulations. Any deviation from these could seriously impair the effectiveness of the acquisition element to function as anticipated.

TABLE C-92
PRESERVATION OF NATURAL STORAGE AREAS
BY MAJOR WETLAND

MAJOR WETLAND AREA	MUNICIPALITY	PROPOSED FOR ACQUISITION
GREAT PIECE MEADOWS	LINCOLN PARK	420
	MONTVILLE	130
	FAIRFIELD	1030
	TOTAL	1580
BOG & VLY MEADOWS	LINCOLN PARK	360
	MONTVILLE	45
	TOTAL	405
LOWER POMPTON	WAYNE	165
	PEQUANNOCK	120
	LINCOLN PARK	0
	TOTAL	285
HATFIELD SWAMP	FAIRFIELD	20
	MONTVILLE	35
	W. CALDWELL	290
	ROSELAND	0
	PAR-TROY	0
	E. HANOVER	85
	TOTAL	430
TROY MEADOWS	PAR-TROY	765
	E. HANOVER	385
	HANOVER	25
	TOTAL	1175
BLACK MEADOWS	E. HANOVER	195
	HANOVER	660
	FLORHAM PARK	255
	TOTAL	1110
HATFIELD SOUTH	E. HANOVER	135
	ROSELAND	0
	LIVINGSTON	55
	TOTAL	190
CANOE BROOK	LIVINGSTON	175
	FLORHAM PARK	0
	CHATHAM	0
	MILLBURN	0
	TOTAL	175

TABLE C-93
PRESERVATION OF NATURAL STORAGE AREAS
BY COMMUNITY

MUNICIPALITY	MAJOR WETLAND AREA	PROPOSED FOR ACQUISITION
E. HANOVER	HATFIELD SWAMP	85
	BLACK MEADOWS	195
	TROY MEADOWS	385
	HATFIELD SOUTH	135
	TOTAL	800
FAIRFIELD	HATFIELD SWAMP	20
	GREAT PIECE MEADOWS	1030
	TOTAL	1050
FLORHAM PARK	CANOE BROOK	0
	BLACK MEADOWS	255
	TOTAL	255
HANOVER	TROY MEADOWS	25
	BLACK MEADOWS	660
	TOTAL	685
LINCOLN PARK	BOG & VLY MEADOWS	360
	LOWER POMPTON	0
	GREAT PIECE MEADOWS	420
	TOTAL	780
LIVINGSTON	CANOE BROOK	175
	HATFIELD SOUTH	55
	TOTAL	780
MONTVILLE	GREAT PIECE MEADOWS	130
	HATFIELD SWAMP	35
	BOG & VLY MEADOWS	45
	TOTAL	210
PAR-TROY	TROY MEADOWS	765
	HATFIELD SWAMP	0
	TOTAL	765
PEQUANNOCK	LOWER POMPTON	120
	TOTAL	120
WAYNE	LOWER POMPTON	165
	TOTAL	165
W. CALDWELL	HATFIELD SWAMP	290
	TOTAL	290

ENVIRONMENTAL EFFECTS

The environmental effects of the selected plan for the Main Stem Passaic River are fully discussed in the Environmental Impact Statement, with the significant impacts summarized on Table C-94. The effects on fish and wildlife are related to aquatic and terrestrial changes. Some of the impacts are associated with construction and would be temporary, but others of a more enduring nature are also involved.

Effects on the aquatic biota will be greatest in areas where the physical measures will be placed. The Pequannock, Wanaque, and Ramapo River complex, where combinations of levees and channels are proposed, will be affected the most by the Dual Inlet Plan. These areas also contain the highest diversities of fish and benthic invertebrate species. Thus, this combination of greatest instream and bank manipulation in the area of the greatest diversity will cause the most impact on the aquatic environment.

The types of effects include: (1) reconfiguration of the stream morphology; (2) elimination of substantial tree shade and, therefore, an increase in water temperature, coupled with a decrease in dissolved oxygen; and (3) removal of aquatic flora and fauna during construction. Use of stream habitat structures such as double wing check dams, would help mitigate for some loss of natural stream habitat. Where trees are present on a south or west bank, efforts would be made to save them in order to limit loss of shade. Reinhabiting of the project area by aquatic flora and fauna will occur naturally with time, through natural immigration and dispersal mechanisms. Occasional need for maintenance of the channel may occur. When needed, this operation will adversely affect recolonized organisms.

Anadromous fish are found in limited numbers in the Passaic River. Generally, they spawn in April and May, seeking low salinity or fresh waters. Offspring reside in the river from May until September. Approximately two acres of aquatic habitat utilized by anadromous fish would be affected by the construction of the selected plan. With the expected low frequency of operation of the tunnel, the high flows anticipated during the majority of the time of operation, the placement of the tunnel outlet on the Main Stem Passaic River as opposed to the original Third River site, and the improvement of four acres of anadromous fish habitat, few long term adverse effects are expected to occur to anadromous fish. In fact, the area of improved habitat is likely to have a beneficial effect.

TABLE C-93
PRESERVATION OF NATURAL STORAGE AREAS
BY COMMUNITY

MUNICIPALITY	MAJOR WETLAND AREA	PROPOSED FOR ACQUISITION
E. HANOVER	HATFIELD SWAMP	85
	BLACK MEADOWS	195
	TROY MEADOWS	385
	HATFIELD SOUTH	135
	TOTAL	800
FAIRFIELD	HATFIELD SWAMP	20
	GREAT PIECE MEADOWS	1030
	TOTAL	1050
FLORHAM PARK	CANOE BROOK	0
	BLACK MEADOWS	255
	TOTAL	255
HANOVER	TROY MEADOWS	25
	BLACK MEADOWS	660
	TOTAL	685
LINCOLN PARK	BOG & VLY MEADOWS	360
	LOWER POMPTON	0
	GREAT PIECE MEADOWS	420
	TOTAL	780
LIVINGSTON	CANOE BROOK	175
	HATFIELD SOUTH	55
	TOTAL	780
MONTVILLE	GREAT PIECE MEADOWS	130
	HATFIELD SWAMP	35
	BOG & VLY MEADOWS	45
	TOTAL	210
PAR-TROY	TROY MEADOWS	765
	HATFIELD SWAMP	0
	TOTAL	765
PEQUANNOCK	LOWER POMPTON	120
	TOTAL	120
WAYNE	LOWER POMPTON	165
	TOTAL	165
W. CALDWELL	HATFIELD SWAMP	290
	TOTAL	290

ENVIRONMENTAL EFFECTS

The environmental effects of the selected plan for the Main Stem Passaic River are fully discussed in the Environmental Impact Statement, with the significant impacts summarized on Table C-94. The effects on fish and wildlife are related to aquatic and terrestrial changes. Some of the impacts are associated with construction and would be temporary, but others of a more enduring nature are also involved.

Effects on the aquatic biota will be greatest in areas where the physical measures will be placed. The Pequannock, Wanaque, and Ramapo River complex, where combinations of levees and channels are proposed, will be affected the most by the Dual Inlet Plan. These areas also contain the highest diversities of fish and benthic invertebrate species. Thus, this combination of greatest instream and bank manipulation in the area of the greatest diversity will cause the most impact on the aquatic environment.

The types of effects include: (1) reconfiguration of the stream morphology; (2) elimination of substantial tree shade and, therefore, an increase in water temperature, coupled with a decrease in dissolved oxygen; and (3) removal of aquatic flora and fauna during construction. Use of stream habitat structures such as double wing check dams, would help mitigate for some loss of natural stream habitat. Where trees are present on a south or west bank, efforts would be made to save them in order to limit loss of shade. Reinhabiting of the project area by aquatic flora and fauna will occur naturally with time, through natural immigration and dispersal mechanisms. Occasional need for maintenance of the channel may occur. When needed, this operation will adversely affect recolonized organisms.

Anadromous fish are found in limited numbers in the Passaic River. Generally, they spawn in April and May, seeking low salinity or fresh waters. Offspring reside in the river from May until September. Approximately two acres of aquatic habitat utilized by anadromous fish would be affected by the construction of the selected plan. With the expected low frequency of operation of the tunnel, the high flows anticipated during the majority of the time of operation, the placement of the tunnel outlet on the Main Stem Passaic River as opposed to the original Third River site, and the improvement of four acres of anadromous fish habitat, few long term adverse effects are expected to occur to anadromous fish. In fact, the area of improved habitat is likely to have a beneficial effect.

TABLE C-94

SIGNIFICANT EQ EFFECTS - DUAL INLET PLAN

Recommended Plan

SIGNIFICANT RESOURCES	ECOLOGICAL	CULTURAL	AESTHETIC
ANADROMOUS FISH, LOWER VALLEY	Loss of 2 acres of habitat due to shoreline modifications. 4 acres created.	No Effect	No Effect
CULTURAL RESOURCES, LOWER VALLEY	No Effect	No Effect	No Effect
WETLANDS BELOW DUNDEE DAM, LOWER VALLEY	Loss of 10 acres, but upgraded in Central Basin project lands.	No Effect	No Effect
WETLANDS ABOVE DUNDEE DAM, LOWER VALLEY	Loss of 5 acres at inlet site; 5 acres scattered loss below Little Falls. 10 acres will be upgraded in Central Basin project lands.	No Effect	No Effect
WATER QUALITY, LOWER VALLEY	No Effect	No Effect	No Effect
ENDANGERED AND THREATENED SPECIES, LOWER VALLEY	No Effect	No Effect	No Effect

TABLE C-94 (CONT)
SIGNIFICANT EQ EFFECTS - DUAL INLET PLAN

Recommended Plan

SIGNIFICANT RESOURCES	ECOLOGICAL	CULTURAL	AESTHETIC
FISHERIES, CENTRAL BASIN	Reduction of resources during construction; recovery afterwards. Use of habitat restoration techniques would help restore fishery.	Angler use high in some areas, with active NJDEP fish stocking program. Reduced temporarily during construction in the Ramapo, Wanaque and Pequannock Rivers confluence area.	No Effect
CULTURAL RESOURCES, CENTRAL BASIN	No Effect	No known effects. During Phase II, cultural resources will be surveyed. If significant resources are discovered, a mitigation plan will be formulated.	No Effect
WETLANDS, CENTRAL BASIN	Preservation of 5200 acres (4860 acres preserved intact, 340 ac. preserved will be used for ponding areas and replanted as wetland). Loss of 185 acres due to physical and hydrological modifications; these acres would be mitigated by upgrading 185 acres of land acquired for preservation of flood storage. 630 acres of emergent wetlands would be created in ponding areas replacing forested wetlands. Trees would be removed from 90 acres of forested wetlands which will revert to scrub/ shrub wetlands.	No Effect	Wetlands will be maintained as wildlife refuges.

TABLE C-94 (CONT)

SIGNIFICANT EQ EFFECTS - DUAL INLET PLAN

Recommended Plan

SIGNIFICANT RESOURCES	ECOLOGICAL	CULTURAL	AESTHETIC
ENDANGERED AND THREATENED SPECIES, CENTRAL BASIN	No Federal species involved. Protection of habitat for State listed species.	No Effect	No Effect
WATER QUALITY, CENTRAL BASIN	No increased degradation. Short-term impacts during construction. Possible temperature increase due to riverbank clearing.	No Effect	No Effect
GROUNDWATER RESOURCES	No Effect	No Effect	No Effect
HAZARDOUS SUBSTANCE SITES	Protection of 50 hazardous substance sites in 100-year floodplain. The 8 sites that are near construction areas may require a Health and Safety Plan.	No Effect	No Effect

TABLE C-94 (CONT)

SIGNIFICANT EQ EFFECTS - DUAL INLET PLAN

Recommended Plan

SIGNIFICANT RESOURCES	ECOLOGICAL	CULTURAL	AESTHETIC
RECREATION (BOATING AND FISHING, HIKING, ETC.)	No Effect	Cleanup of shoreline, but access only at selected points. Fisheries impacted during construction. Preservation of natural storage, along with recreational areas as part of plan components, should help prevent increased deficits.	No Effect
AESTHETICS	No Effect	No Effect	Riverine views improved due to shoreline clean-up would be offset by heights of levees and floodwalls. Wetlands are protected. Some loss of wetlands in the Ramapo, Pequannock and Wanaque Rivers confluence area.

TABLE C-94(cont)

SIGNIFICANT EQ EFFECTS - DUAL INLET PLAN

Recommended Plan

SIGNIFICANT RESOURCES	ECOLOGICAL	CULTURAL	AESTHETIC
NOISE	No Effect	No Effect	No change. High due to the basin's urban nature, especially near major thoroughfares.
TRANSPORTATION	No Effect	Elimination of most flooding delays. Delays experienced during construction.	No Effect
PUBLIC HEALTH AND SAFETY	No Effect	Flood risk is reduced up to the 500 yr level in many areas.	
DAMAGE AND CLEANUP COSTS	No Effect	No costs associated up to 100 yr event in the protected areas. Property values increase.	No Effect

The recommended plan would impact on 905 acres of wetlands, of which 630 acres are compensated for through wetland planting in ponding areas, and 185 acres would be mitigated through wetland reclamation or management measures in the Central Basin project lands. An additional 90 acres of forested wetland would be converted to scrub-shrub cover type due to tree removal upstream of the Pompton River tunnel inlet.

ENVIRONMENTAL ELEMENTS OF THE DUAL INLET TUNNEL PLAN

Adverse environmental effects of the selected plan on the Passaic River Basin would be minimized by including mitigation measures formulated to offset some of these impacts on aquatic and terrestrial habitats. The following mitigation measures are recommended:

i. Separable Fish and Wildlife Mitigation Measures:

- To mitigate for the loss of aquatic habitat, wing-dam habitat structures will be placed in the Pompton River downstream of the flow restrictor. This will provide food and shelter, thus creating a fish holding area to help offset project related adverse effects. This in turn would help support the N.J. State trout stocking program.

- To mitigate for loss of wetland habitat from structural components of the plan (e.g. levees), 185 acres of land would be manipulated to restore or improve the quality of existing degraded wetlands.

- To provide cover for insectivorous birds, nest boxes would be placed in the ponding areas and in other locations where nesting habitat would be lost.

ii. Standard Engineering Practice Mitigation Measures:

- A weir will be placed near the downstream terminus of the Great Piece Meadows (Figure C-127) which would allow for the maintenance of existing wetland habitat.

- A weir across the Pequannock River above the Pompton River tunnel inlet would allow for saturation of wetlands, and maintenance of aquatic habitat.

- The existing U.S.G.S. weir downstream of the Pompton inlet will be maintained, thus preserving wetlands by maintaining water surface elevations.

- The diversion structures located at the Pompton and Two Bridges inlets will be operated to allow the bypass of non-flood discharges up to the one year flow after the peak flood has passed, thus maintaining fish habitat.

- Channel modification reaches will provide adequate water depths to maintain passage by fish.

- Channel meanders in modified channel reaches will be maintained where compatible with sound engineering practice and design.

- 630 acres of wetlands, which will be converted to interior flood control ponds, will be planted with perennial flora to maintain wildlife food and cover for game and non-game species. The planting of flora will result in a substantial reduction in operation and maintenance costs compared to the traditional seeding of grass.

- Cobble will be placed in the Passaic River downstream of Dundee Dam and will be used in the modified channels along the Pequannock, Wanaque and Ramapo Rivers upstream of the Pequannock River weir.

- Erosion control methods will be employed during construction, using techniques similar to those utilized by the Soil Conservation Service (SCS).

- Banks susceptible to erosion will be protected by riprap.

- Riparian vegetation will be maintained where compatible with the project.

- Riprap will be used where appropriate for engineering function; this will provide substrate habitat.

- Areas disturbed during construction will have vegetation planted in the first growing season following project completion.

- Topsoil will be replaced to existing depths to allow flora planting.

- Present modal flows will be maintained because only flood flows will be diverted, thus maintaining fish habitat.

- Acquisition of natural storage areas for proper functioning of the plan includes a large amount of wetlands. The preservation of natural storage areas, in concert with the State/Corps' agreement to maintain existing floodways in acquisition areas, would help avoid secondary development impacts as a result of plan implementation.

- Upstream of the Pompton Inlet, scrub/shrub vegetation would be planted to offset the removal of trees.

- Pilot channels would be included along the upstream portions of the affected reaches of the Pequannock and Wanaque Rivers.

- Public access for fishing in the affected reaches of the Ramapo, Pequannock and Wanque Rivers will be provided.

- Levee designs incorporate walking/biking paths on top of the levees, overlooks, benches, lighting, comfort facilities, river access and planting/ beautification measures aimed at providing recreational opportunities.

- Compensation for residual project impacts on parks will include providing equivalent recreation activities on project lands or monetary payments based on fair market value of equivalent public recreation usefulness, size, quality and location.

- Phase II Engineering and Design Studies:

    - Habitat Evaluation Procedures.

    - Plant community succession modeling.

    - Development of Comprehensive Wetlands Management to help refine site-specific mitigation.

    - Organize an Environmental Advisory Board to guide the detailed environmental planning and design.

    - Utilize Instream Flow Incremental Methodology to refine site-specific aquatic mitigation.

    - Conduct cultural resources surveys; prepare mitigation plans if necessary.

- Coordinate with USEPA and NJDEP regarding the status of on hazardous substance sites in the vicinity of the project; develop a Health & Safety Plan if necessary.

- Finalize levee designs in concert with further recreational mitigation refinements in corrdination with NJDEP and local recreation planners.

The Fish and Wildlife Service made eighteen recommendations for mitigation in the FWCA report. The ability to accommodate these recommendations is discussed in Section 1 of the EIS. The Corps is able to fully accommodate fourteen recommendations, including plant successional modeling. The plant community succession modeling, has been agreed to by FWS and the Corps as a tool to be used in the Phase II Design effort. Through additional plan modifications and refinements, the Corps was able to partially accommodate three other recommendations, which have been provided to the greatest extent possible.

The remaining FWCA recommendation for mitigation is an unresolved conflict. It is unresolved because it would work in opposition to the goals and purposes of the plan. This FWS recommendation, which calls for eliminating or greatly reducing channel modification upstream of the Pompton inlet, would not allow floodwaters to enter the tunnel efficiently. This would cause extensive backwater flooding and is, therefore, a recommendation which can not be incorporated into the plan.

OPERATIONAL DETAILS OF THE TUNNEL

The operation of the tunnel component of the selected plan, both for flood control and environmental objectives, is reliant upon specific rules which designate when the tunnel would be placed into operation and what flows would bypass the tunnel inlets. Due to the nature of the flooding in the basin, it is possible to define initial bypass flows past the tunnel inlets during the ascending limb of the storm hydrograph for flood control purposes, and a significantly greater bypass flow to produce the 1 year flood event for environmental purposes during the descending limb of the storm hydrograph, once the peak flows have passed each of the respective inlets.

The tunnel would not operate for any flow less than or equal to the one year flood event. The tunnel would operate only when a flood greater than the one year flood is predicted to occur. This prediction would be based upon an enhanced Passaic River Basin Floodwarning and Forecasting System with additional streamflow and rain gages to ensure accurate, timely forecasting of expected flood levels.

The recommended Pompton/Passaic Dual Inlet Tunnel Diversion Plans calls for two inlets as follows: the Pompton River Inlet near the upstream limit of the Pompton River, and the Passaic River Inlet downstream of Two Bridges. The purpose of including two inlets in the plan is to make more effective use of the tunnel throughout the duration of the storm while diverting flood flows away from the major damage areas in the Pompton Valley and along the Passaic River. This would be accomplished by taking advantage of the timing difference between flood flows of the Pompton River and those of the Passaic River. Table C-95 presents data on peak discharges, velocities and stages for the 1 year, 2 year and 100 year flood events under with and without project conditions. Although the operation of the Pompton Inlet is discussed first, in fact, the operation of the two inlets act in concert.

The Pompton River Inlet consists of three major elements: a river flow restrictor; a gated diversion spillway; and a morning glory diversion spillway. The river flow restrictor lies across the Pompton River and has five gated openings see Figure C-125. During non-flood conditions, the center gate of the flow restrictor would remain open to permit normal flows to continue downstream.

In the event that flood flows are predicted to exceed the one year flood, the river flow restrictor would be operated for flood damage reduction purposes so that water starts to pond behind it and a maximum of 500 cubic feet per second (cfs) would bypass the inlet early in the storm. (By comparison, the average daily flow for the Pompton River is approximately 482 cfs.) At the same time the diversion spillway gates would be opened to permit the water that has ponded behind the river flow restrictor to enter the inlet basin and pass into the morning glory inlet, thereby initiating the diversion. The inlet basin is lower in elevation than the river channel, permitting the diversion of flood flows at non-damaging elevations while maintaining water surface elevations greater than the 1 year stage at upstream wetlands areas for all floods. Should flood flows exceed the capacity of the tunnel, the five gated openings on the river flow restrictor would be opened in order to pass the larger flows while maintaining maximum diversion through the tunnel.

The diversion into the tunnel would continue until several conditions are met. These conditions, which occur in the course of every flood event, are: (1) Rainfall has stopped; (2) Peak flood flows have passed the inlet; and (3) Pompton River stages downstream of the inlet are below the annual flood stage.

TABLE C-95

DUAL INLET TUNNEL PLAN
PEAK FLOWS (Q), PEAK STAGES (H) AND VELOCITIES (V)
CORRESPONDING TO PEAK STAGES

1 YEAR FLOOD

LOCATION	NODE	STATION	WITHOUT PROJECT CONDITIONS 1986 Q	V	H	WITHOUT PROJECT CONDITIONS 2040 Q	V	H	WITH PROJECT CONDITIONS 2040 Q	V	H	DIFFERENCE BETWEEN 2040 CONDITIONS WITH PROJECT AND WITHOUT PROJECT Q	V	H
Pompton River, USGS gage	25	34975	3992	1.2	174.3	4672	1.2	175.0	4672	1.2	175.0	0	0.0	0.0
Pompton River	26	25060	3997	0.5	170.3	4658	0.5	171.0	4659	0.5	171.0	1	0.0	0.0
Pompton River, above Pack. Brk	31	16710	4050	0.6	168.3	4717	0.5	169.0	4700	0.6	168.9	-17	0.1	-0.1
Pompton River, at Pack. Brk	33	7940	4132	0.2	165.6	4800	0.2	166.1	4783	0.2	165.8	-17	0.0	-0.3
Pompton River at mouth	34	1480	4128	0.3	164.2	4805	0.3	164.8	4778	0.3	164.4	-27	0.0	-0.4
Passaic River, Pine Brk	23	235585	2933	2.7	167.6	3504	3.0	168.1	3262	2.9	168.0	-242	-0.1	-0.1
Passaic River, at Horseneck Rd	24	219860	2511	2.2	166.4	2822	2.5	166.7	2773	2.3	166.7	-49	-0.2	0.0
P.R., 1.5 m. above Tom's Point	24	213370	2511	1.8	166.0	2822	1.6	166.3	2773	1.7	166.2	-49	0.1	-0.1
P.R., 1 m. below Tom's Point	24	194000	2511	1.6	164.4	2822	1.4	164.9	2773	1.6	164.8	-49	0.2	-0.1
Passaic River above Pompton	24	184170	2511	0.9	164.3	2822	0.7	164.8	2773	0.8	164.6	-49	0.1	-0.2
Passaic River below Pompton	35	169300	5201	2.4	163.1	5918	2.6	163.5	5871	2.5	163.5	-47	0.1	0.0
Passaic R. above Little Falls	41	157310	5486	2.6	161.3	6232	2.8	161.6	6182	2.6	161.6	-50	-0.2	0.0
P.R. below Beatties Dam	100	151270	5492	2.2	123.5	6243	2.3	124.0	6194	2.3	124.0	-49	0.0	0.0
P.R. above Great Falls	200	134220	5505	2.4	117.9	6262	2.7	118.2	6213	2.6	118.2	-49	-0.1	0.0
P.R. @ Diamond Brook	300	117468	5517	2.7	33.3	6277	2.9	33.6	6228	2.9	33.6	-49	0.0	0.0
P.R. above Dundee Dam	400	92400	5514	1.0	28.0	6271	1.1	28.2	6225	1.1	28.2	-46	0.0	0.0
P.R. @ Saddle River	500	82200	5576	1.8	6.0	6351	1.9	6.8	6305	1.9	6.8	-46	0.0	0.0
P.R. @ Third R. above outlet	600	58765	5576	1.1	5.2	6350	1.1	5.8	6305	1.1	5.8	-45	0.0	0.0
P.R. @ Third R. below outlet	700	54243	5603	0.9	5.2	6379	1.0	5.8	6335	1.0	5.8	-44	0.0	0.0
P.R. @ Second River	800	30018	5596	0.7	4.9	6370	0.8	5.5	6329	0.8	5.5	-41	0.0	0.0
P.R. above mouth	800	22200	5596	0.4	4.9	6370	0.4	5.5	6329	0.4	5.5	-41	0.0	0.0

Flow in cfs, velocity in fps, stage in ft NGVD.
P.R. = Passaic River

TABLE C-95 (CONT)

DUAL INLET TUNNEL PLAN
PEAK FLOWS (Q), PEAK STAGES (H) AND VELOCITIES (V)
CORRESPONDING TO PEAK STAGES

2 YEAR FLOOD

LOCATION	NODE	STATION	WITHOUT PROJECT CONDITIONS 1986 Q	V	H	2040 Q	V	H	WITH PROJECT CONDITIONS 2040 Q	V	H	DIFFERENCE BETWEEN 2040 CONDITIONS WITH PROJECT AND WITHOUT PROJECT Q	V	H
Pompton River, USGS gage	25	34975	6462	1.2	176.6	7279	1.2	177.2	4672	1.2	175.0	-2607	0.0	-2.2
Pompton River	26	25060	6449	0.4	172.8	7237	0.4	173.5	4622	0.5	171.1	-2615	0.1	-2.4
Pompton River, above Pack. Brk	31	16710	6429	0.5	170.3	7254	0.4	170.9	4703	0.5	169.0	-2551	0.1	-1.9
Pompton River, at Pack. Brk	33	7940	6529	0.2	166.9	7357	0.2	167.2	4806	0.2	166.1	-2551	0.0	-1.1
Pompton River at mouth	34	1480	6521	0.2	165.8	7360	0.2	166.2	4800	0.3	164.8	-2560	0.1	-1.4
Passaic River, Pine Brk	23	235585	3876	3.7	168.9	4649	4.3	169.5	4321	0.3	164.8	-328	-1.0	-0.2
Passaic River, at Horseneck Rd	24	219860	3447	3.0	167.2	3944	3.7	167.5	4132	1.3	167.5	188	-2.4	0.0
P.R., 1.5 m. above Tom's Point	24	213370	3447	1.6	166.8	3944	1.5	167.1	4132	1.4	167.1	188	-0.1	0.0
P.R., 1 m. below Tom's Point	24	194000	3447	1.6	166.0	3944	1.3	166.4	4132	2.2	165.8	188	0.9	-0.6
Passaic River above Pompton	24	184170	3447	0.8	165.8	3944	0.6	166.3	4132	1.1	165.4	188	0.5	-0.9
Passaic River below Pompton	35	169300	7535	2.8	164.4	8214	3.0	164.8	6273	2.4	163.6	-1941	-0.6	-1.2
Passaic R. above Little Falls	41	157310	7787	3.2	162.2	8496	3.4	162.4	6273	2.8	161.6	-2223	-0.6	-0.8
P.R. below Beatties Dam	100	151270	7795	2.6	124.1	8503	2.6	125.6	6279	2.3	124.1	-2224	-0.3	-1.5
P.R. above Great Falls	200	134220	7806	3.2	118.8	8523	3.4	119.1	6288	2.7	118.3	-2235	-0.7	-0.8
P.R. @ Diamond Brook	300	117468	7817	3.3	34.3	8540	3.5	34.6	6295	2.9	33.6	-2245	-0.6	-1.0
P.R. above Dundee Dam	400	92400	7821	1.3	28.6	8554	1.4	28.8	6296	1.1	28.2	-2258	-0.3	-0.6
P.R. @ Saddle River	500	82200	7893	2.3	7.0	8621	2.4	7.7	6345	1.7	7.5	-2276	-0.7	-0.2
P.R. @ Third R. above outlet	600	58765	7902	1.5	5.5	8635	1.5	6.1	6348	1.1	6.8	-2287	-0.4	-0.7
P.R. @ Third R. below outlet	700	54243	7940	1.3	5.4	8674	1.4	6.0	13257	2.0	6.7	4583	0.6	0.7
P.R. @ Second River,	800	30018	7951	1.0	4.9	8694	1.1	5.5	13312	1.7	5.6	4618	0.6	0.1
P.R. above mouth	800	22200	7951	0.6	4.9	8694	0.6	5.5	13312	0.9	5.5	4618	0.3	0.0

Flow in cfs, velocity in fps, stage in ft NGVD.
P.R. = Passaic River

TABLE C-95 (CONT)

DUAL INLET TUNNEL PLAN
PEAK FLOWS (Q), PEAK STAGES (H) AND VELOCITIES (V)
CORRESPONDING TO PEAK STAGES

100 YEAR FLOOD

LOCATION	NODE	STATION	WITHOUT PROJECT CONDITIONS 1986 Q	1986 V	1986 H	WITHOUT PROJECT CONDITIONS 2040 Q	2040 V	2040 H	WITH PROJECT CONDITIONS 2040 Q	2040 V	2040 H	DIFFERENCE BETWEEN 2040 CONDITIONS WITH PROJECT AND WITHOUT PROJECT Q	Q	V	H
Pompton River, USGS gage	25	34975	32515	4.6	185.9	32907	4.5	186.1	5171	2.2	175.2	-27736	-2.3	-10.9
Pompton River	26	25060	30575	4.3	182.7	32405	4.4	183.0	4536	2.0	171.4	-27869	-2.4	-11.6
Pompton River, above Pack. Brk	31	16710	28969	2.8	180.6	30561	2.8	180.7	4914	2.4	169.4	-25647	-0.4	-11.3
Pompton River, at Pack. Brk	33	7940	29200	4.9	175.9	30821	4.8	176.6	5191	1.7	167.2	-25630	-3.1	-9.4
Pompton River at mouth	34	1480	29144	6.1	173.6	30802	5.8	175.0	5180	1.6	166.4	-25622	-4.2	-8.6
Passaic River, Pine Brk	23	235585	12283	1.6	174.2	14921	2.9	176.4	13768	3.5	172.1	-1153	0.6	-4.3
Passaic River, at Horseneck Rd	24	219860	12040	0.9	173.6	14451	1.8	175.2	11482	2.1	170.1	-2969	0.3	-5.1
P.R., 1.5 m. above Tom's Point	24	213370	12040	0.5	173.6	14451	0.7	175.1	11482	2.0	169.6	-2969	1.3	-5.5
P.R., 1 m. below Tom's Point	24	194000	12040	0.4	173.5	14451	0.6	175.0	11482	2.2	167.7	-2969	1.6	-7.3
Passaic River above Pompton	24	184170	12040	0.4	173.5	14451	0.5	175.0	11482	1.2	166.6	-2969	0.7	-8.4
Passaic River below Pompton	35	169300	26843	4.9	171.8	32547	5.2	173.2	9232	3.1	165.2	-23315	-2.1	-8.0
Passaic R. above Little Falls	41	157310	27533	7.0	167.3	33053	7.2	168.4	9232	3.8	162.7	-23821	-3.4	-5.7
P.R. below Beatties Dam	100	151270	27566	4.4	134.3	33085	4.8	135.9	9496	2.7	126.4	-23589	-2.1	-9.5
P.R. above Great Falls	200	134220	27626	7.7	123.8	33123	8.6	124.8	9768	3.7	119.5	-23355	-4.9	-5.3
P.R. @ Diamond Brook	300	117468	27692	5.9	41.4	33157	6.4	42.7	12774	4.3	36.4	-20383	-2.1	-6.3
P.R. above Dundee Dam	400	92400	27693	3.2	32.4	33098	3.6	33.2	12402	1.8	29.7	-20696	-1.8	-3.5
P.R. @ Saddle River	500	82200	28207	4.3	15.7	33621	4.4	18.3	18892	2.7	17.2	-14729	-1.7	-1.1
P.R. @ Third R. above outlet	600	58765	28222	4.0	9.7	33592	3.8	11.3	21279	2.1	15.4	-12313	-1.7	4.1
P.R. @ Third R. below outlet	700	54243	28362	3.8	9.4	33706	4.2	10.8	50543	5.3	14.7	16837	1.1	3.9
P.R. @ Second River	800	30018	28635	3.6	5.2	33645	4.2	5.9	48544	5.9	6.5	14899	1.7	0.6
P.R. above mouth	800	22200	28635	2.0	5.0	33645	2.3	5.6	48544	3.3	5.9	14899	1.0	0.3

Flow in cfs, velocity in fps, stage in ft NGVD.
P.R. = Passaic River

At this point, the Pompton River flow restrictor would be opened to permit the bypass of a discharge sufficient to produce the annual flood stage along the Pompton Valley for environmental purposes. Subsequently, as downstream flows continue to recede, the gates to the inlet basin would close, thereby bypassing all flows as discharges return to normal conditions.

The major elements of the Two Bridges inlet consist of a gated diversion spillway and a morning glory diversion spillway. A river flow restrictor is not included for the Two Bridges Inlet since the design pool stage at the diversion spillway is created by the natural rock ledge in the river upstream of Beatties Dam. During non-flood conditions, the gated diversion spillway would be closed so that normal flows would bypass the inlet and continue downstream over Beatties Dam. As with the Pompton Inlet, when it is predicted that flooding greater than the 1 year event is imminent, the gates in the diversion spillway would open. The diversion gates would be operated to divert Passaic River flows into the tunnel and maintain a maximum 100 cfs bypass flow down the Passaic River during the early portion of the flood when the Lower Valley tributaries are peaking. The Central Basin contribution to these Lower Valley tributary flows must be minimized early in the storm to prevent flooding in the Lower Valley.

Since the Pompton River flows would have priority use of the tunnel's capacity, the amount of Passaic River water actually diverted over the course of the event would be a function of how much tunnel capacity is available while the Pompton River is being diverted. For floods between the 50-year and 100-year events, as the flow into the Pompton Inlet increases to its peak, the Two Bridges Inlet diversion would be closed down to permit the maximum diversion of Pompton River water. At this point only Pompton River water would enter the tunnel. There would be no diversion of Passaic River flows at this time; all Passaic River flow would be bypassed downstream. As discussed in Section 8 under Spur Tunnel, during a 100-year flood event, diversion of Pompton River flows would require the tunnel to carry only Pompton River water for a period of 11 hours, during the middle of the storm, while the Pompton River flows are peaking. During that period no water would enter the Two Bridges Inlet and about 9,000 cfs would be bypassed downstream along the Passaic River. Since this timeframe is well after the peaking of the Lower Valley tributary flooding, these additional flows can be passed downstream of the Two Bridges Inlet without flooding in the Lower Valley. Later in the storm, after the Pompton River flows have receded so that there is excess tunnel capacity, the gates to the Passaic River Inlet would reopen thereby resuming diversion so as to reduce the Passaic River

peak flow entering the Lower Valley, which occurs approximately two days after the Pompton peak. (It is noted that for more frequent storms between the 1 year and 50 year floods, the Pompton River flow diversion is not sufficient to fill the tunnel to capacity and the Two Bridges diversion need not completely shut down).

The Two Bridges Inlet would continue to divert flow in this manner until several conditions are met. As for the Pompton Inlet, these conditions are: (1) Rainfall has stopped; (2) Passaic River peak flows downstream of Little Falls have receded; and (3) Passaic River stages downstream and upstream of the inlet are below damaging elevations.

At this time, the Passaic River spillway diversion gates would be gradually closed. This would permit the bypass of a discharge sufficient to produce the annual flood flow for environmental purposes downstream of the inlet and would result in the annual flood stage upstream to and beyond Two Bridges.

In addition to the diversion works associated with the two tunnel inlets, two gated weir structures, the Great Piece Meadows Weir and the Pequannock River Weir, would be operated in concert with the tunnels for environmental purposes. The Great Piece Meadows Weir would be located in the Passaic River upstream of Two Bridges. The Pequannock River Weir would be located in the modified Pequannock River channel.

During periods of normal flow, the gates in the Great Piece Meadows Weir would remain open (lowered) and the flow regime would remain unchanged from current conditions. Under flood conditions the gates in the Great Piece Meadows Weir would remain open (in the lowered position) until the peak flow has passed during a flood event. When the peak flood stage has receded to the one year stage, or, if peak stages have not reached the one year stage as predicted, the weir gates would be raised to replicate the one year flood stage in the Central Basin wetlands upstream of the weir. The one year flood stage would be maintained for a period of time determined necessary to satisfy fish and wildlife needs in the Great Piece Meadows. Once these needs have been met, the gates would be gradually lowered and would again remain completely open under normal conditions. Since the tunnel would not operate for events up to and including the 1 year flood, there would be no change in the flow regime for these frequent floods. For all floods larger than the 1 year event, the operation of the weir would result in at least the 1 year water surface elevation upstream of the weir

in the Great Piece Meadows. For the 100 acres of wetlands downstream of the weir, the 1 year flow bypass rules at the tunnel inlets would insure that these wetlands also receive the 1 year flood stage, although the flooding duration for these 100 acres would be reduced.

The Pequannock River Weir would remain closed (in the raised position) during normal conditions to reproduce the water surface elevations that would occur under without project conditions. This condition would maintain normal river stages and flows over the old Morris Canal Feeder Dams on the Pequannock and Ramapo Rivers. During flood events, the gates in the weir would be opened (lowered) to allow the modified channel to function as designed in conjunction with the levee/floodwall systems to provide a 100-year level of protection to the upstream damage areas. As flood flows recede, the gates would be raised to their normal closed position.

CONSTRUCTION OF THE DUAL INLET TUNNEL PLAN

This plan combines: surface works consisting of channel modifications, levee/floodwall elements, inlet and outlet works and a river flow restrictor; and subsurface works consisting of tunnel excavation. The surface works would be constructed through traditional methods, while the tunnel construction would utilize specialized methods. This plan would have a construction duration of 90 months.

The tunnel would be constructed at an elevation lower than its outlet structure to a depth necessary to reach competent rock which would allow underground construction. In this situation, those occupants located above the route would not be physically aware of the tunnel construction except at the inlet, outlet and construction shaft locations. It has been determined that the most efficient way to construct the 13.5-mile, 39-foot diameter main tunnel and the 1.2-mile long, 22-foot diameter spur tunnel would be through the use of tunnel boring machines (TBM's). The TBM's would be used throughout except in the excavation of the vertical inlets and outlet, and 4 construction shafts which will utilize conventional excavation methods.

Two TBM's would be used to excavate the main tunnel. They would each be 42.5 feet in diameter. The first machine would begin at Workshaft #1 near the tunnel outlet and excavate through to Workshaft #2 in an abandoned quarry near Montclair College. Concurrent with the operation of the first machine, the second would begin at the Montclair workshaft and excavate through to Workshaft #3 in Preakness Valley Park in Wayne, just above the point where the spur tunnel would join the main tunnel. One smaller TBM, 24.5 feet in diameter, would excavate the spur tunnel beginning at Workshaft #4, located 700 feet west

561

of where the spur will join the main tunnel. Figures C-123 and C-124 depict the locations of the workshafts. After the main tunnel excavation has progressed to Workshaft #3 in Wayne, drill and shoot excavation will be used to connect the main and spur tunnels. The upper leg of the main tunnel would be excavated last. The TBM would begin at the Pompton inlet and excavate through to Workshaft #3. The concrete lining would be placed in each section of the main and spur tunnels after the TBM's have been removed from these sections.

Whenever the tunnel penetrates groundwater deposits, construction methods will prevent infiltration into the tunnel. The concrete tunnel lining will seal the tunnel against both groundwater infiltration and exfiltration.

It is estimated that approximately 6,506,000 cubic yards of rock would be excavated as part of the main and spur tunnels. There would be no problem in disposing of this material since it is highly marketable and non-contaminated. As part of the surface works, approximately 1,491,000 cubic yards of earth would be excavated. A portion of this material would be marketable. Materials not marketable would be disposed of in suitable disposal areas.

OPERATION AND MAINTENANCE OF THE DUAL INLET TUNNEL PLAN

After completion of the project, operation and maintenance of project facilities and related mitigation measures would be performed by the local cooperating agency in accordance with government regulations. Depending upon the project feature under consideration, either periodic or annual maintenance would be required. As part of this plan, periodic inspection of the tunnel structure and more frequent testing of mechanical equipment at gated structures and pump stations would be required. Annual maintenance activities required for the remaining project elements would consist of: debris removal at interior flood control facilities and tunnel inlets and outlet structures; shoal removal, riprap repair, trash pickup, brush and tree control in the modified channels; repair and patching of concrete structures; mowing, trash pickup, and weed control along levees and ponding areas.

ECONOMICS OF THE SELECTED PLAN

Methodology. The tangible economic justification of the proposed plan was determined by comparing the equivalent average annual charges (i.e. interest, amortization and maintenance costs) with the estimated equivalent average annual benefits anticipated to accrue over the economic life of the project. A discount rate of 8-5/8% and October 1986 price levels were used

to obtain comparable equivalent annual costs and benefits. In accordance with the economic criteria for the project, a 100-year project life was used in the economic analysis. The analysis also reflects detailed refinements to the economic data. It was verified that these refinements, which are only included in the selected plan data, would not have affected previous plan formulation decisions.

The selected plan of protection is expected to be constructed in 90 months. Interest during construction was included for the entire period of construction. It has been determined, however, that the project would begin to accrue benefits after the first 50 months of construction. Benefits were claimed, therefore, on segments of the project operating by that time.

Estimate of First Cost. The estimated first cost of the selected plan for the Passaic River Basin is $841,200,000, as shown in Table C-96.

Estimate of Annual Charges. The estimated annual charges for the selected plan are based on an interest rate of 8-5/8% for the Federal and non-Federal interests. Charges for amortization of the costs of various works and real estate are based on a 100-year useful life expectancy. The total estimated annual cost for the selected plan is $85,500,000, including operation, maintenance, replacement charges, the portion of residual damages associated with the operation of the tunnel, and interest during construction, as shown on Table C-96. Table C-91 summarizes, by economic damage reach, the induced damages not eliminated by the project.

Estimate of Annual Benefits. The benefits derived from the selected plan of protection in the Passaic River Basin consist of the equivalent annual flood damages that the works would prevent, more intense utilization of property as a result of less frequent flooding, a reduction in traffic and PATH delays, and a reduction in Federal Flood Insurance Administration costs.

a. Annual Flood Control Benefits

The flood damage reduction benefits, including benefits in advance of the base year, resulting from the tunnels, channels, levees and floodwalls, total $103,900,000.

Future inundation reduction benefits utilize an affluence factor based on the most probable future values of residential and apartment contents. Average annual benefits resulting from affluence are $6,800,000. The specific figure utilized is based

TABLE C-96

ECONOMIC SUMMARY OF RECOMMENDED PLAN 1/
(October 1986 Price Levels, 8-5/8%
Interest Rate, 100 Year Project Life
Base Year 2000, $1,000's)

FIRST COST	841,200
INTEREST DURING CONSTRUCTION	114,200
TOTAL INVESTMENT COST	955,400
ANNUAL COSTS:	
INTEREST DURING CONSTRUCTION	9,800
INTEREST AND AMORTIZATION	72,600
OPERATION AND MAINTENANCE	2,100
RESIDUAL INDUCED DAMAGES	1,000
TOTAL ANNUAL COST	85,500
ANNUAL BENEFITS:	
FLOOD DAMAGE REDUCTION	103,900
AFFLUENCE	6,800
PRESERVATION OF NATURAL STORAGE	3,200
TRAFFIC DELAYS	2,500
PATH DELAYS	1,300
FLOOD INSURANCE ADMINISTRATION COST REDUCTION	1,100
RESIDENTIAL INTENSIFICATION	1,100
INDUSTRIAL CONTENT GROWTH	2,600
TOTAL ANNUAL BENEFITS	122,500
B/C RATIO	1.4/1.0

1/ NUMBERS HAVE BEEN ROUNDED AND, THEREFORE, MAY DIFFER FROM THOSE IN THE COST ESTIMATES AND THE ECONOMICS SUPPORTING DOCUMENTATION.

on economic information and projections and is applied only to residential and apartment contents. Future inundation reduction benefits based on the preservation of natural storage areas would total $3,200,000.

b. Traffic Delays

An assessment was made of the additional costs incurred by vehicular traffic due to the inundation of major arteries in the Passaic River Basin. There are essentially two major categories of benefits that were considered. These are benefits resulting from loss of time, and benefits from additional costs of operating the vehicle through diversion of traffic. Expected annual benefits accumulated due to the reduction of traffic delays total $2,500,000 in the Passaic River Basin.

c. PATH Delays

An assessment was also made of the additional cost incurred by those using the Port Authority Trans-Hudson (PATH) commuter rail line due to inundation of track and the system's electrical network. These are benefits resulting from the loss of time by passengers and additional operating costs incurred by the PATH corporation. Expected annual benefits accumulated due to the reduction of PATH delays total $1,300,000 in the Passaic River Basin.

d. Federal Flood Insurance Administration Cost Reduction

A national cost of the flood insurance program is in its administration. This cost includes the cost of servicing flood insurance policies and adjusting claims, and can be expressed as an average cost per policy. Such costs are solely administrative in nature and do not include any floodplain occupants' costs which are indirectly reimbursed or externalized as insurance claim payments or policy subsidies. Thus, these administrative costs are separate from floodplain activities and are not included in existing flood damages. With project conditions have the effect of shrinking the 100-year floodplain, thereby removing structures from the flood hazard area and from the FIA program. The expected annual benefits accruing due to reduction in FIA costs total $1,100,000.

e. Residential Intensification

The selected plan of protection for the Passaic River Basin would allow intensification benefits to be realized in the floodplain. Due to the frequent flooding in the study area, residents have modified the utilization of their homes, specifically basement areas. During damage surveys conducted at the onset of the study, residents indicated a desire to

intensify and fully utilize basement areas. This lost utility, or the utility obtainable with the implementation of the selected plan, is the basis of the intensification benefits accrued. Average annual benefits accumulated due to residential intensification total $1,100,000.

f. Industrial Content Growth

As with residential intensification, industrial building space in the Passaic River Basin has not been utilized to the extent possible because frequent flooding results in damage to contents. Damage surveys indicated a desire to recover full use of these areas contingent upon a reduction in the frequency of flooding. The fuller use of these areas and the ability to increase the contents of these structures form the basis of the industrial content growth benefits accrued. The expected annual benefits accumulated due to industrial content growth total $2,600,000.

g. Annual Benefit Summary

The total benefits from the recommended plan are estimated at $122,500,000.

Economic Justification. The comparison of average annual benefits and the average annual costs result in a benefit-to-cost ratio of 1.4 to 1 for the selected plan of protection for the Passaic River Basin.

COST SHARING RESPONSIBILITIES

General

The requirements for the Federal and non-Federal sharing of responsibilities in the construction, operation and maintenance of Federal water resources projects are set forth in the Water Resources Development Act of 1986 (PL 99-662). These responsibilities are discussed in the following paragraphs and Federal and non-Federal shares of the project cost are detailed in Table C-97.

Federal Responsibilities

The Federal share of the project's total first cost is $622.5 million. The Federal Government will design the project, prepare detailed plans and construct the project, exclusive of those items specifically required of non-Federal interests.

TABLE C-97

COST APPORTIONMENT OF THE RECOMMENDED PLAN

(OCTOBER 1986 PRICE LEVEL; 100 YEAR PROJECT LIFE; 8-5/8% INTEREST RATE)

	FEDERAL	NON-FEDERAL	TOTAL
FIRST COSTS:			
Flood Control	566,000,000	188,600,000	754,600,000
(Percent Apportionment)	(75%)	(25%)	-
Hurricane & Storm Damage Reduction	54,700,000	29,500,000	84,200,000
(Percent Apportionment)	(65%)	(35%)	-
Fish and Wildlife Mitigation	1,800,000	600,000	2,400,000
TOTAL	$622,500,000	$218,700,000	$841,200,000
ANNUAL COSTS: 1/			
Interest and Amortization	53,700,000	18,900,000	72,600,000
Operation and Maintenance	-	2,100,000	2,100,000
Residual Induced Flood Damages	-	1,000,000	1,000,000
TOTAL	53,700,000	22,000,000	75,700,000

1/ Interest during construction is not included.

These Federal Government responsibilities will commence after Congressional authorization and funding and upon the consummation of an agreement for local cooperation required by Section 221 of the Flood Control Act of 1970, and completion of the items of local cooperation required prior to construction.

Non-Federal Responsibilities

The non-Federal share of the estimated total first cost of the proposed project is $218.7 million, which consists of lands, easements, rights-of-way, relocations and disposals totaling $58.3 million, and a cash contribution of $160.4 million. In addition, the non-Federal interests are responsible for the operation and maintenance costs of the project which are estimated at $2,000,000 annually. New cost sharing policies for Federal water resources projects were established in 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, and must pay during construction a minimum of 25% of the total cost assigned to flood control, including 5% of costs in cash, and provide lands, easements, rights-of-way and dredged material disposal areas (LERRD). If the 5% cash plus LERRD exceed 30% of the total cost assigned to flood control, non-Federal interests may reimburse the excess over 15 years. The non-Federal share is limited to 50%. For nonstructural components, such as the acquisition of natural flood storage areas, the non-Federal share is limited to 25% of the cost. For hurricane and storm damage reduction measures, such as the Lower Valley tidal levee/floodwall systems, the non-Federal share is 35%. In the case of the Lower Valley levee/floodwall systems, a separable cost-remaining benefits (SCRB) analysis was applied to account for the costs of the two purposes served, tidal surge and fluvial flooding. This analysis is discussed below. Section 906 of PL-99-662 states that fish and wildlife mitigation costs are to be allocated among the purposes which caused the requirement for mitigation and to be cost-shared to the same extent as project costs allocated to these purposes.

Separable Cost-Remaining Benefits Analysis

The separable cost-remaining benefits (SCRB) analysis was performed for the Lower Valley levee/floodwall systems since these systems serve two purposes: they protect against both tidal flooding and fluvial flooding. The objective of this analysis was to allocate the costs of these dual purpose levees and floodwalls to the individual purposes in order to determine the appropriate cost-sharing.

For the Lower Valley levee/floodwall systems integral to the tunnel, the results of the analysis indicated that 50% of the cost of these systems should be allocated to flood control and 50% to hurricane protection. However, since inclusion of these systems in the plan is essential in order to protect against the tunnel outflows, the total cost of these systems was allocated to flood control.

For the Lower Valley tidal levee/floodwall systems, the overwhelming majority of the benefits accruing to these systems result from hurricane protection. Only a small fraction of the benefits are attributed to flood control. Therefore, the total cost of these systems was allocated to hurricane protection.

RISK AND UNCERTAINTY

The risk and uncertainty associated with the recommended plan were considered. "Risk" situations are defined as those where potential outcomes can be described in reasonably well-known probability distributions. In situations of "uncertainty," potential outcomes cannot be described in probability distributions.

A determination was made of the probability of certain flood events occurring during the life of the project. This analysis indicated that during the 100-year project life, the probability of occurrence would be 63 percent for a 100-year flood event, and 18 percent for a 500-year flood. The probability of occurrence of the Standard Project Flood would vary throughout the basin, but would be less than 17 percent.

A sensitivity analysis of various economic parameters is contained in the Economics Supporting Documentation.

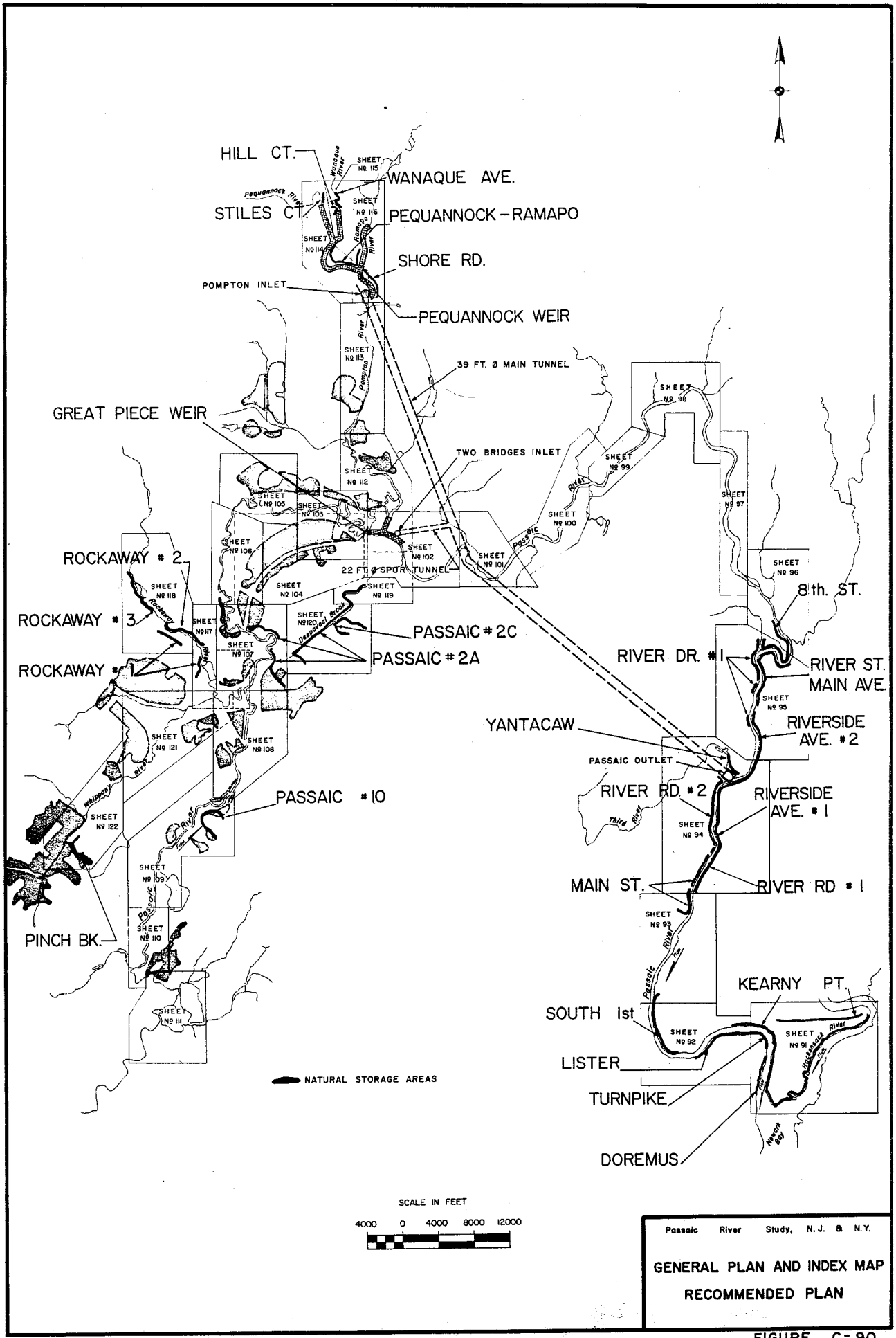
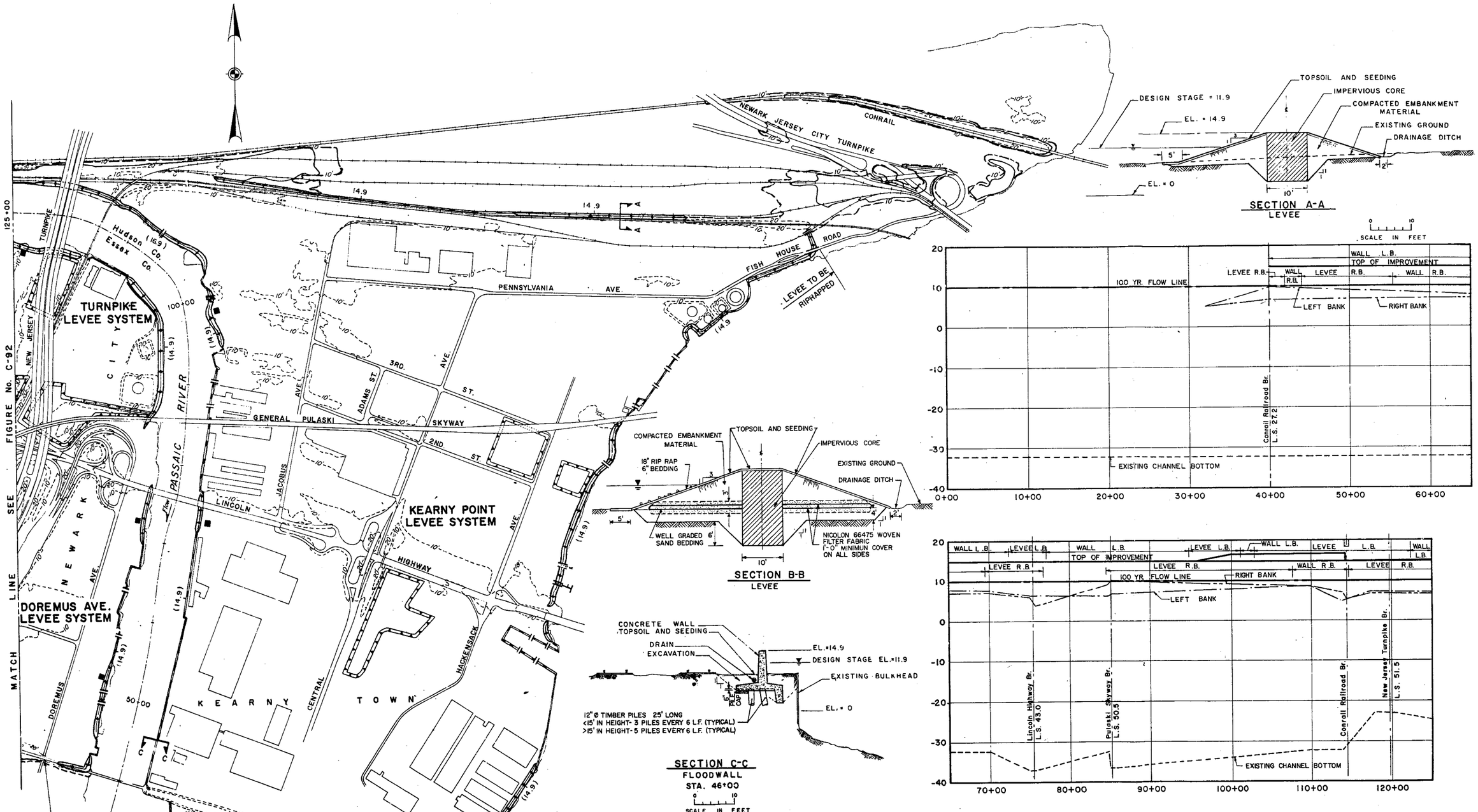

HILL CT.
WANAQUE AVE.
STILES CT.
PEQUANNOCK - RAMAPO
SHORE RD.
POMPTON INLET
PEQUANNOCK WEIR
39 FT. Ø MAIN TUNNEL
GREAT PIECE WEIR
TWO BRIDGES INLET
22 FT. Ø SPUR TUNNEL
ROCKAWAY # 2
ROCKAWAY # 3
ROCKAWAY # 1
PASSAIC # 2C
PASSAIC # 2A
PASSAIC # 10
PINCH BK.
8th. ST.
RIVER DR. # 1
RIVER ST.
MAIN AVE.
YANTACAW
RIVERSIDE AVE. # 2
PASSAIC OUTLET
RIVER RD. # 2
RIVERSIDE AVE. # 1
MAIN ST.
RIVER RD # 1
KEARNY PT.
SOUTH 1st
LISTER
TURNPIKE
DOREMUS
NATURAL STORAGE AREAS
SCALE IN FEET
4000 0 4000 8000 12000
Passaic River Study, N.J. & N.Y.
GENERAL PLAN AND INDEX MAP
RECOMMENDED PLAN

FIGURE C-90



PLAN

SCALE IN FEET
500 0 500 1000

SECTION A-A
LEVEE

SCALE IN FEET
0 10

SECTION B-B
LEVEE

SECTION C-C
FLOODWALL
STA. 46+00

SCALE IN FEET
0 10

PROFILE

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

SCALE IN FEET
HOR. 500 0 500 1000
VERT. 10 0 10 20

Passaic River Study, N.J. & N.Y.

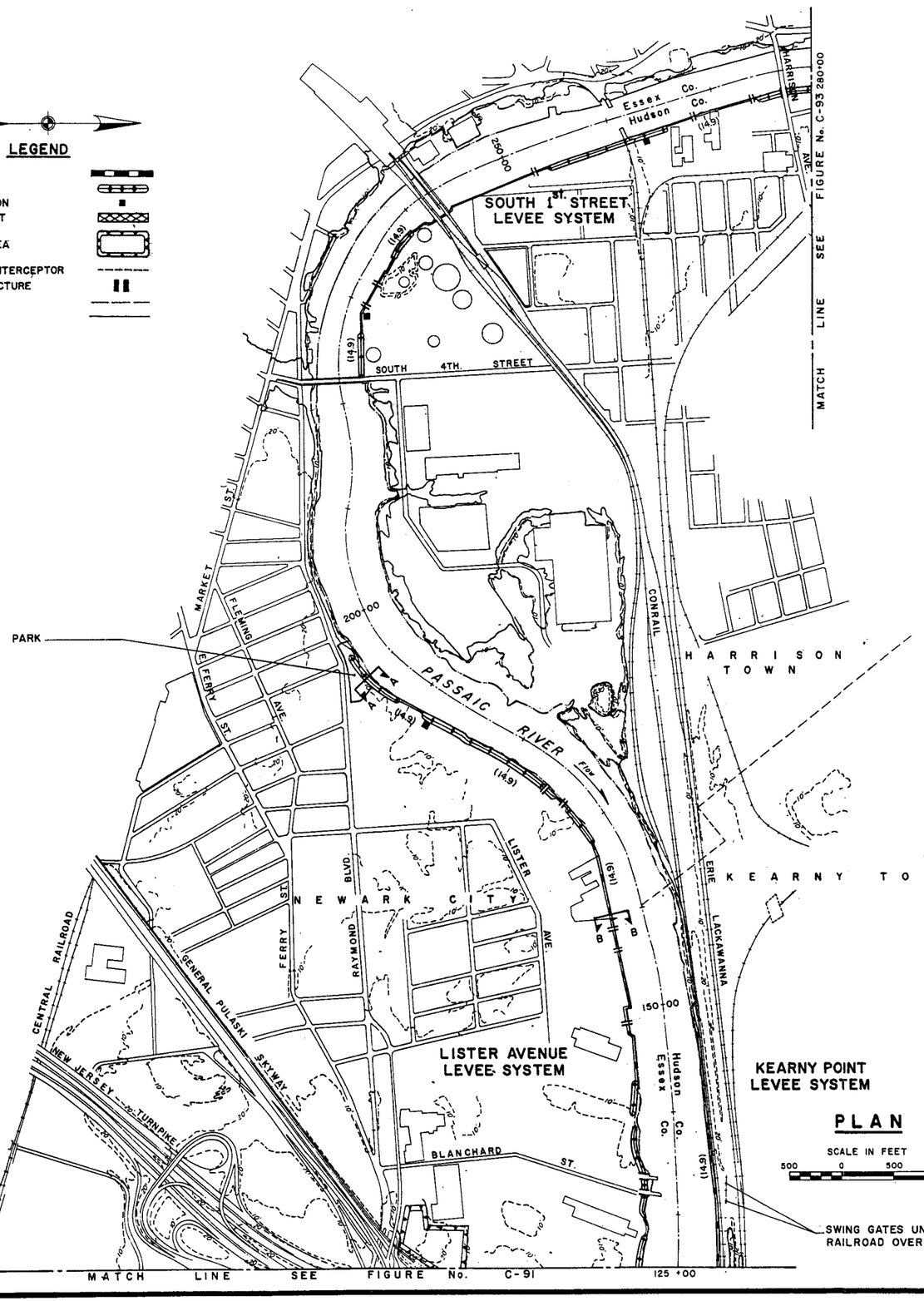
Passaic River

STA. 0+00 TO STA. 125+00

RECOMMENDED PLAN

LEGEND

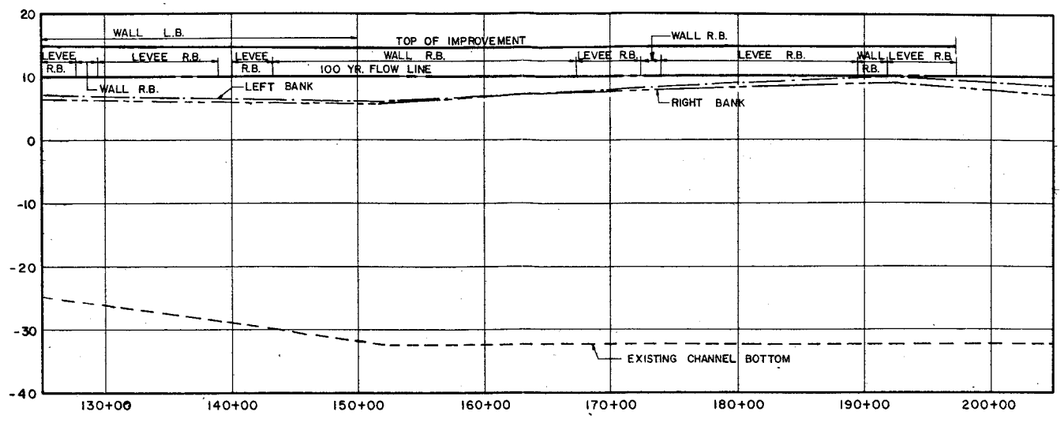
FLOODWALL
LEVEE
PUMP STATION
CHANNEL CUT
PONDING AREA
PRESSURE INTERCEPTOR
GATED STRUCTURE
100 YR.
500 YR.

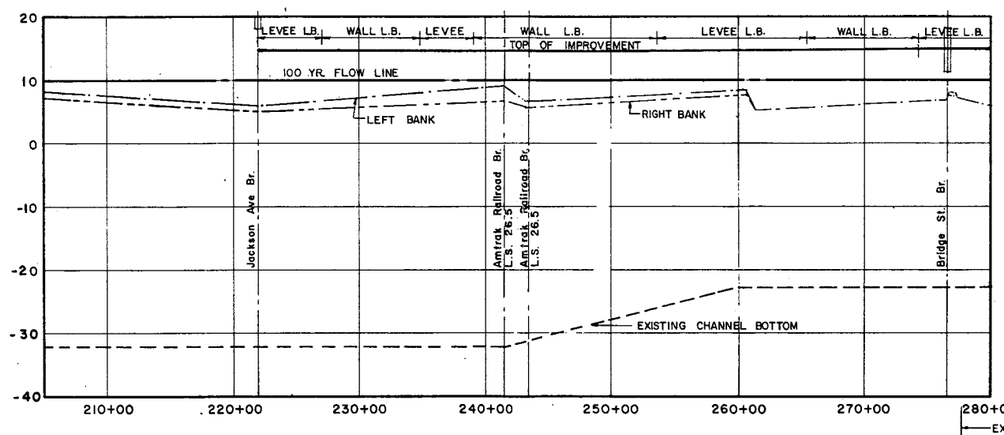


PLAN

SCALE IN FEET
500 0 500 1000

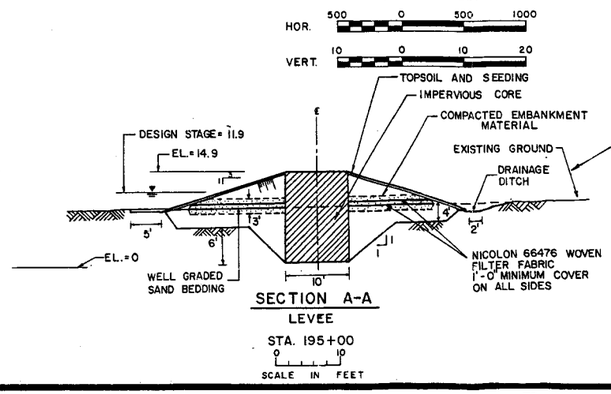
SWING GATES UNDER RAILROAD OVERPASSES



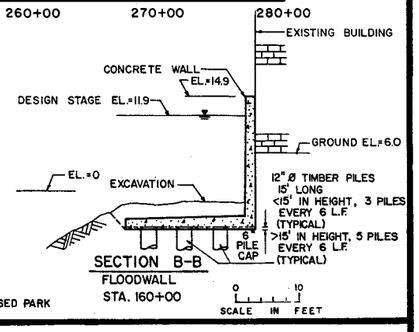


PROFILE

SCALE IN FEET
HOR. 500 0 500 1000
VERT. 10 0 10 20



SECTION A-A
LEVEE
STA. 195+00
0 10
SCALE IN FEET



SECTION B-B
FLOODWALL
STA. 160+00
0 10
SCALE IN FEET

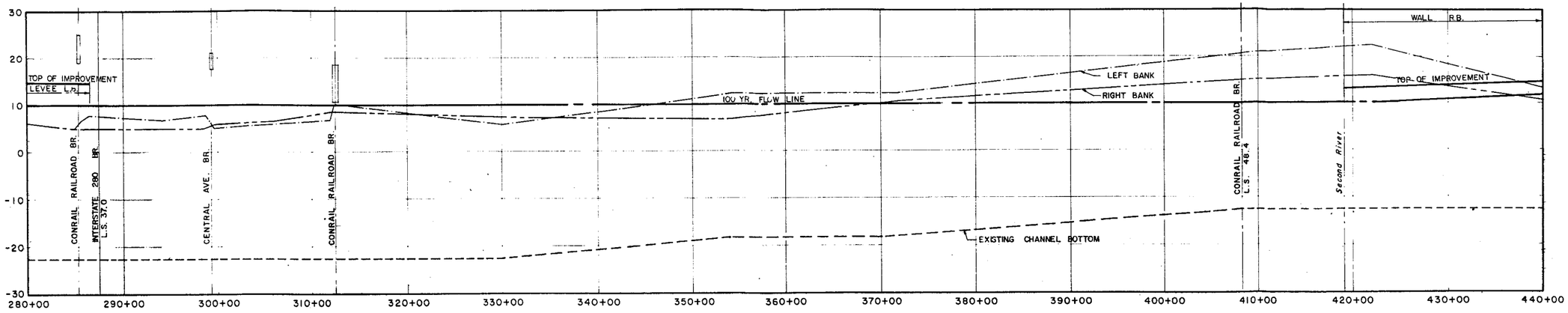
Passaic River Study, N.J. & N.Y.

Passaic. River
STA. 125+00 TO STA. 280+00

RECOMMENDED PLAN

52.

FIGURE No. C-92

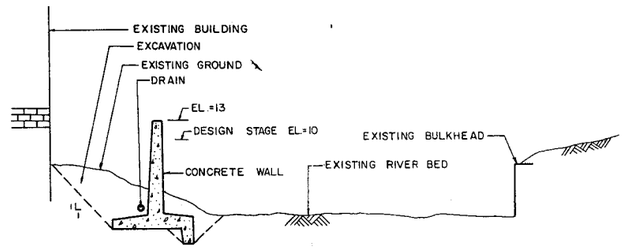


PROFILE

SCALE IN FEET

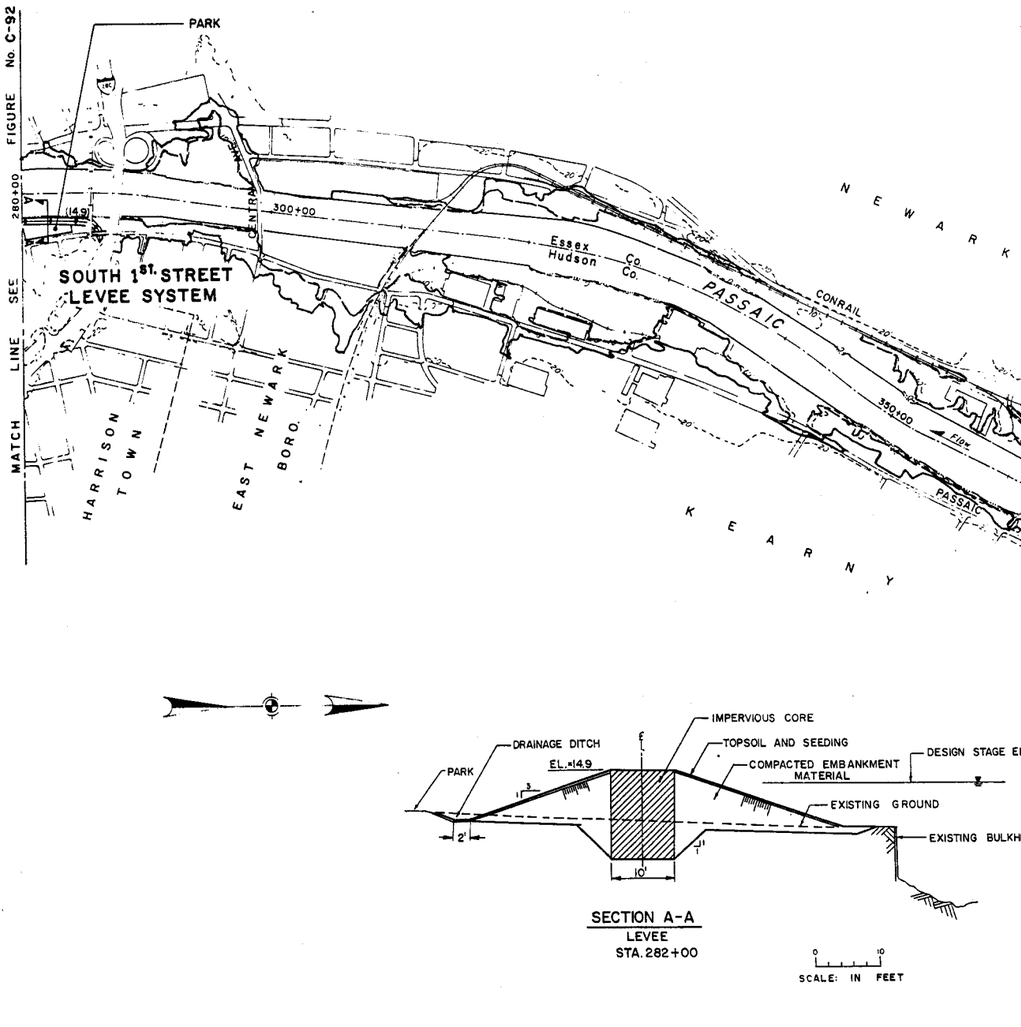
HOR 500 0 500 1000

VERT 10 0 10 20



SECTION B-B
FLOODWALL
STA. 4+60 (SECOND RIVER)

0 10
SCALE IN FEET



SECTION A-A
LEVEE
STA. 282+00

0 10
SCALE: IN FEET

PLAN

SCALE IN FEET
500 0 500 1000

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

Passaic River Study, N.J. & N.Y.

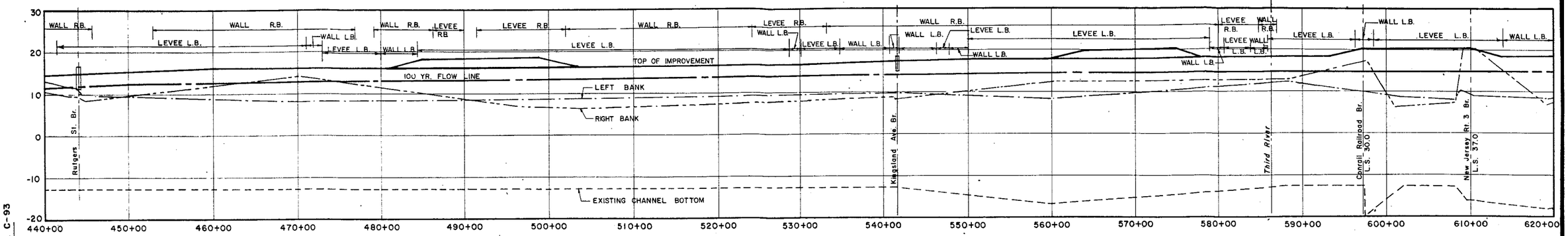
Passaic River

STA. 280+00 TO STA. 440+00

RECOMMENDED PLAN

FIGURE No. C-93

573

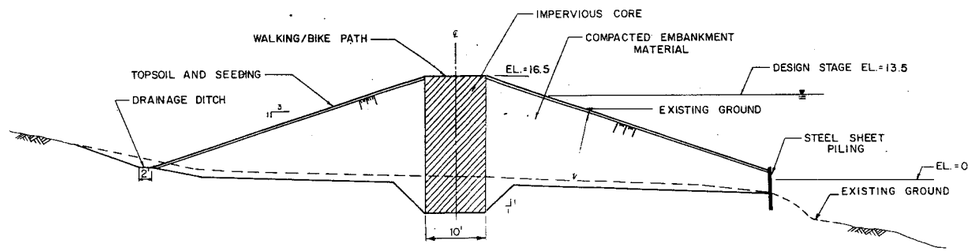


PROFILE

SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20



SECTION B-B
LEVEE
STA. 504+00
0 10
SCALE IN FEET

SECTION A-A
FLOODWALL
STA. 504+00
0 10
SCALE IN FEET

PLAN

SCALE IN FEET 500 0 500 1000

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

Passaic River Study, N.J. & N.Y.

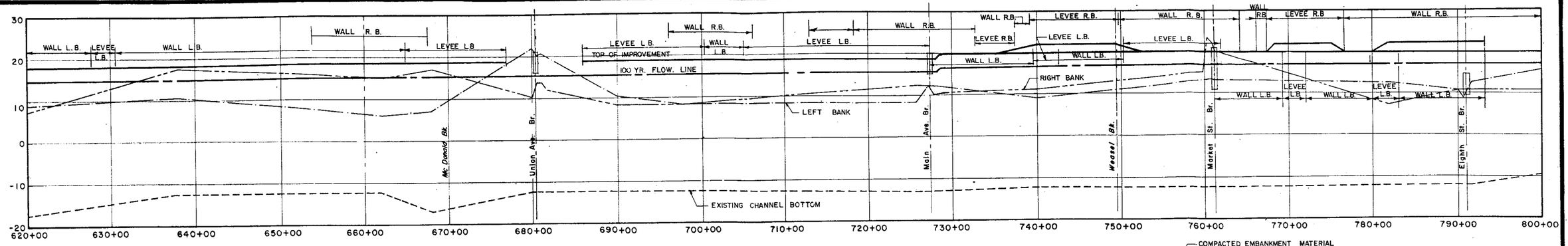
Passaic River

STA. 440+00 TO STA. 620+00

RECOMMENDED PLAN

FIGURE No. C-94

574

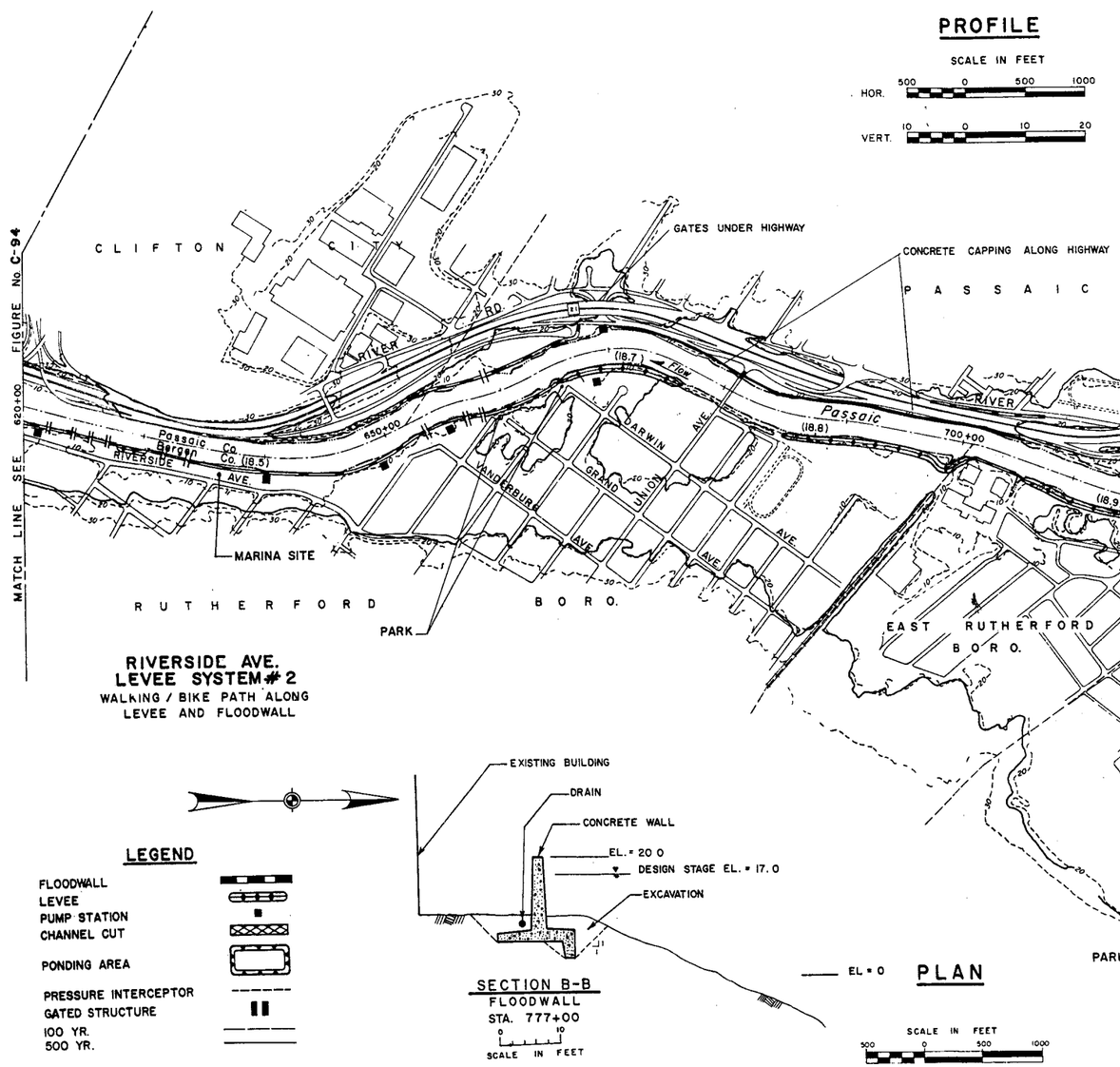


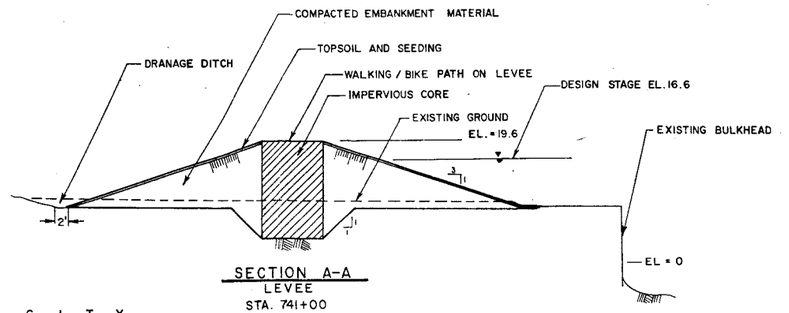
PROFILE

SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20





SECTION A-A
LEVEE
STA. 741+00
0 10
SCALE IN FEET

SECTION B-B
FLOODWALL
STA. 777+00
0 10
SCALE IN FEET

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

EL = 0

PLAN

SCALE IN FEET 500 0 500 1000

Passaic River Study, N.J. & N.Y.

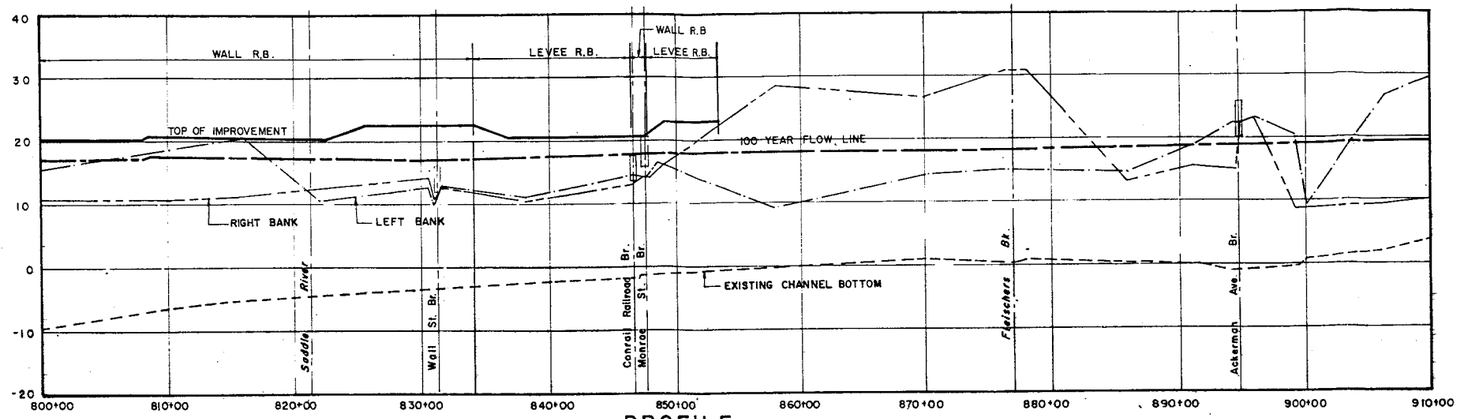
Passaic River

STA. 620+00 TO STA. 800+00

RECOMMENDED PLAN

FIGURE No. C-95

575

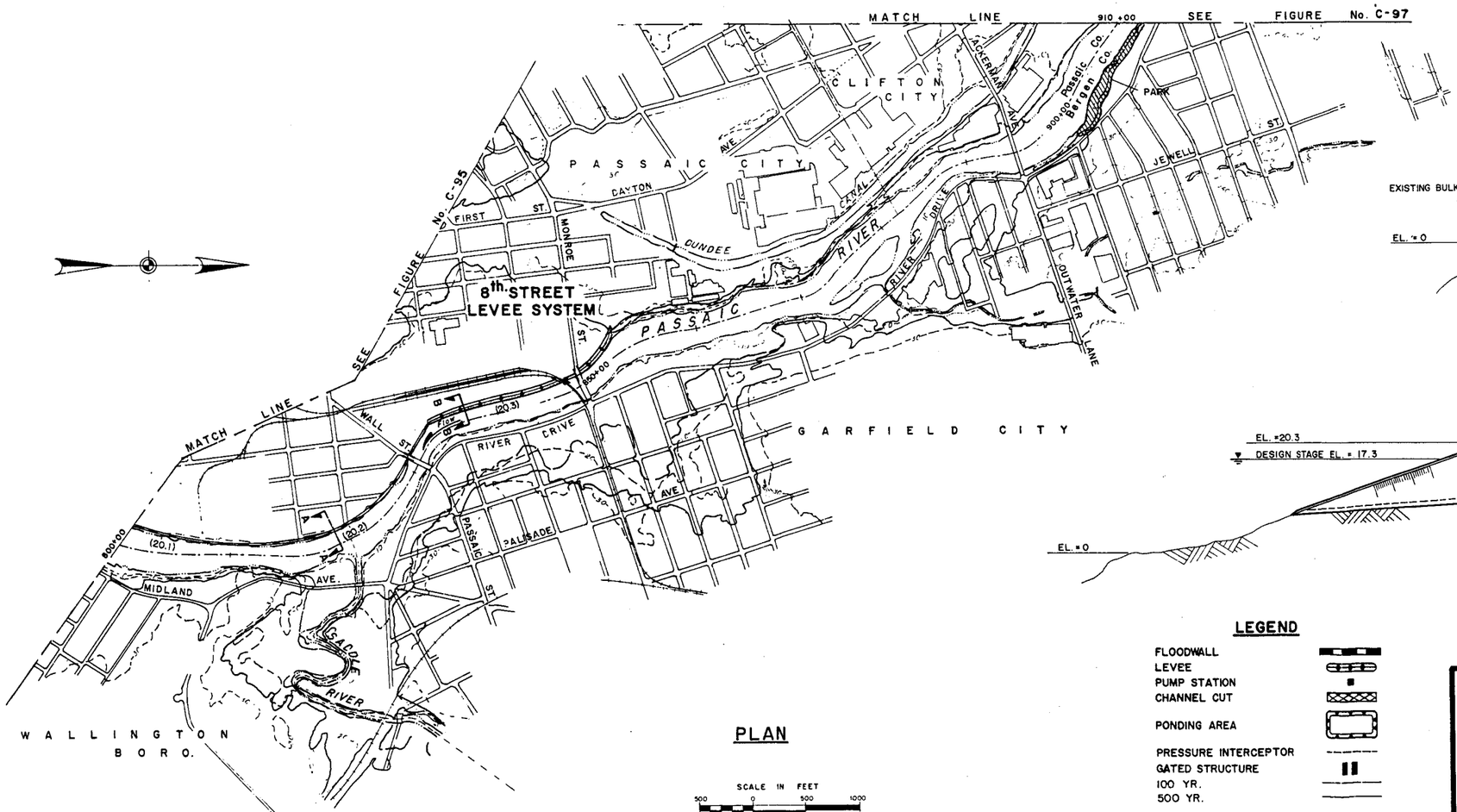


PROFILE

SCALE IN FEET

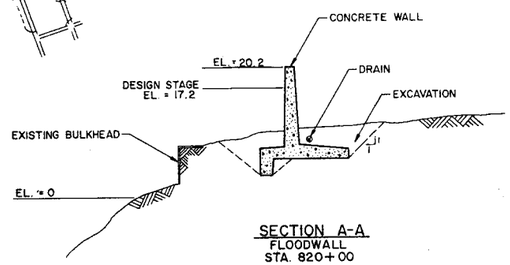
HOR. 500 0 500 1000

VERT. 10 0 10 20



PLAN

SCALE IN FEET 500 0 500 1000



SECTION A-A
FLOODWALL
STA. 820+00
0 10
SCALE IN FEET

SECTION B-B
LEVEE
STA. 837+00
0 10
SCALE IN FEET

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

Passaic River Study, N.J. & N.Y.

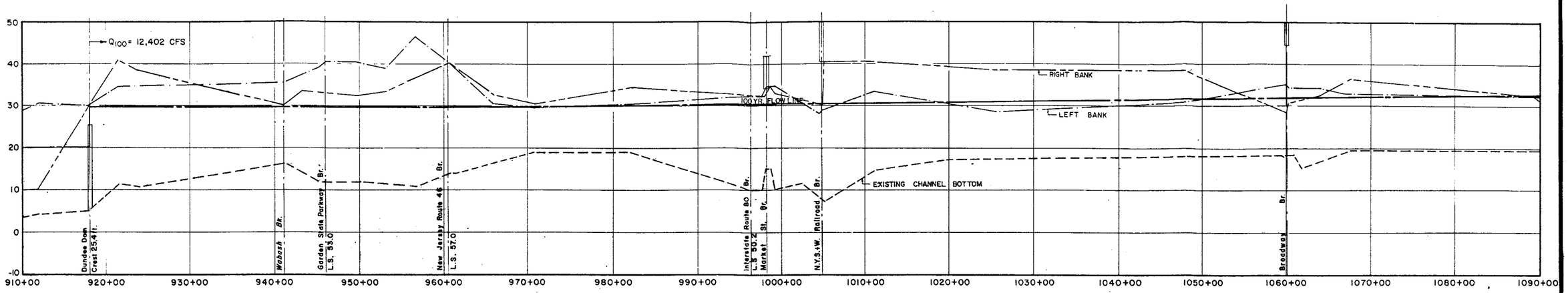
Passaic River

STA. 800+00 TO STA. 910+00

RECOMMENDED PLAN

FIGURE No. C-96

576

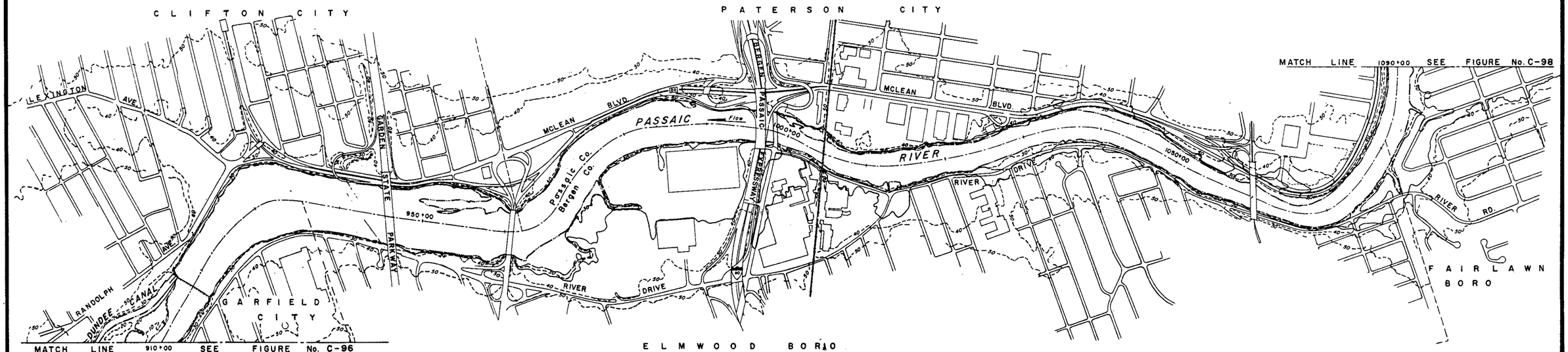


PROFILE

SCALE IN FEET

HOR: 500 0 500 1000

VERT. 10 0 10 20



PLAN

SCALE IN FEET

500 0 500 1000

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

Passaic River Study, N.J. & N.Y.

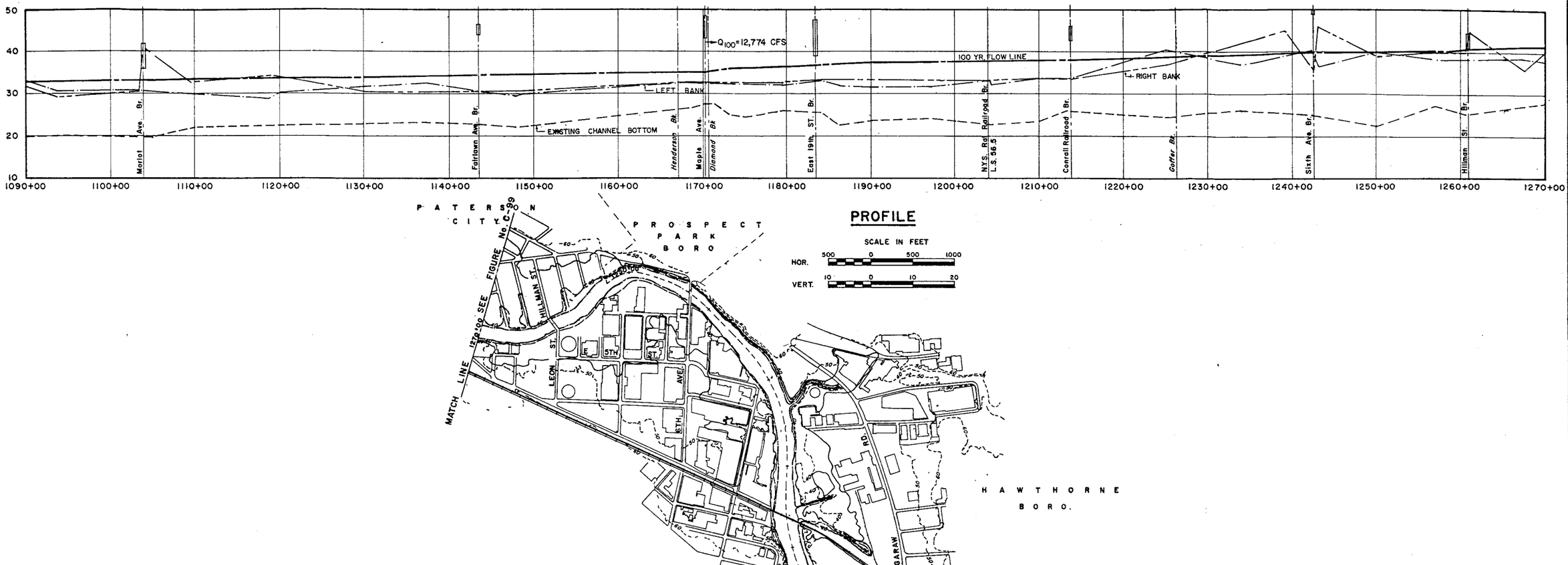
Passaic River

STA. 910+00 TO STA. 1090+00

RECOMMENDED PLAN

FIGURE No. C-97

577

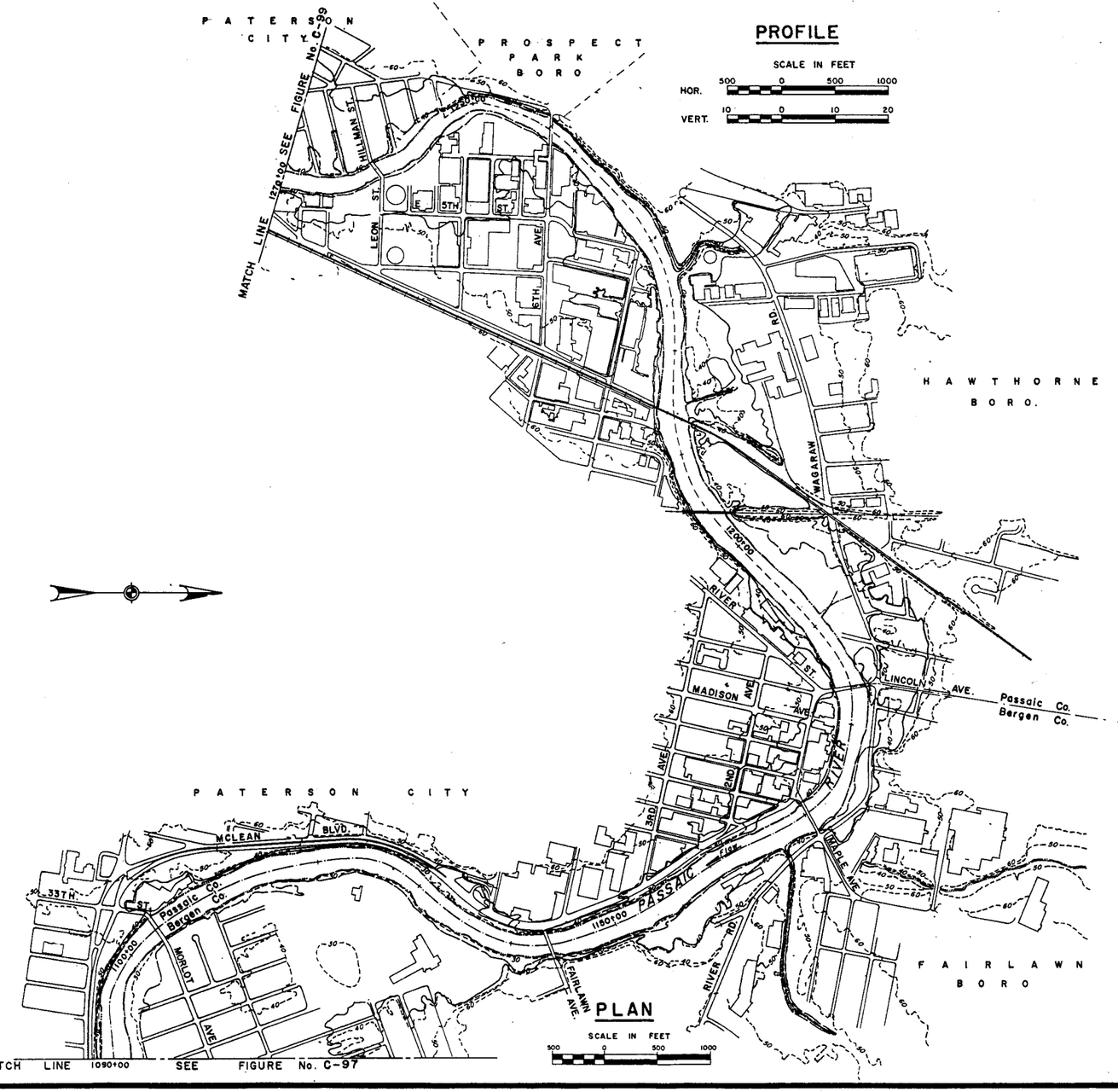


PROFILE

SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20



PLAN

SCALE IN FEET 500 0 500 1000

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

Passaic River Study, N.J. & N.Y.

Passaic River

STA. 1090+00 TO STA. 1270+00

RECOMMENDED PLAN

578

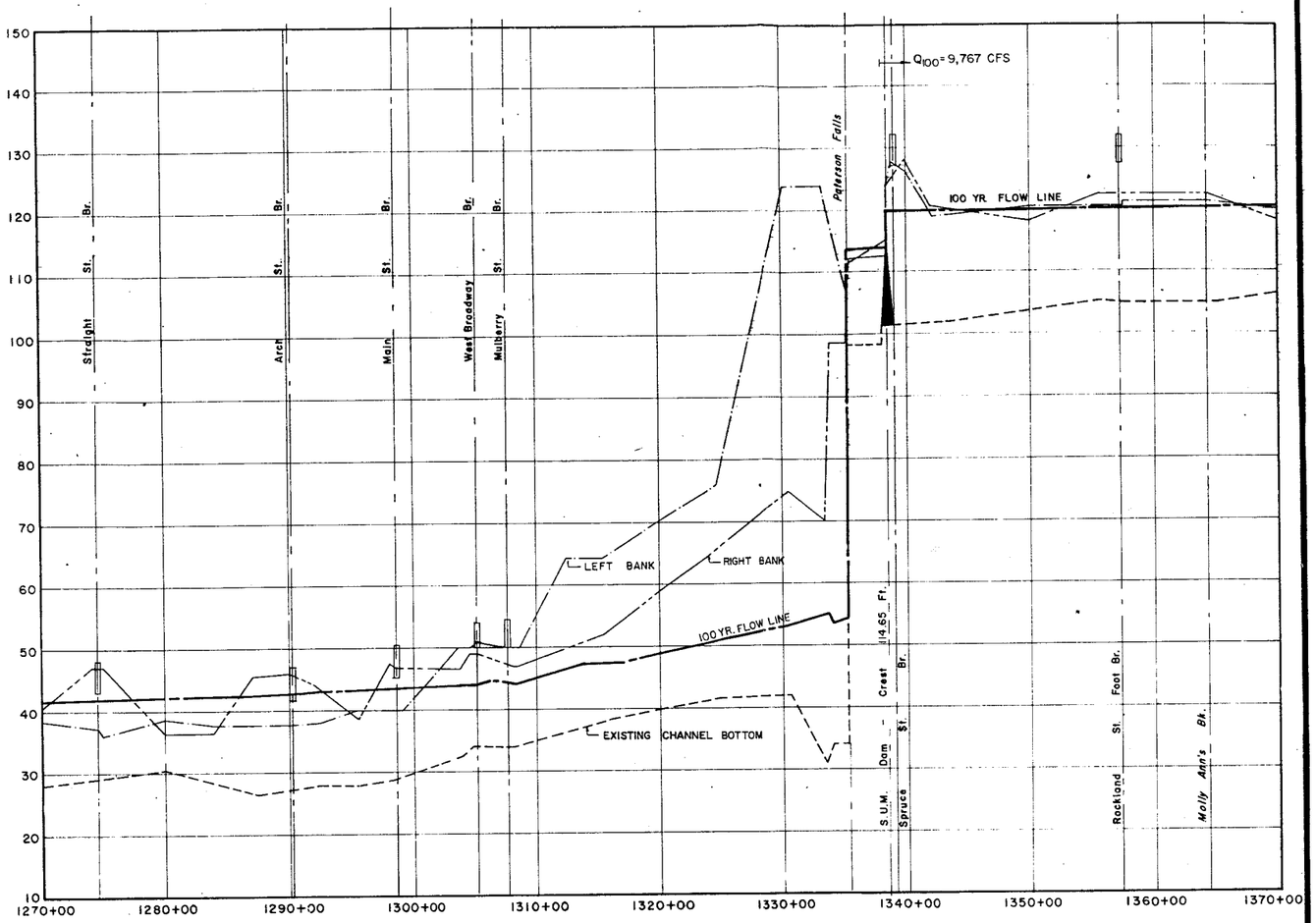
FIGURE No. C-98



PLAN

SCALE IN FEET

500 0 500 1000



PROFILE

SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR

Passaic River Study, N.J. & N.Y.

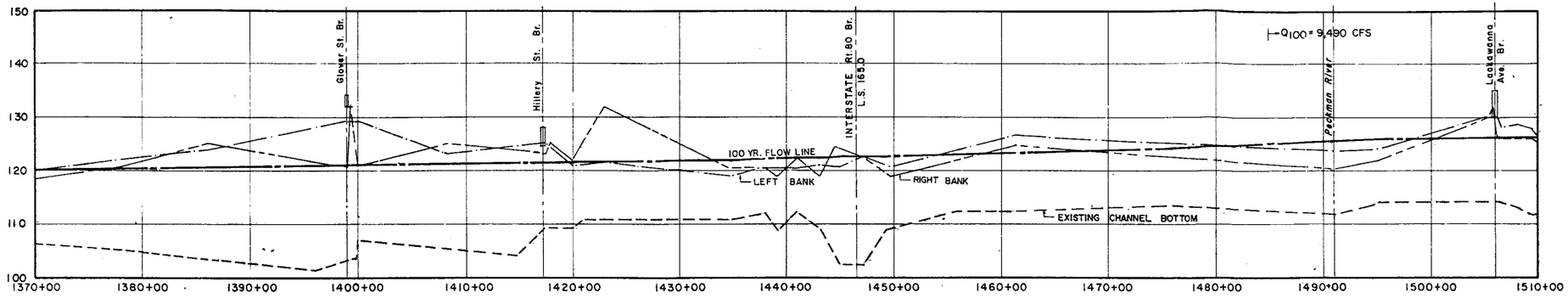
Passaic River

STA. 1270+00 TO STA. 1370+00

RECOMMENDED PLAN

FIGURE No. C-99

579

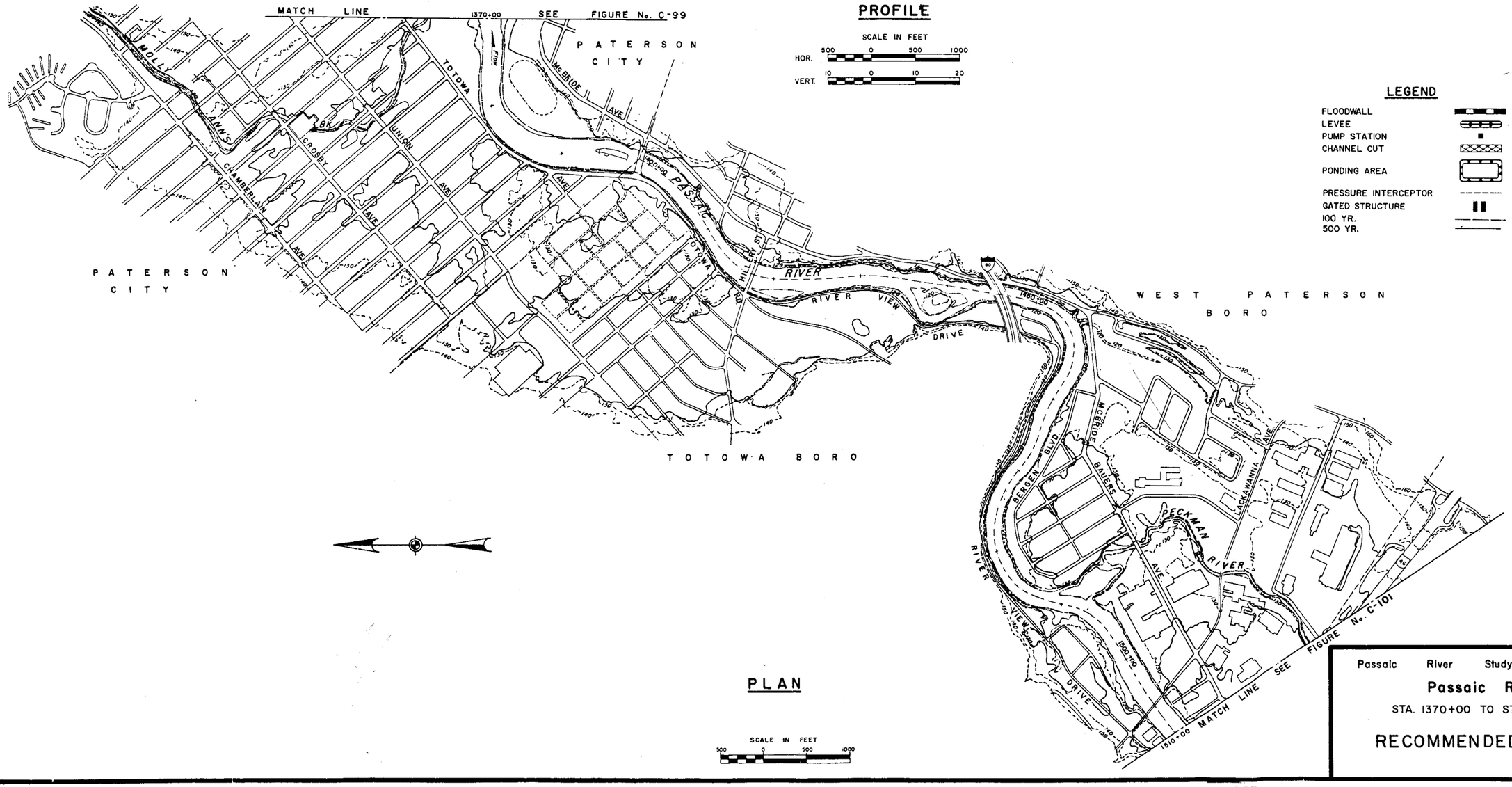


PROFILE

SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20



PLAN

SCALE IN FEET 500 0 500 1000

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

Passaic River Study, N.J. & N.Y.

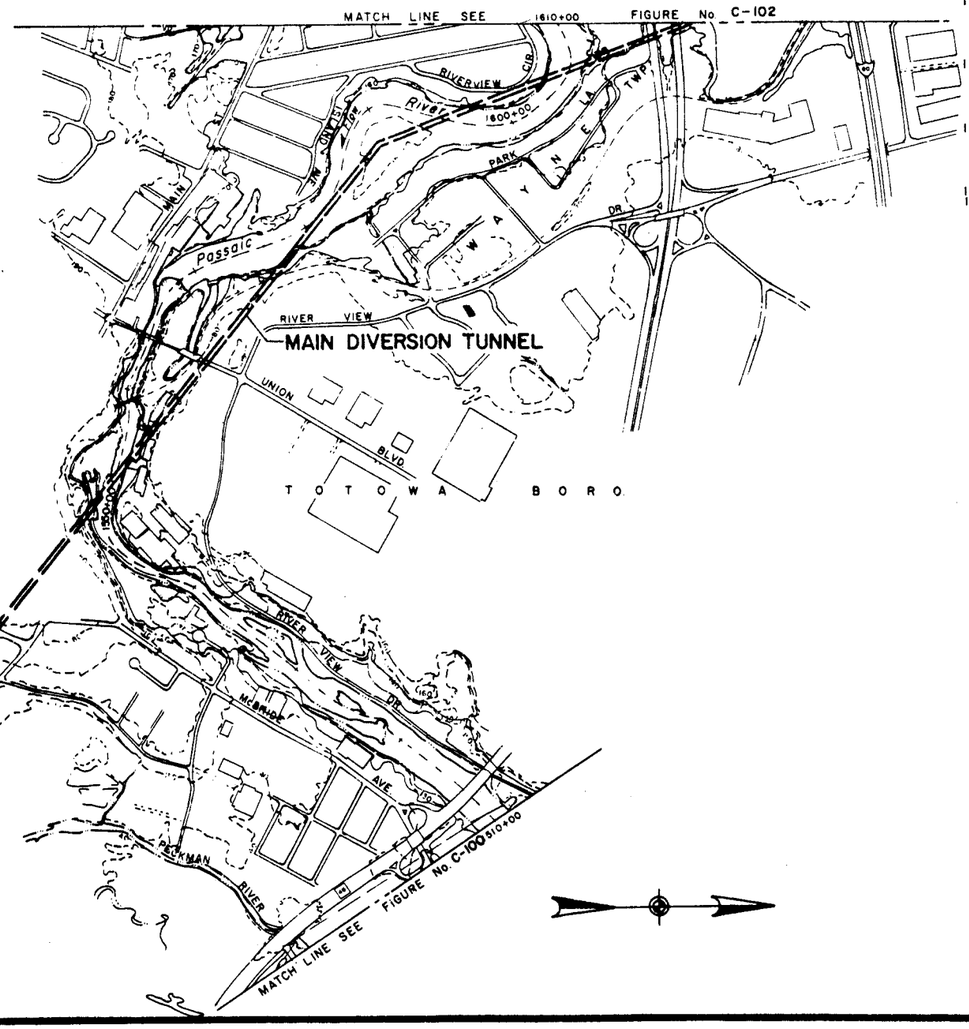
Passaic River

STA. 1370+00 TO STA. 1510+00

RECOMMENDED PLAN

FIGURE No. C-100

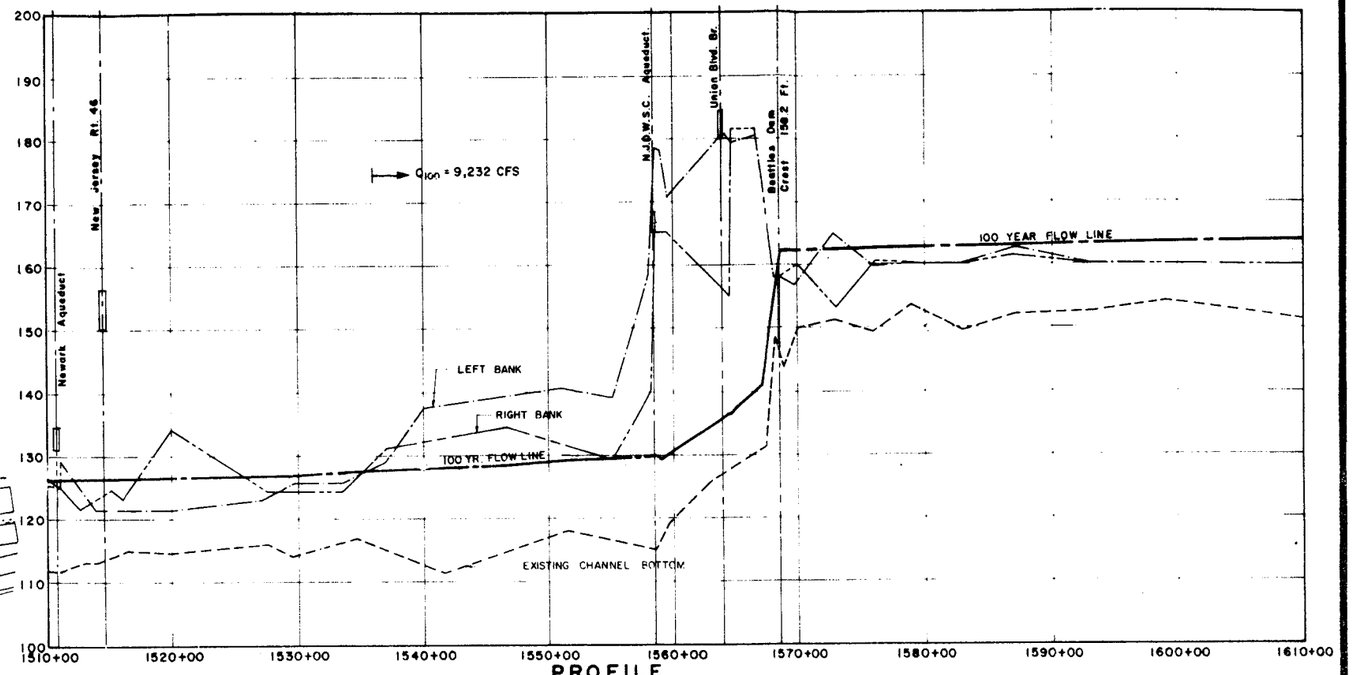
580



PLAN

SCALE IN FEET

300 0 500 1000



PROFILE

HOR. 500 0 500 1000

VERT. 0 5 10 20

SCALE IN FEET

LEGEND

FLOODWALL	
LEVEE	
PUMP STATION	
CHANNEL CUT	
PONDING AREA	
PRESSURE INTERCEPTOR	
GATED STRUCTURE	
100 YR.	
500 YR.	

Passaic River Study, N.J. & N.Y.

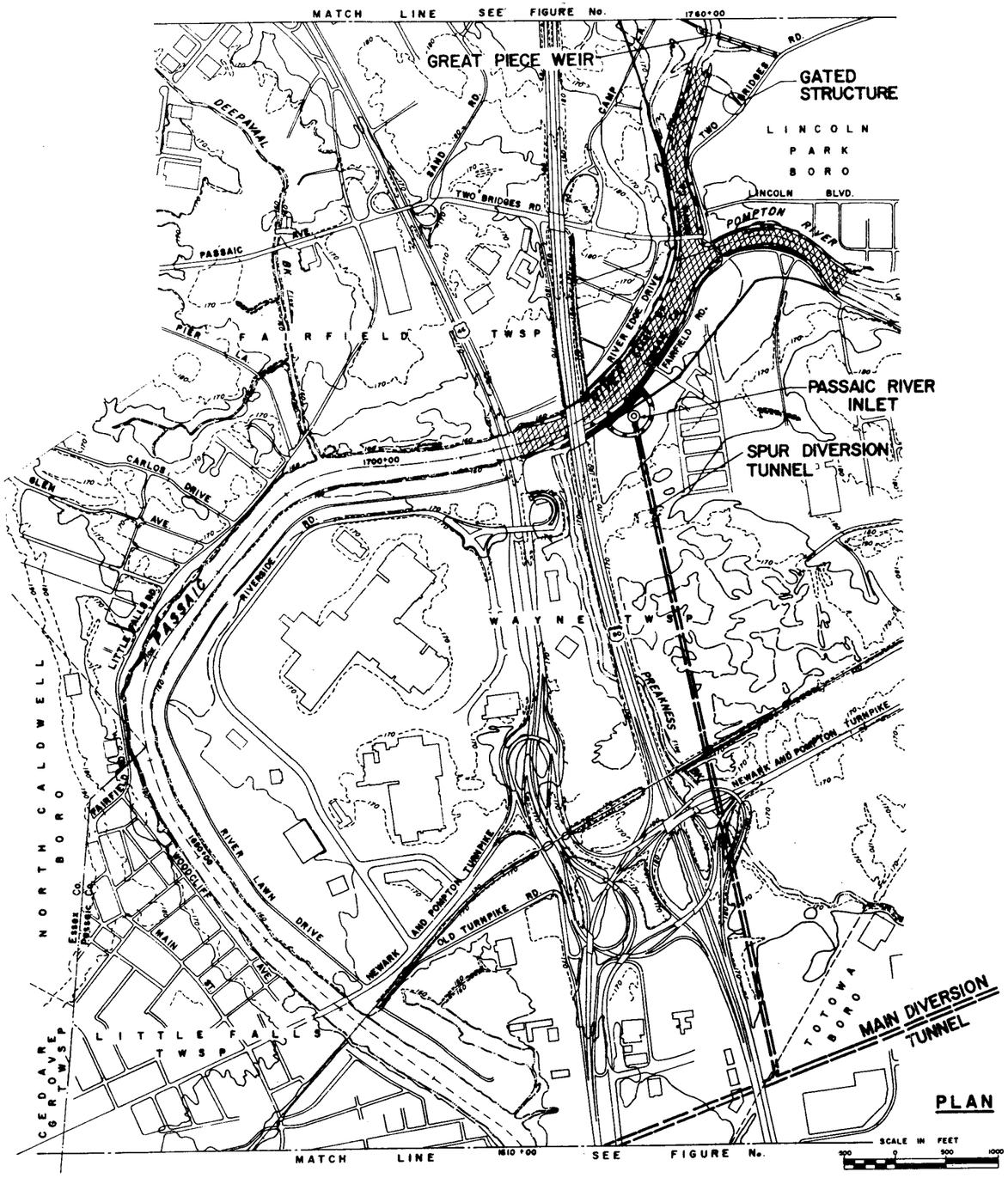
Passaic River

STA. 1510+00 TO STA. 1610+00

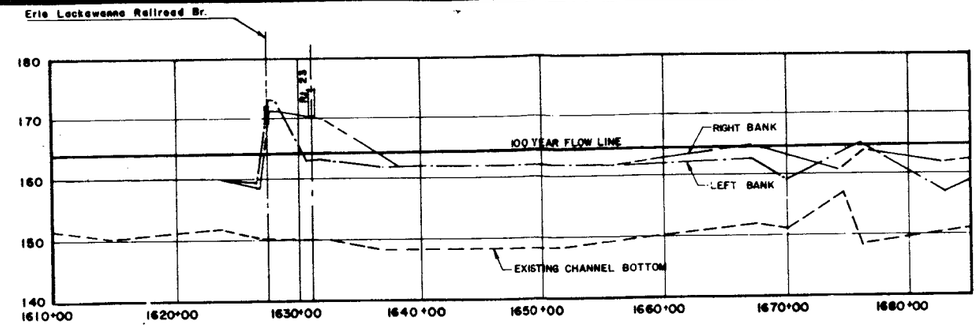
RECOMMENDED PLAN

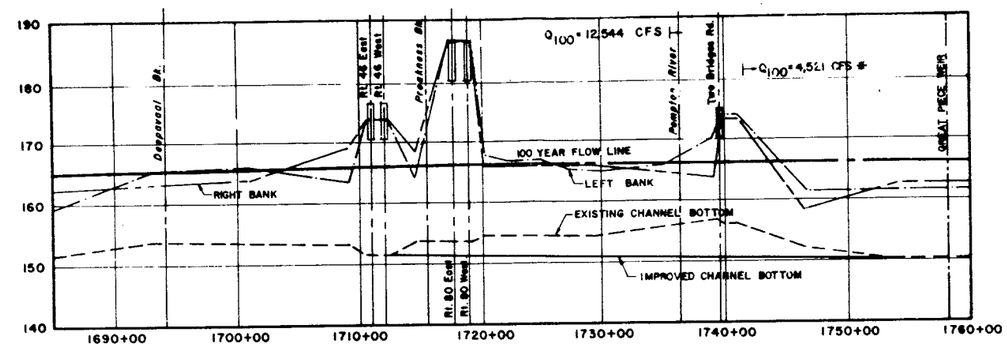
FIGURE No. C-101

581



PLAN





COINCIDENTAL FLOW *

PROFILE

SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.
- STATE DESIGNATED FLOODWAYS

Passaic River Study, N.J. & N.Y.

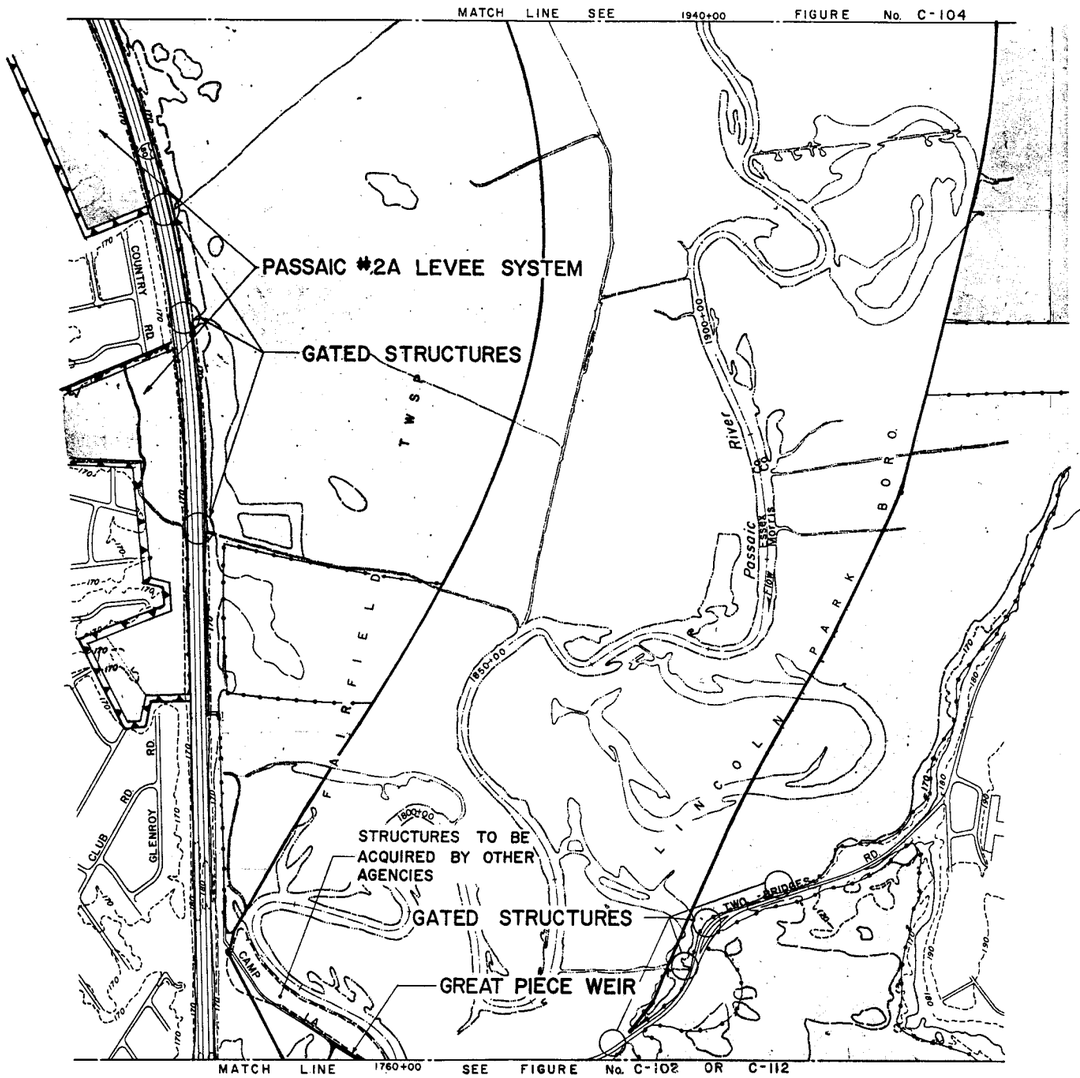
Passaic River

STA. 1610+00 TO STA. 1760+00

RECOMMENDED PLAN

FIGURE No. C-102

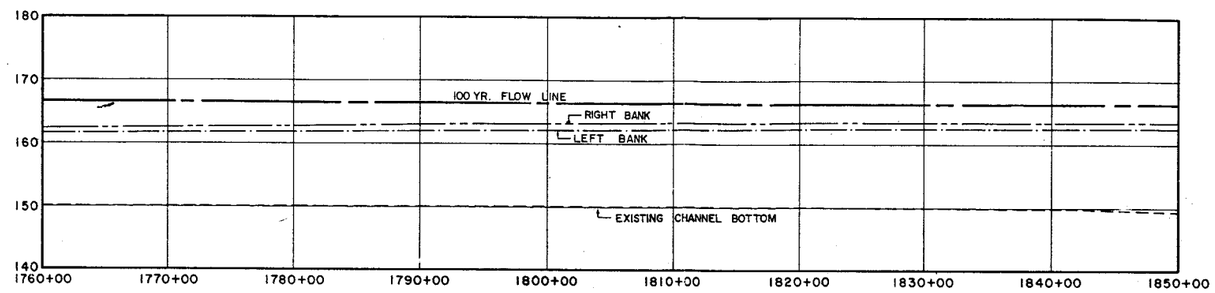
582

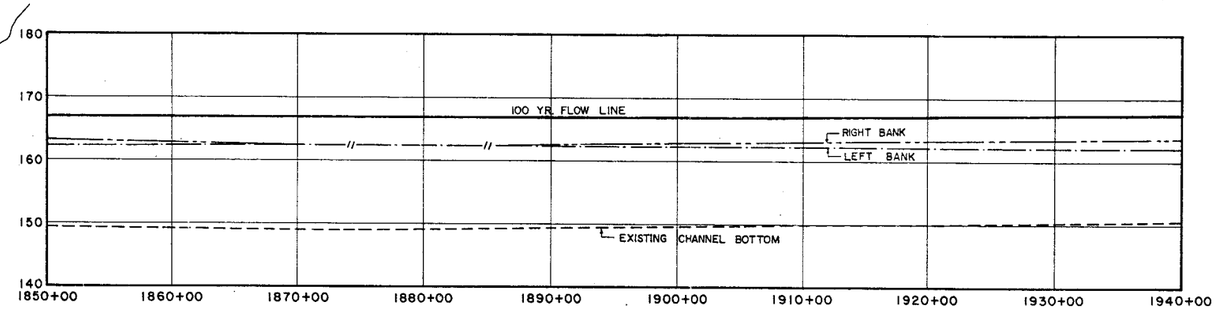


PLAN

SCALE IN FEET

500 0 500 1000





PROFILE

SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20

LEGEND

- ACQUISITION OF NATURAL STORAGE AREAS
- STATE DESIGNATED FLOODWAYS
- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

Passaic River Study, N.J. & N.Y.

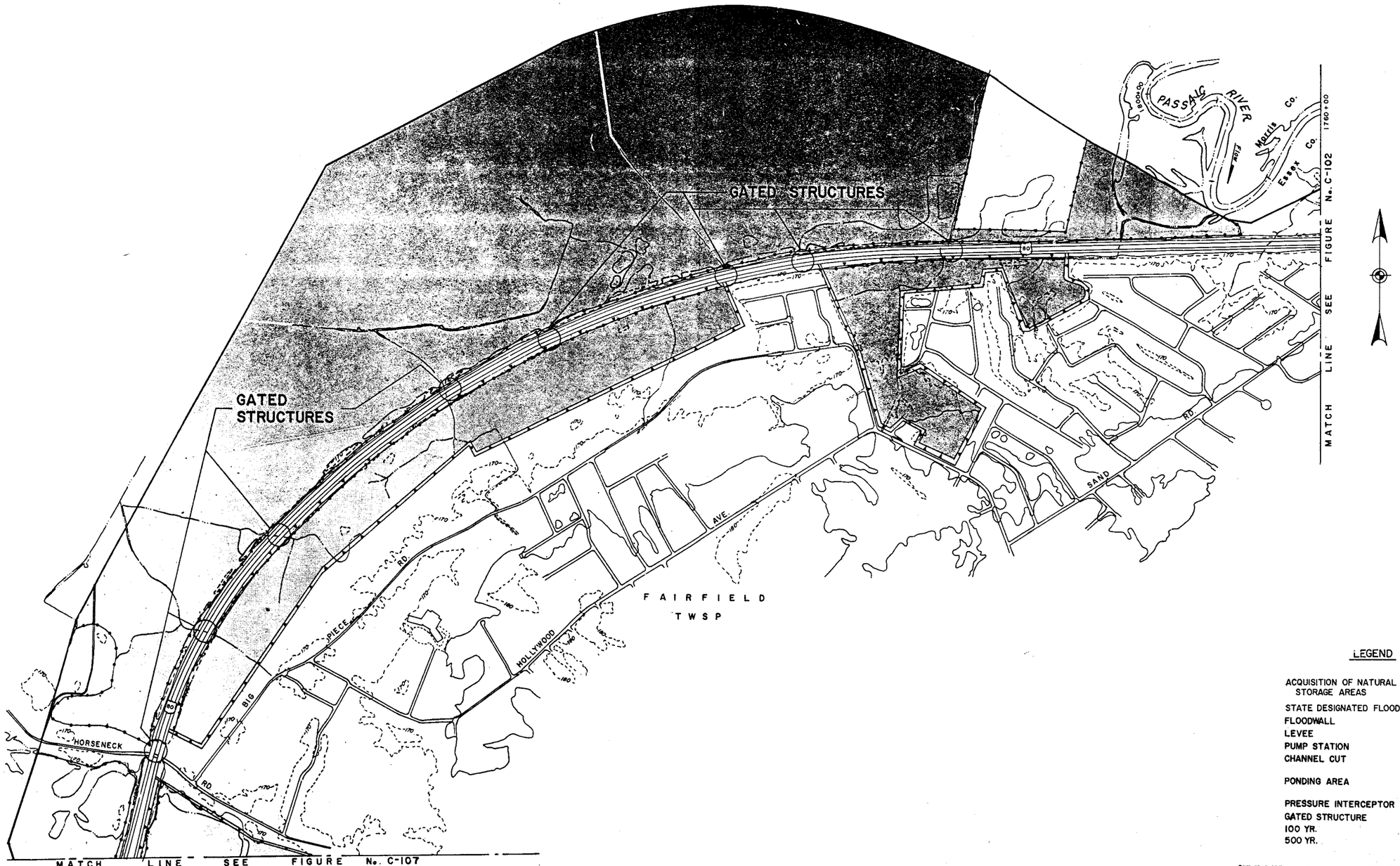
Passaic River

STA. 1760+00 TO STA. 1940+00

RECOMMENDED PLAN

FIGURE No. C-103

583



PLAN

SCALE IN FEET
500 0 500 1000

LEGEND

- ACQUISITION OF NATURAL STORAGE AREAS
- STATE DESIGNATED FLOODWAY
- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

Passaic River Study, N.J. & N.Y.

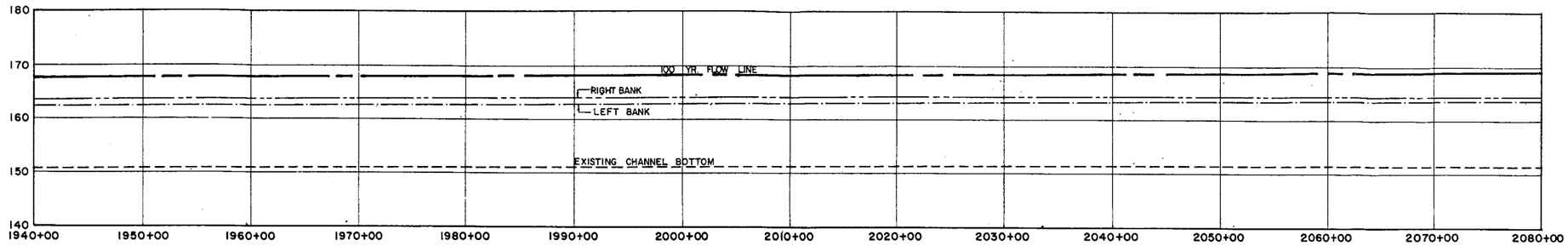
Passaic River

OVERBANK STA. 1760+00
TO STA. 2240+00

RECOMMENDED PLAN

FIGURE No. C-104

5611

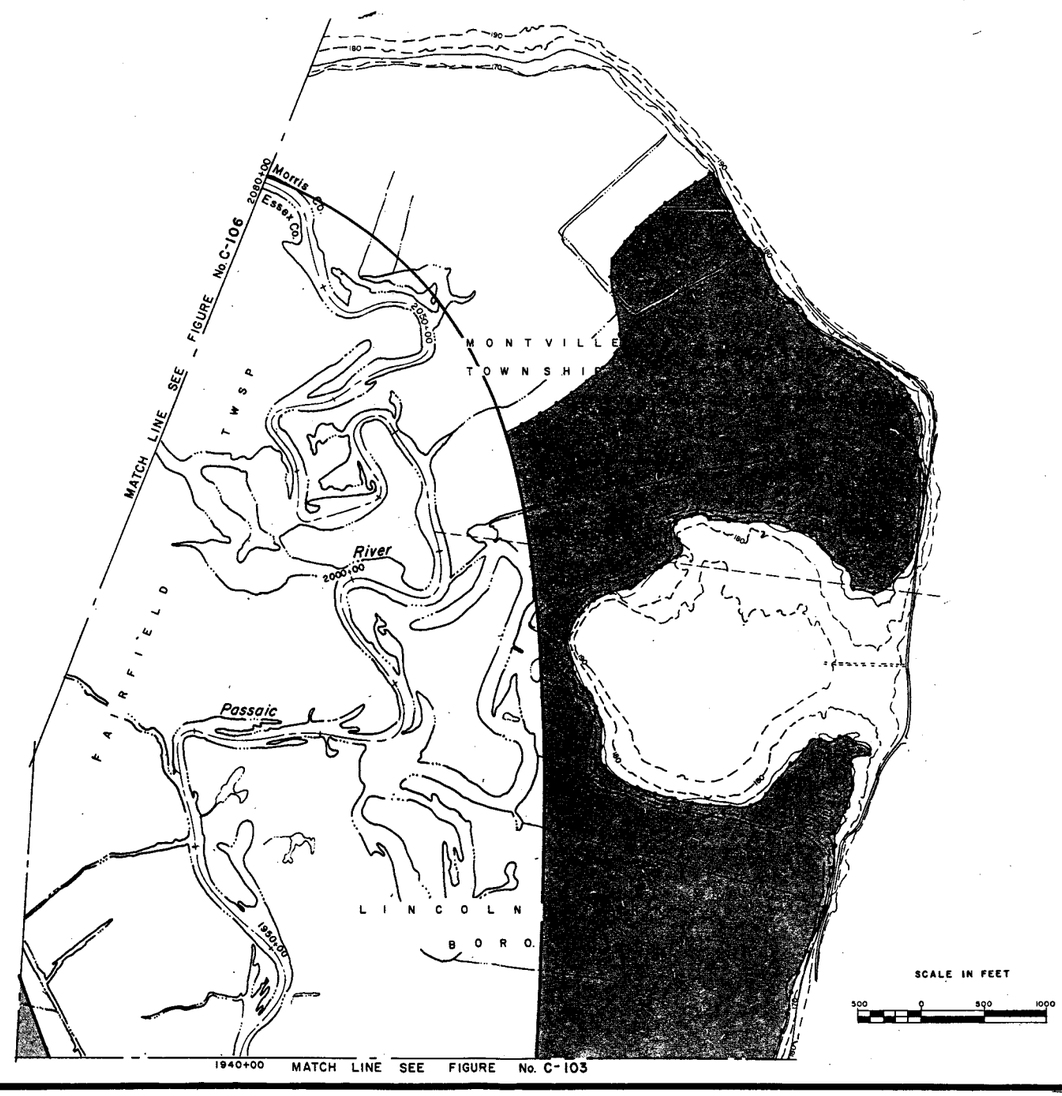


PROFILE

SCALE IN FEET

HORZ. 500 0 500 1000

VERT. 10 0 10 20



LEGEND

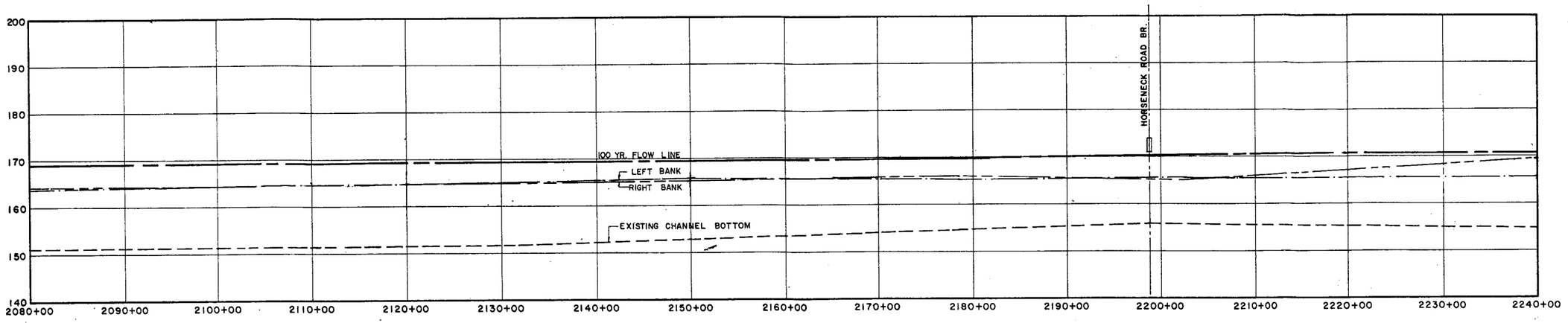
- ACQUISITION OF NATURAL STORAGE AREAS
- STATE DESIGNATED FLOODWAYS
- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

Passaic River Study, N.J. & N.Y.

Passaic River

STA. 1940+00 TO STA. 2080+00

RECOMMENDED PLAN

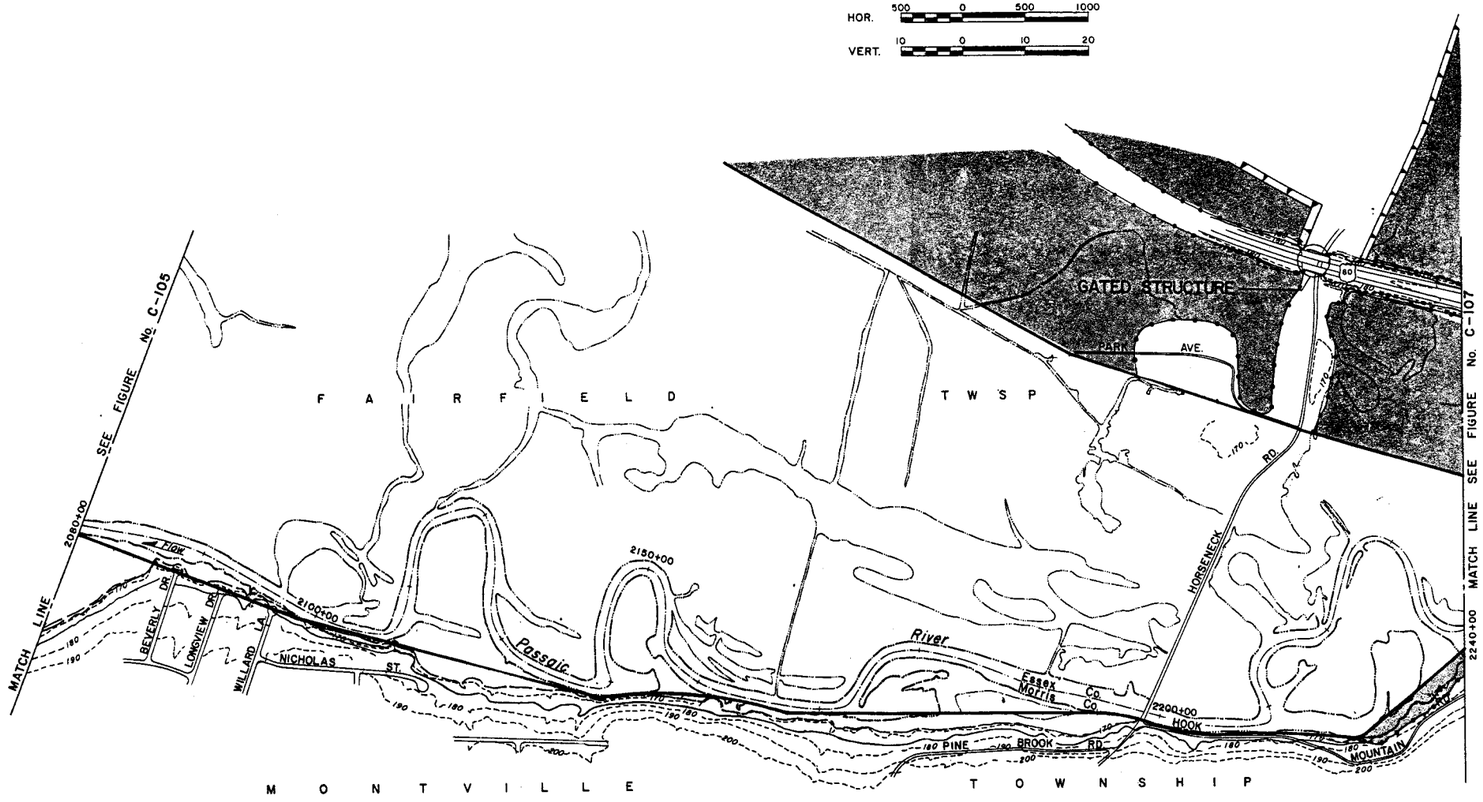


PROFILE

SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20



PLAN

SCALE IN FEET

500 0 500 1000

LEGEND

- ACQUISITION OF NATURAL STORAGE AREAS
- STATE DESIGNATED FLOODWAYS
- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

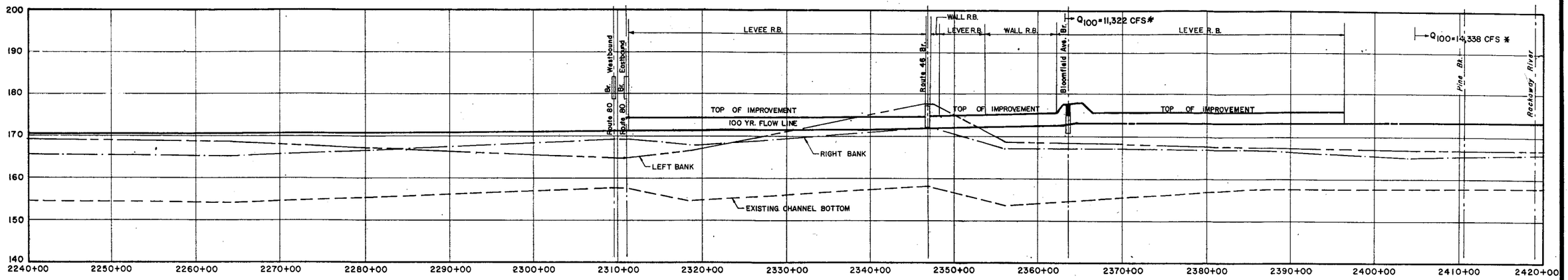
Passaic River Study, N.J. & N.Y.

Passaic River

STA. 2080+00 TO STA. 2240+00

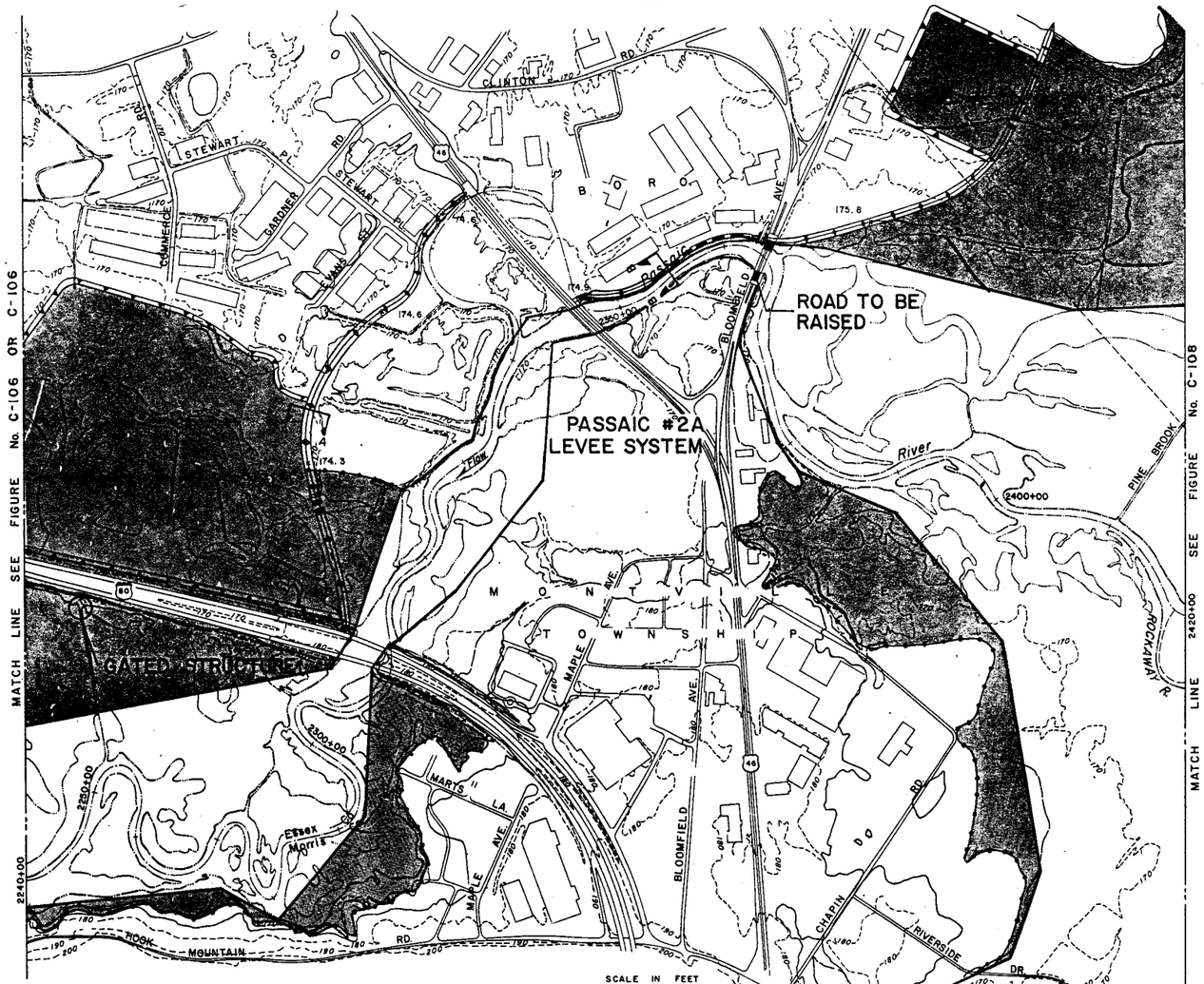
RECOMMENDED PLAN

FIGURE No. C-106



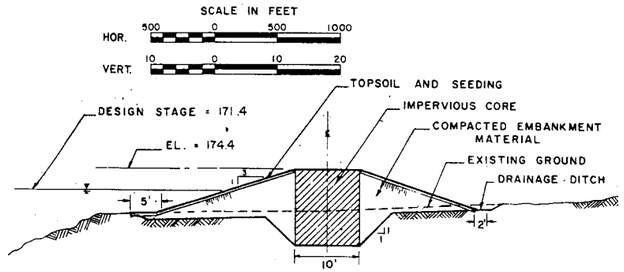
COINCIDENTAL FLOW *

PROFILE



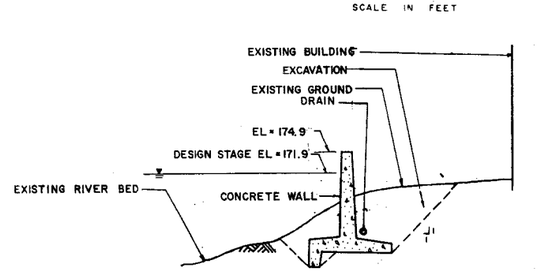
PLAN

SCALE IN FEET 500 0 500 1000



SECTION A-A
LEVEE
STA. 2330+00

SCALE IN FEET 0 10



SECTION B-B
FLOODWALL STA. 2354+00

SCALE IN FEET 0 10

LEGEND

- ACQUISITION OF NATURAL STORAGE AREAS
- STATE DESIGNATED FLOODWAYS
- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

Passaic River Study, N.J. & N.Y.

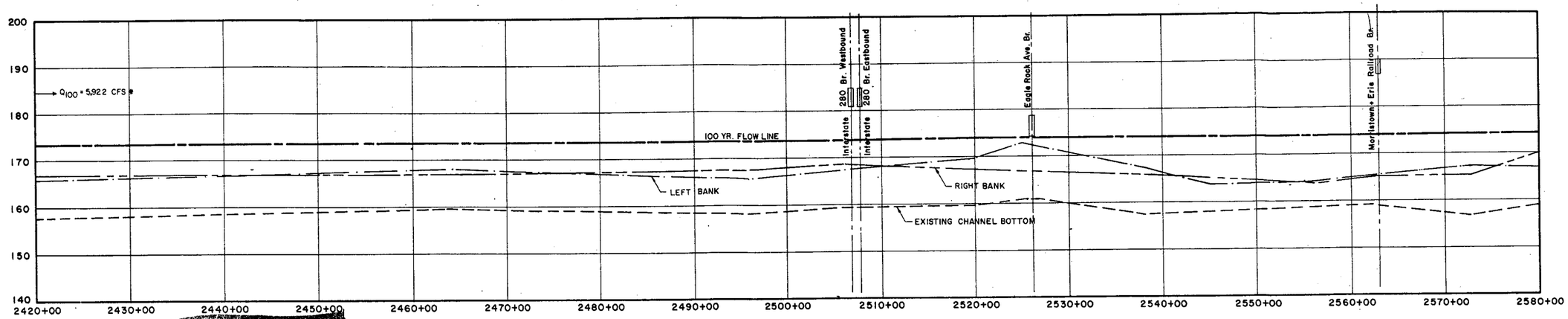
Passaic River

STA. 2240+00 TO STA. 2420+00

RECOMMENDED PLAN

587

FIGURE No. C-107

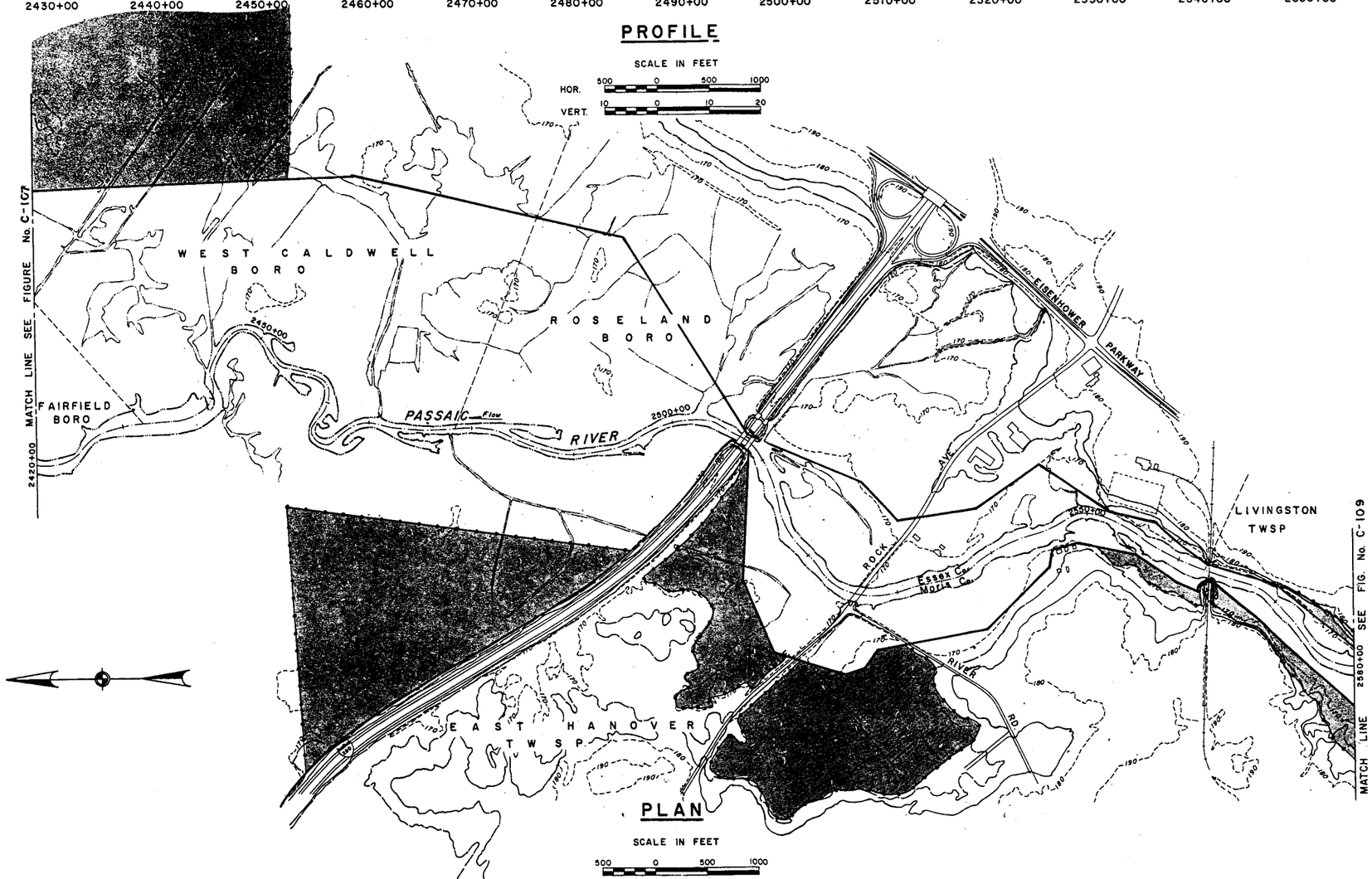


PROFILE

SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20



PLAN

SCALE IN FEET

500 0 500 1000

LEGEND

- ACQUISITION OF NATURAL STORAGE AREAS
- STATE DESIGNATED FLOODWAYS
- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

Passaic River Study, N.J. & N.Y.

Passaic River

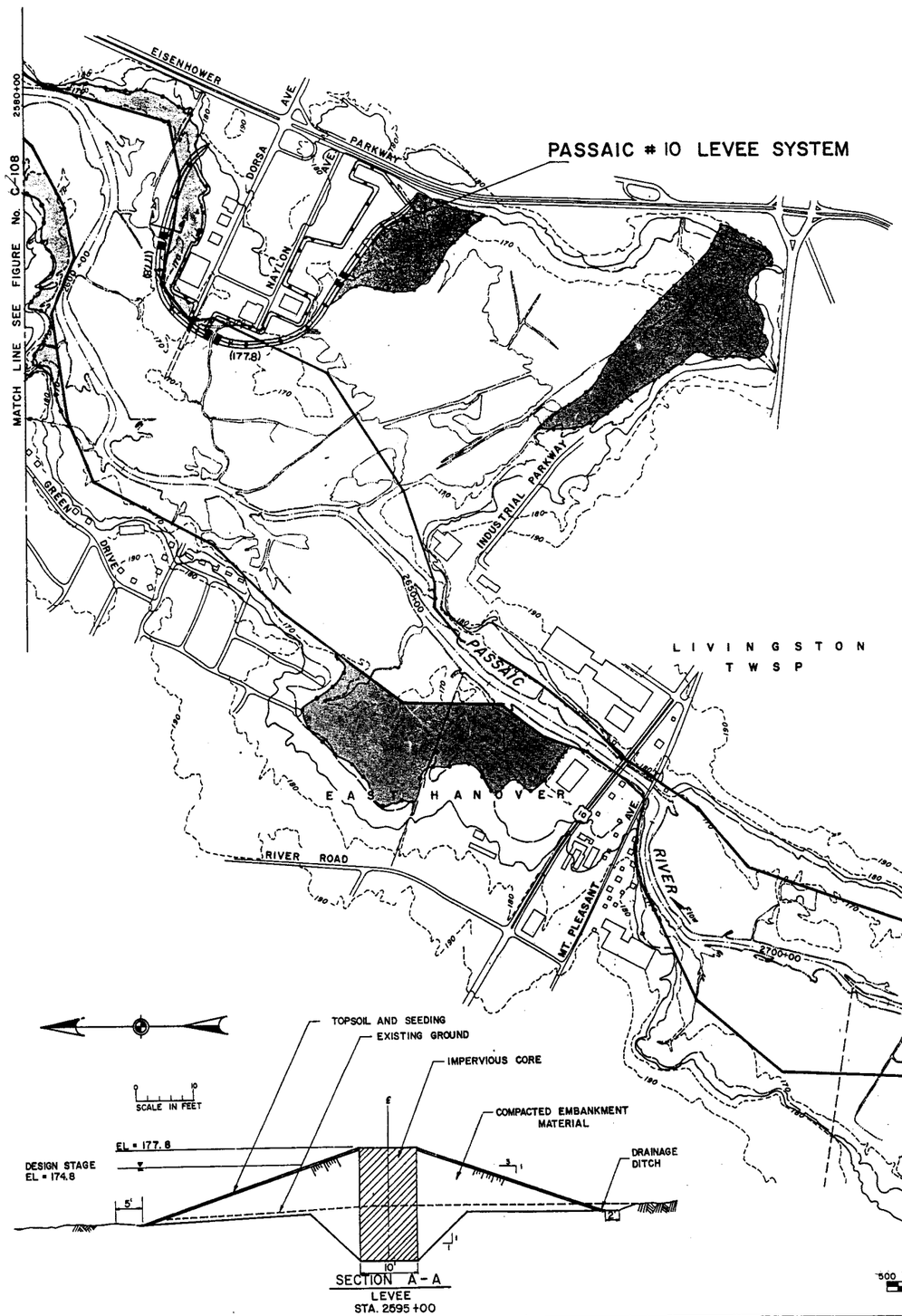
STA. 2420+00 TO STA. 2580+00

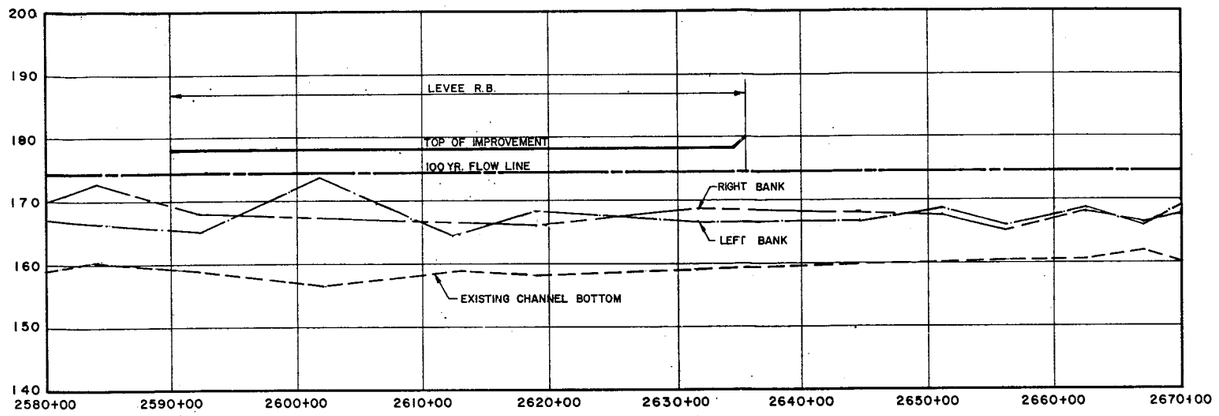
RECOMMENDED PLAN

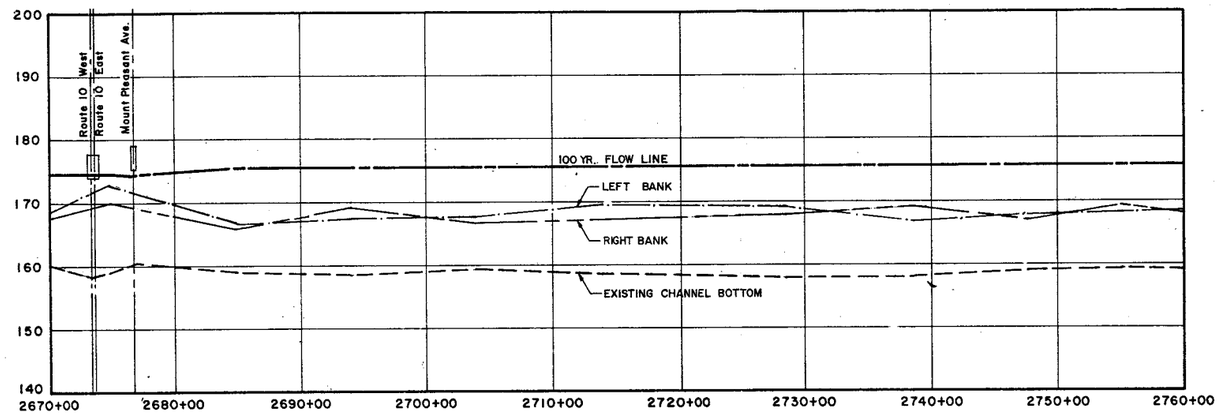
FIGURE No. C-108

588

PASSAIC # 10 LEVEE SYSTEM







PROFILE

SCALE IN FEET
HOR. 500 0 500 1000
VERT. 10 0 10 20

SECTION A-A
LEVEE
STA. 2595+00

SCALE IN FEET
500 0 500 1000

LEGEND

- ACQUISITION OF NATURAL STORAGE AREAS
- STATE DESIGNATED FLOODWAYS
- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING, AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- ROAD RAISING / RELOCATION
- 100 YR.
- 500 YR.

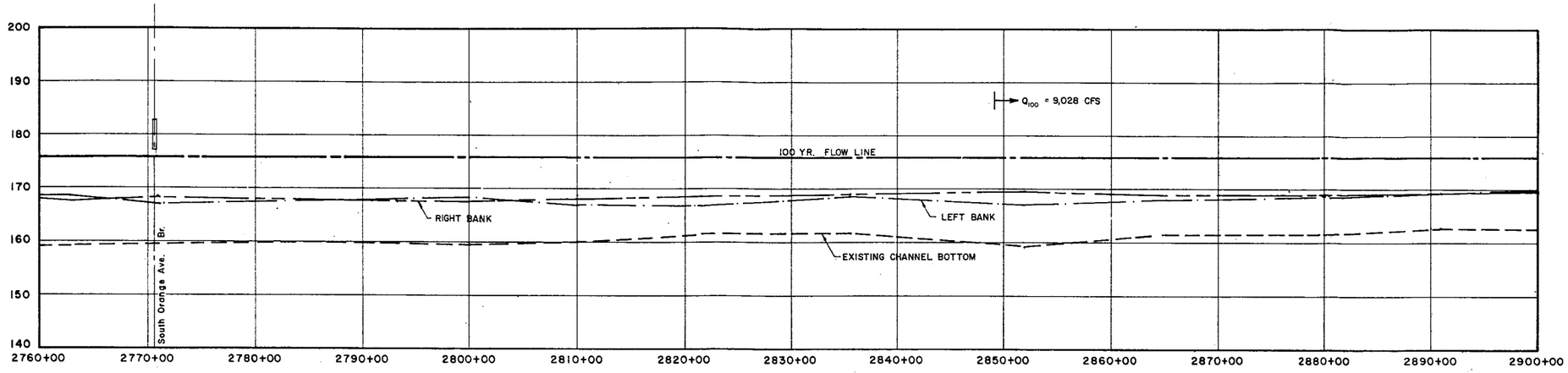
Passaic River Study, N.J. & N.Y.

Passaic River

STA. 2580+00 TO STA. 2760+00

RECOMMENDED PLAN

FIGURE No. C-109

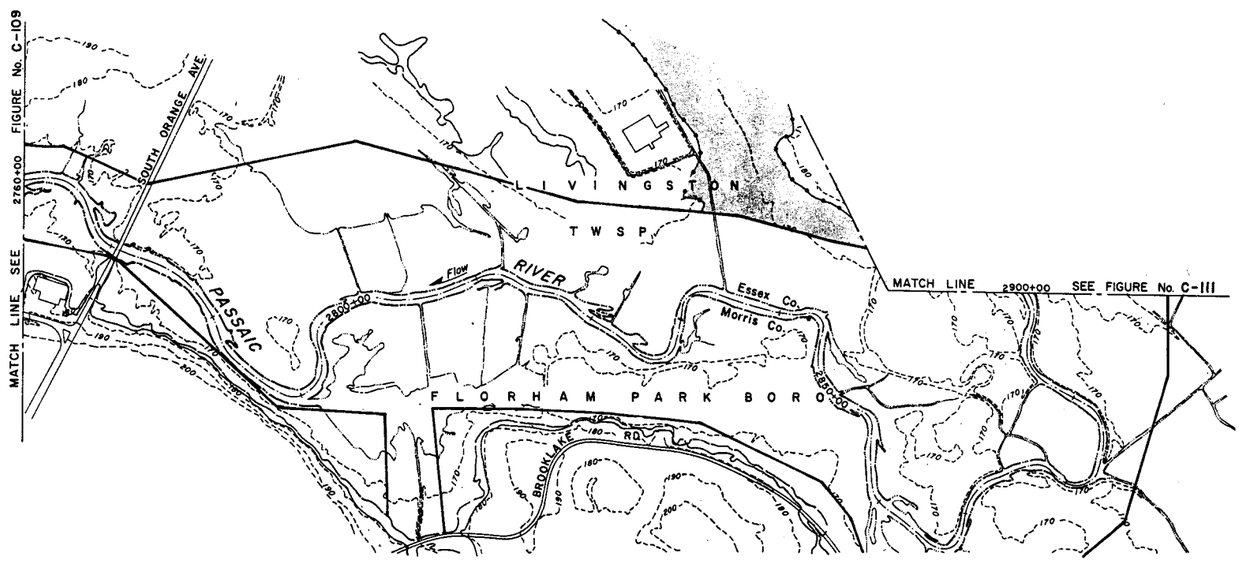


PROFILE

SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20



PLAN

SCALE IN FEET 500 0 500 1000

LEGEND

- ACQUISITION OF NATURAL STORAGE AREAS
- STATE DESIGNATED FLOODWAY
- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

Passaic River Study, N.J. & N.Y.

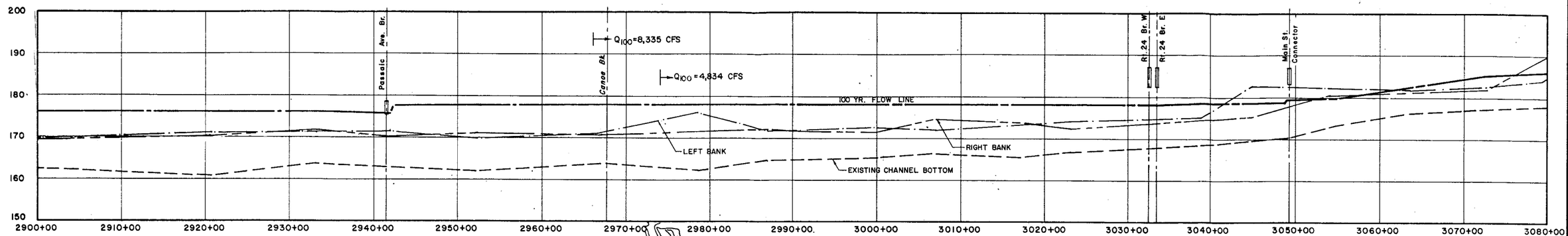
Passaic River

STA. 2760+00 TO STA. 2900+00

RECOMMENDED PLAN

FIGURE No. C-110

590

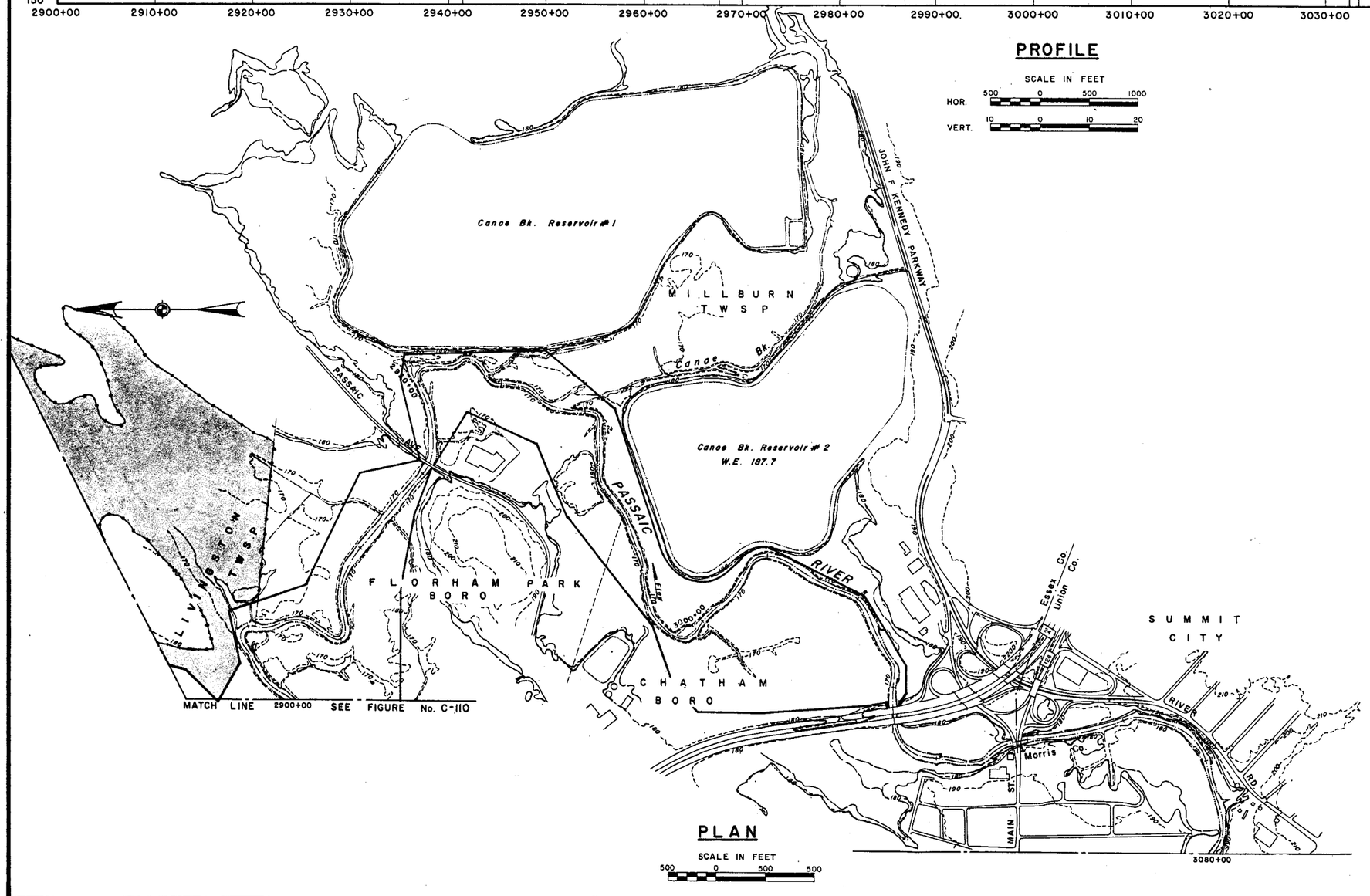


PROFILE

SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20



PLAN

SCALE IN FEET

500 0 500 500

LEGEND

- ACQUISITION OF NATURAL STORAGE AREAS
- STATE DESIGNATED FLOOWAY
- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

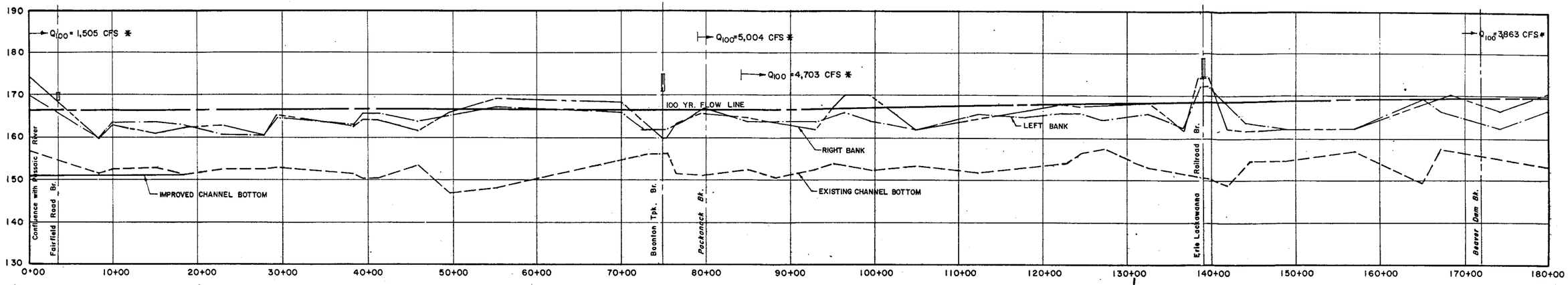
Passaic River Study, N.J. & N.Y.

Passaic River

STA. 2900+00 TO STA. 3080+00

RECOMMENDED PLAN

FIGURE No. C-111



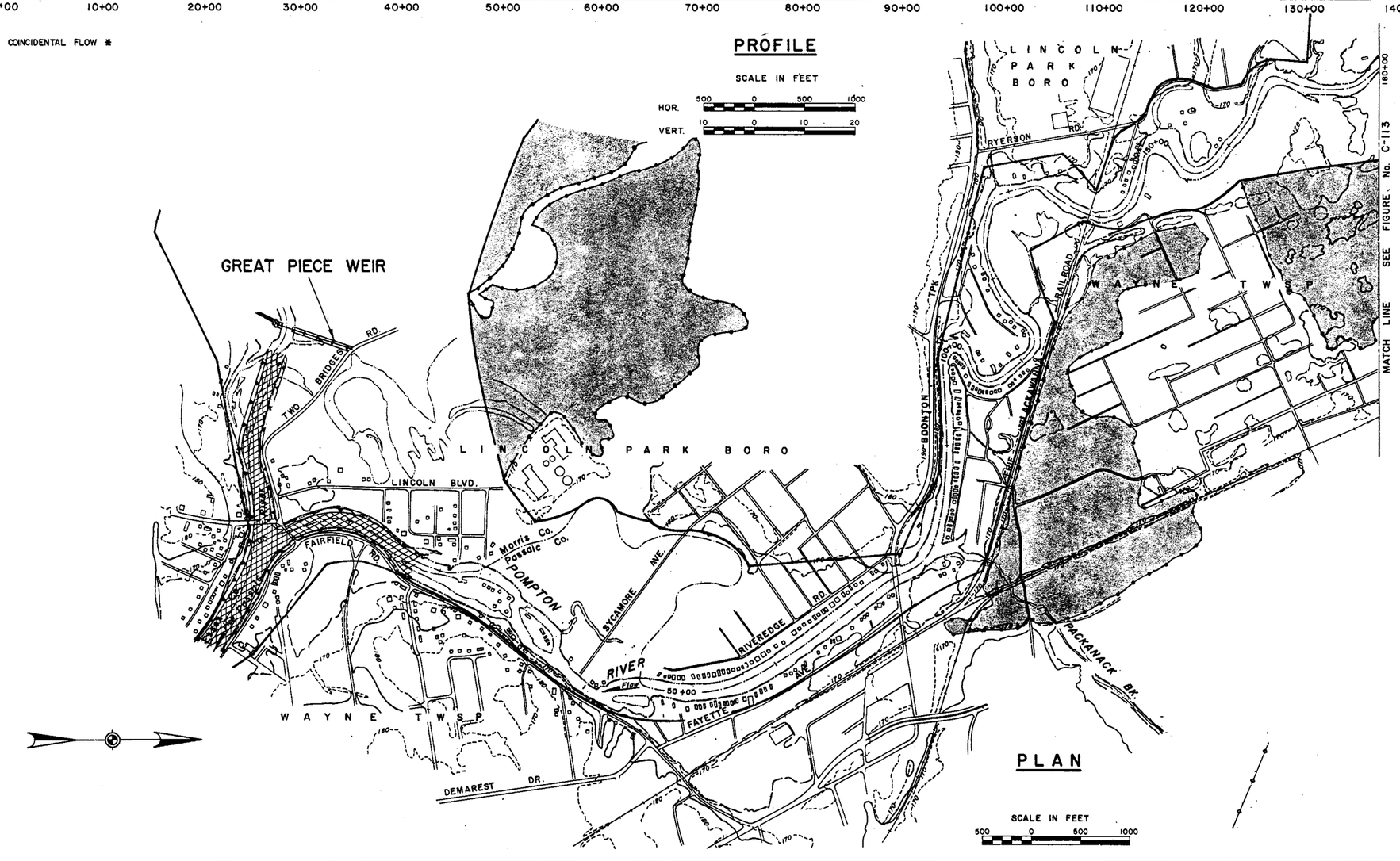
COINCIDENTAL FLOW *

PROFILE

SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20



PLAN

SCALE IN FEET 500 0 500 1000

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.
- ACQUISITION OF NATURAL STORAGE AREA
- STATE DESIGNATED FLOODWAY

Passaic River Study, N.J & N.Y.

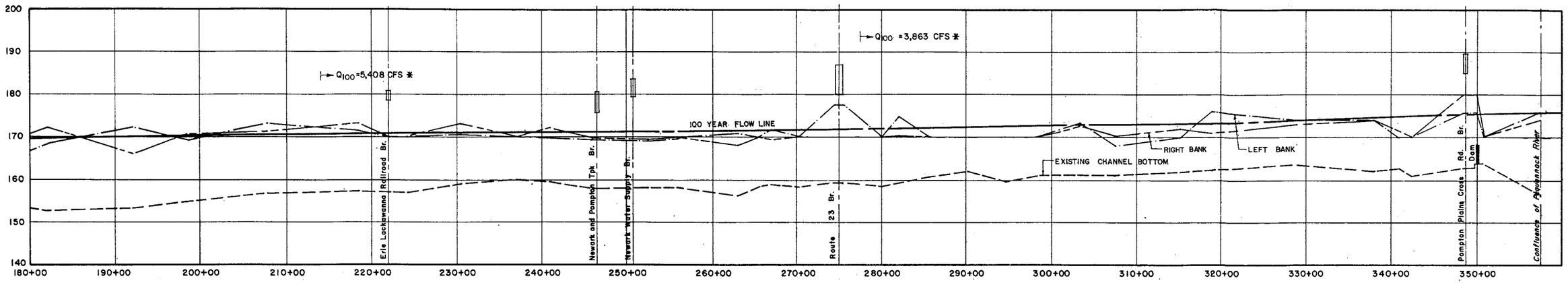
Pompton River

STA. 0+00 TO STA. 180+00

RECOMMENDED PLAN

FIGURE No. C-112

597



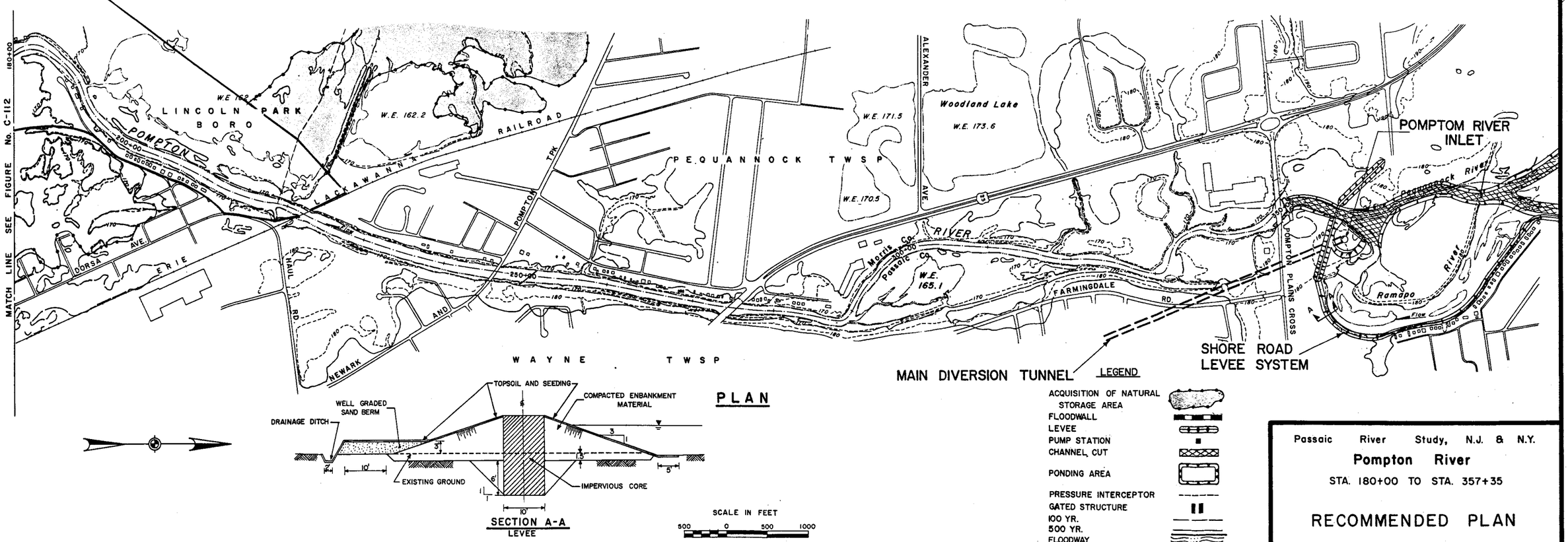
COINCIDENTAL FLOW *

PROFILE

SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20



PLAN

SECTION A-A
LEVEE

SCALE IN FEET

500 0 500 1000

LEGEND

- ACQUISITION OF NATURAL STORAGE AREA
- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.
- FLOODWAY

Passaic River Study, N.J. & N.Y.

Pompton River

STA. 180+00 TO STA. 357+35

RECOMMENDED PLAN

FIGURE No. C-113

593

Q_{100} = 33,880 CFS

Q_{100} = 17,321 CFS

Q_{100} = 17,584 CFS

Q_{100} = 7,912 CFS

Confluence with Pompton River

Dam

LEVEE L.B.

TOP OF IMPROVEMENT

100 YR. FLOW LINE

RIGHT BANK

LEFT BANK

EXISTING CHANNEL BOTTOM

IMPROVED CHANNEL BOTTOM

EXIST. INV. = 162.5

PROP. INV. = 156.5

EXISTING 72" AQUEDUCT

300' RIPRAP CHANNEL PROTECTION

500' RIPRAP

RIPRAP @ BRIDGE

Riverdale Road Br.

Wanaque River

Peterson Hamburg Tpk. Br.

200' TRANSITION RIPRAP

LEVEE L.B.

TOP OF IMPROVEMENT

LIMIT OF STUDY

240 230 220 210 200 190 180 170 160 150 140 130

0+00 10+00 20+00 30+00 40+00 50+00 60+00 70+00 80+00 90+00 100+00 110+00 120+00 130+00 140+00 150+00 160+00 170+00 180+00

PROFILE

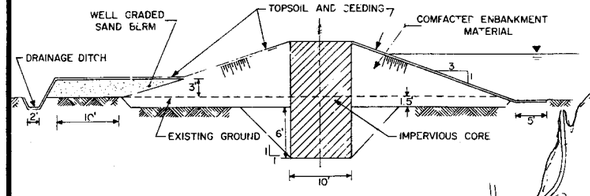
SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20

TRAPEZOIDAL CHANNEL
100' BOTTOM WIDTH
2:1 SIDE SLOPES

TRAPEZOIDAL CHANNEL
74' BOTTOM WIDTH
2:1 SIDE SLOPE



SECTION A-A

LEVEE
STA. 89+00

PEQUANNOCK TWSP

RIVERDALE BORO

PEQUANNOCK WEIR

PEQUANNOCK · RAMAPO LEVEE SYSTEM

POMPTON LAKES BORO

SEE FIGURE No. C-115 FOR WANAQUE RIVER DETAILS

STILES COURT LEVEE SYSTEM

Morris Co. Passaic Co.

Pequannock River

Riverdale Blvd.

Garden Rd.

Ringwood Ave.

Paterson Hamburg Tpk.

Wanaque Flow River

Pompton Plains Cross Rd.

Pompton River

(190.0) (189.8) (191.2) (194.9)

PLAN

SCALE IN FEET

500 0 500 1000

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

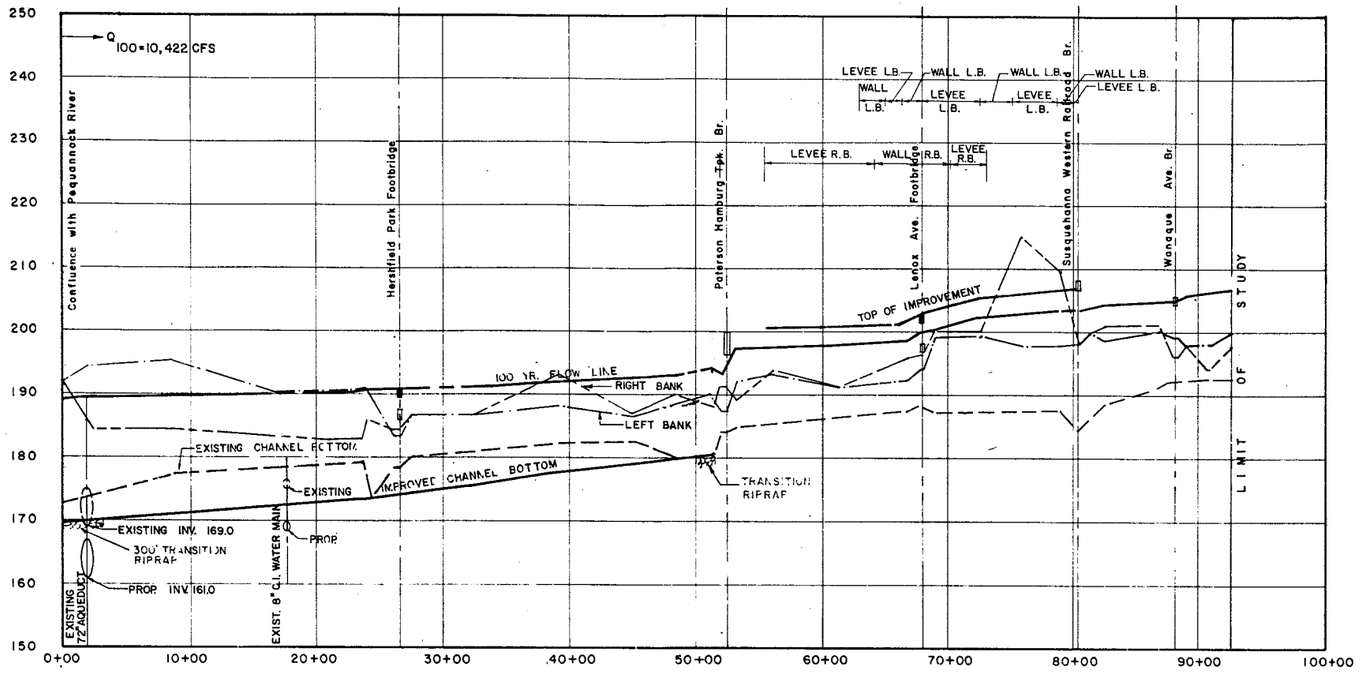
Passaic River Study, N.J. & N.Y.

Pequannock River

STA. 0+00 TO STA 170+55

RECOMMENDED PLAN

FIGURE No. C-114

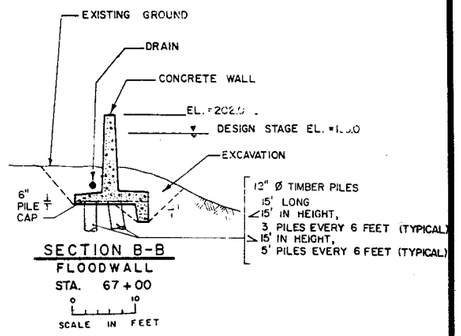


PROFILE

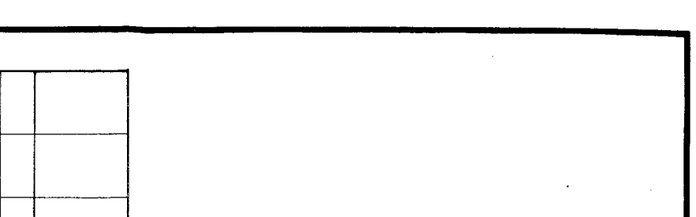
SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20



SECTION B-B
FLOODWALL
STA. 67+00
0 10
SCALE IN FEET



SECTION A-A
LEVEE
STA. 56+00
0 10
SCALE IN FEET

PLAN

SCALE IN FEET

500 0 500 1000

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

Passaic River Study, N.J. & N.Y.

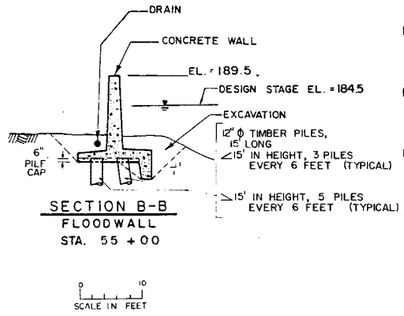
Wanaque River

STA. 0+00 TO STA. 92+65

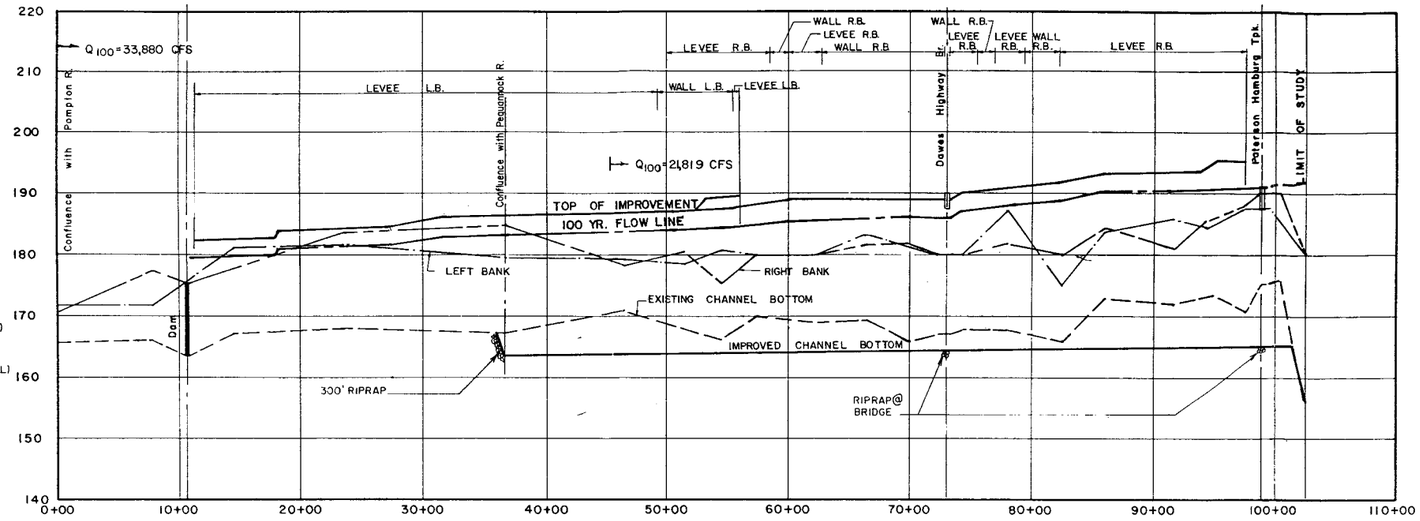
RECOMMENDED PLAN

FIGURE No. C-115

595

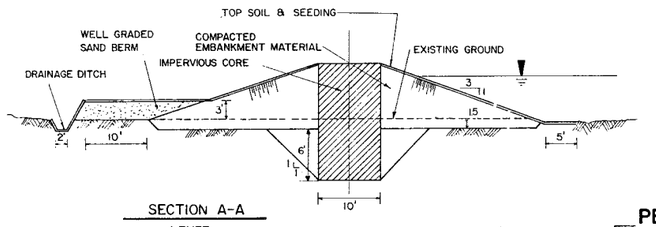


SECTION B-B
FLOODWALL
STA. 55 + 00



PROFILE

SCALE IN FEET
HOR. 500 0 500 1000
VERT. 10 0 10 20



SECTION A-A
LEVEE

PLAN

SCALE IN FEET
500 0 500 1000

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.
- FLOODWAY

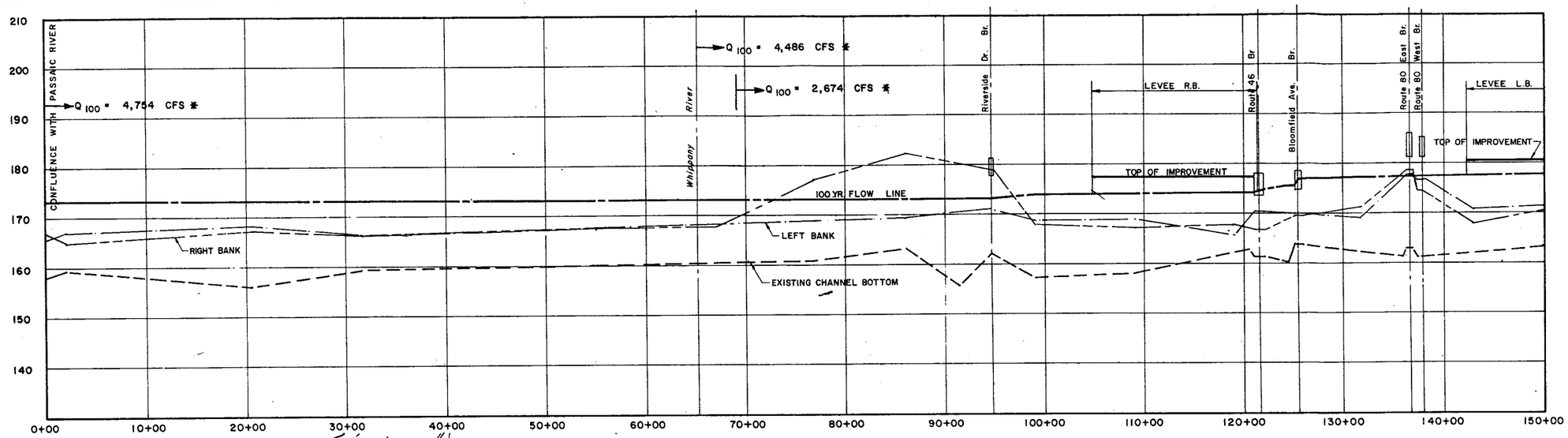
Passaic River Study, N.J. & N.Y.

Ramapo River

STA. 0+00 TO STA. 102+45

RECOMMENDED PLAN

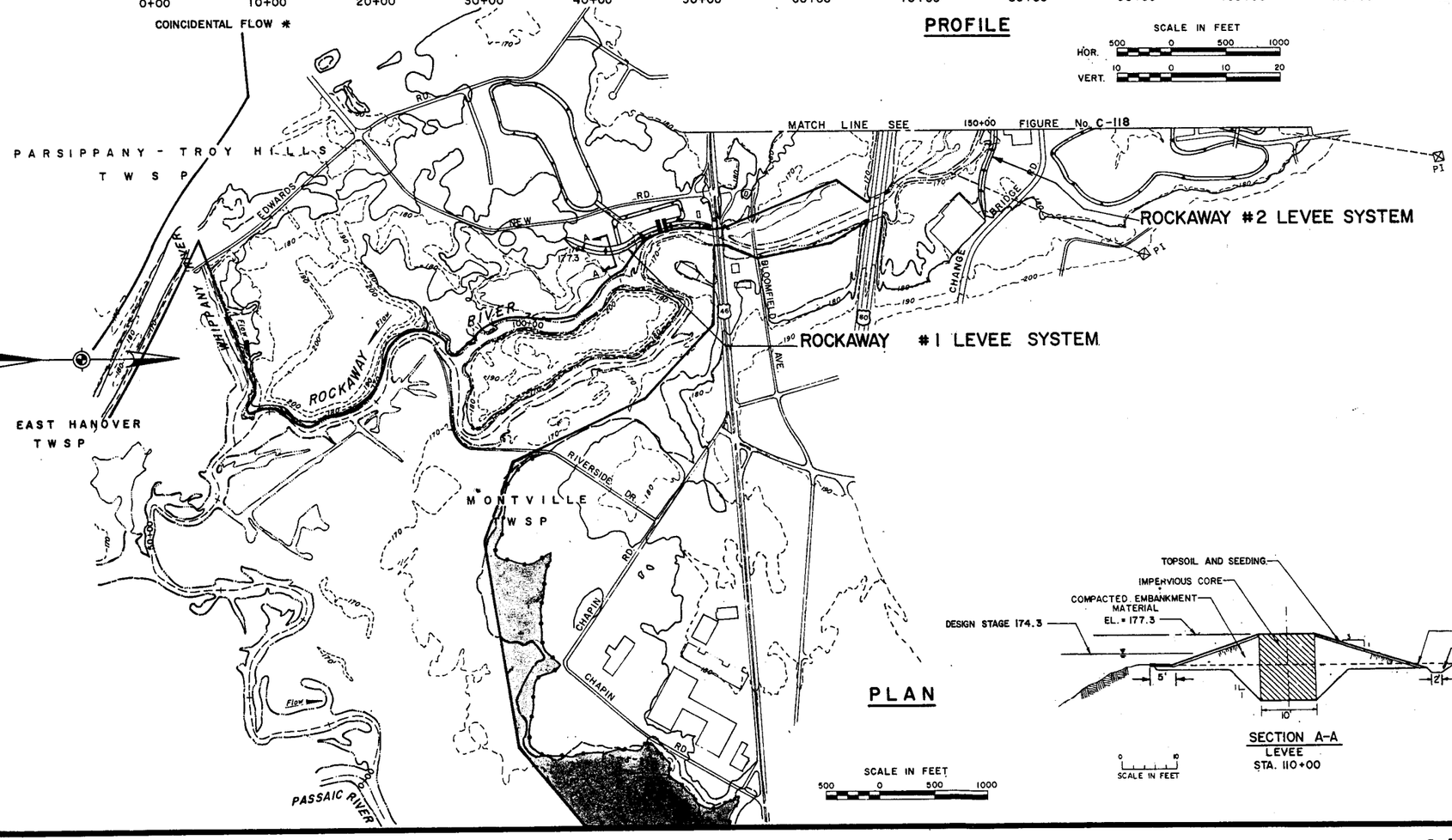
FIGURE No. C-116



COINCIDENTAL FLOW *

PROFILE

SCALE IN FEET
HOR. 500 0 500 1000
VERT. 10 0 10 20



PLAN

SCALE IN FEET
500 0 500 1000

SECTION A-A
LEVEE
STA. 110+00

0 10
SCALE IN FEET

LEGEND

- ACQUISITION OF NATURAL STORAGE AREAS
- STATE DESIGNATED FLOODWAYS
- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

Passaic River Study, N.J. & N.Y.

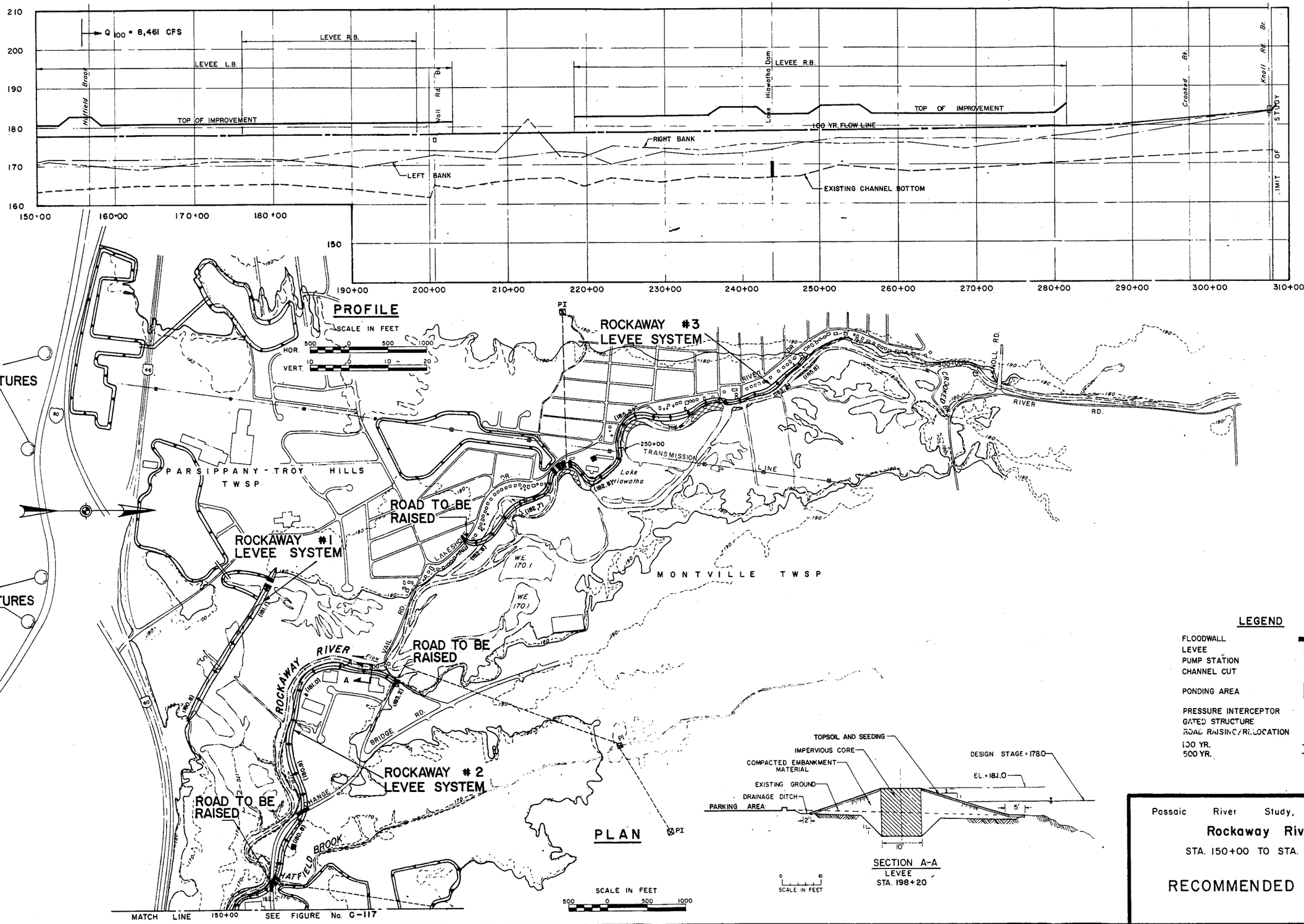
Rockaway River

STA. 0+00 TO STA. 150+00

RECOMMENDED PLAN

FIGURE ~~No.~~ C-117

597



Passaic River Study, N.J. & N.Y.

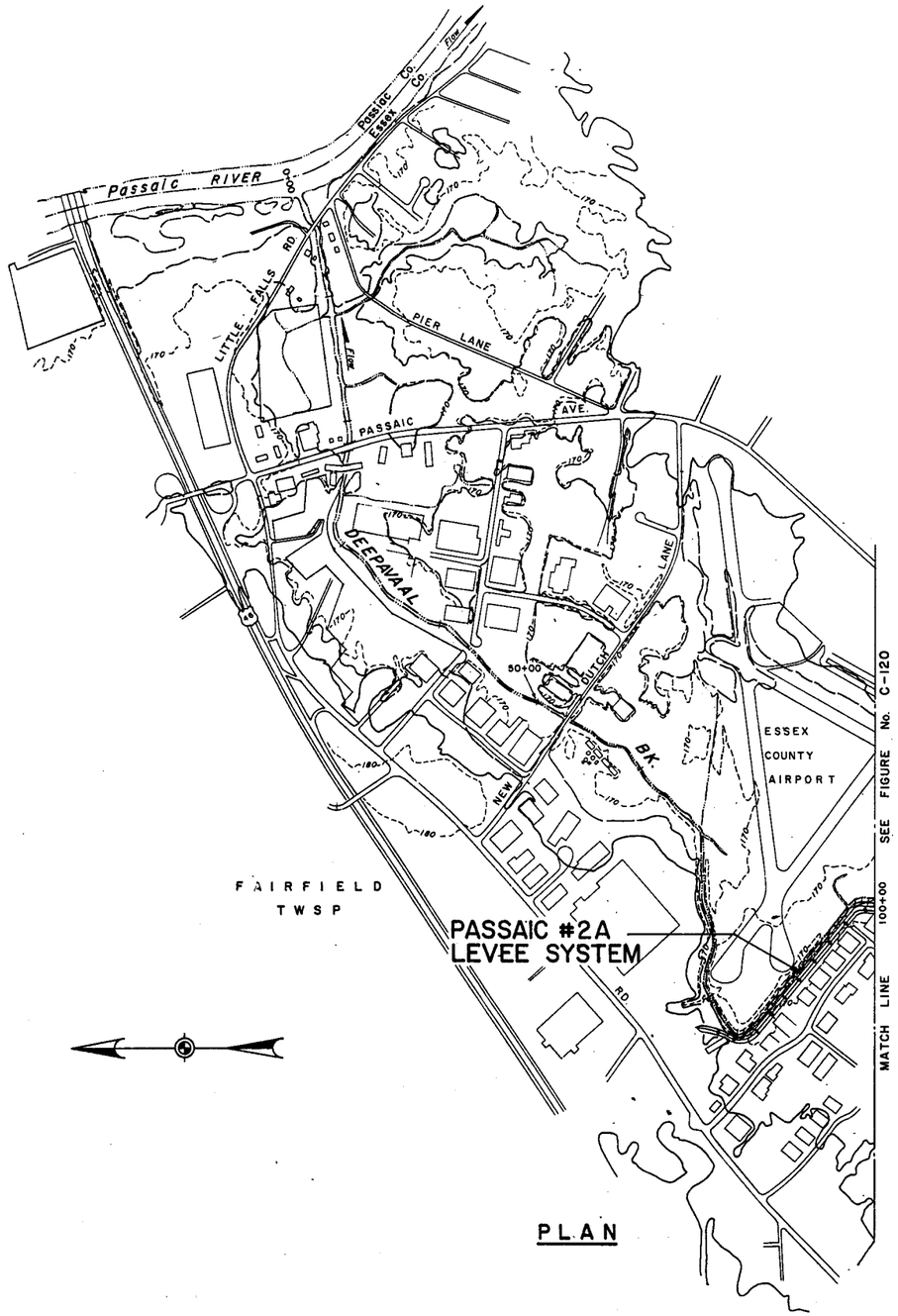
Rockaway River

STA. 150+00 TO STA. 308+00

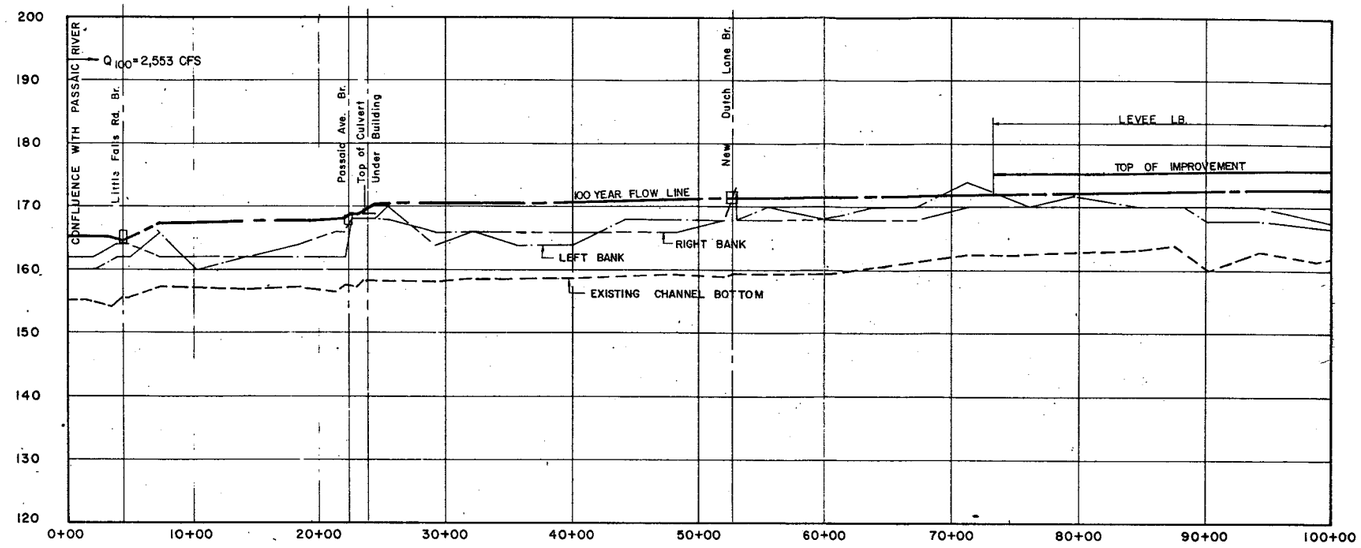
RECOMMENDED PLAN

FIGURE No. C-118

598



PLAN

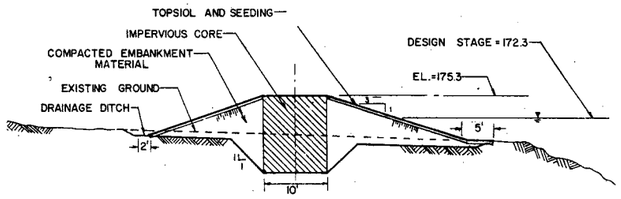


PROFILE

SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20



SECTION A-A
LEVEE
STA. 90+00

0 10
SCALE IN FEET

SCALE IN FEET
500 0 500 1000

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR

Passaic River Study, N. J. & N. Y.

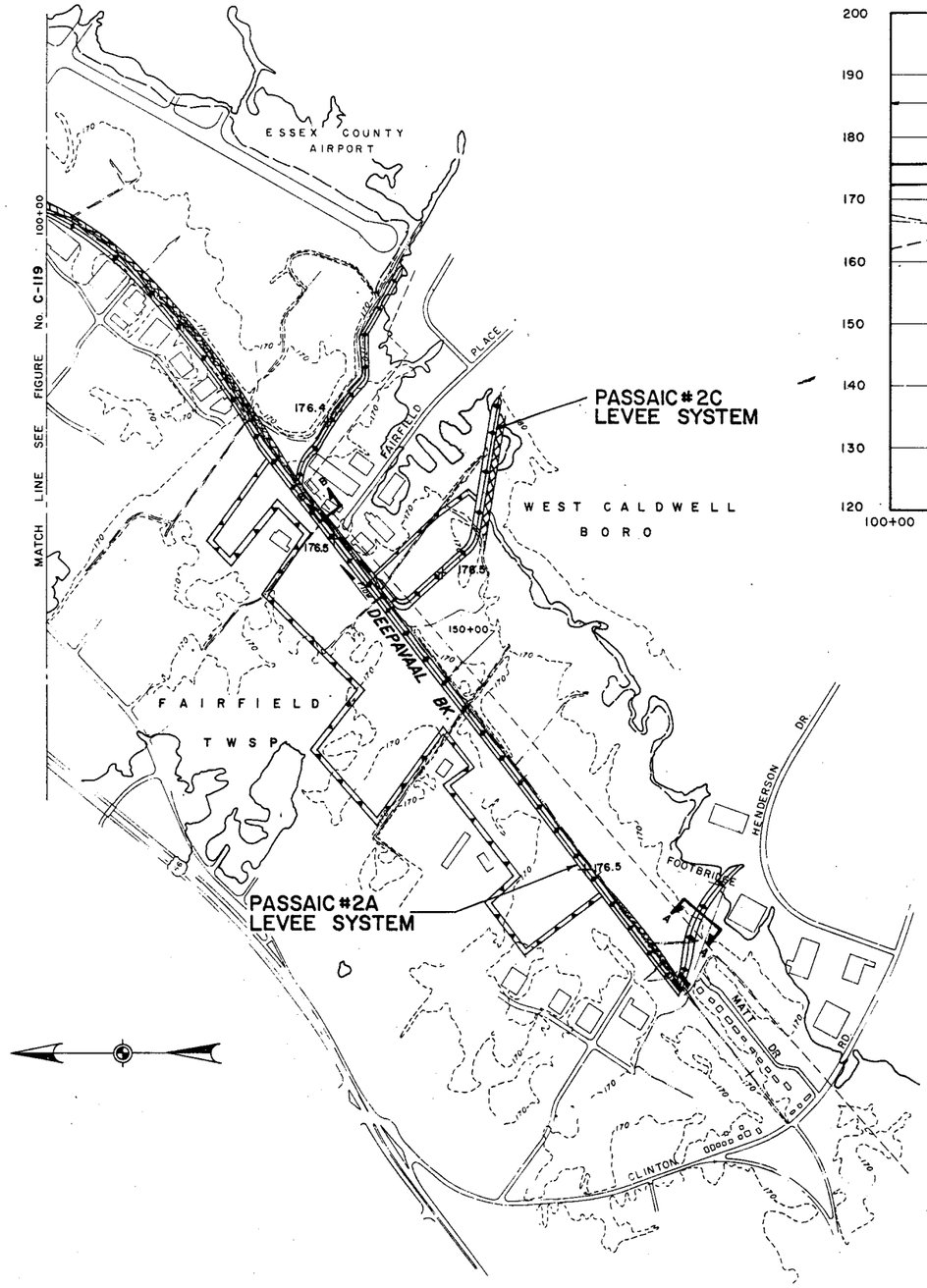
Deepavaal Brook

STA. 0+00 TO STA. 100+00

RECOMMENDED PLAN

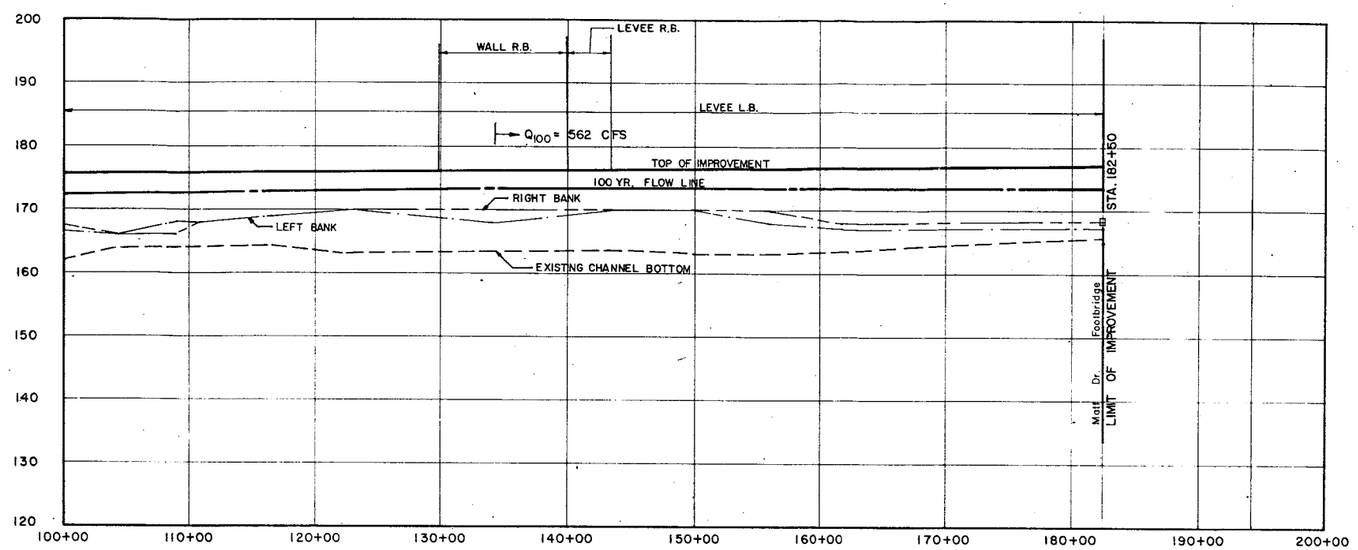
FIGURE No. C-119

500



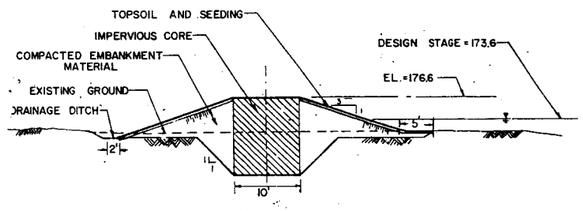
PLAN

SCALE IN FEET
500 0 500 1000



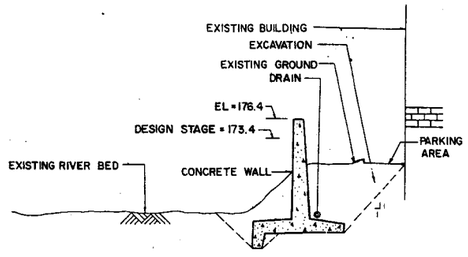
PROFILE

SCALE IN FEET
HOR. 500 0 500 1000
VERT. 10 0 10 20



SECTION A-A
LEVEE

0 10
SCALE IN FEET



SECTION B-B
FLOODWALL
STA. 134+00

0 10
SCALE IN FEET

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

Passaic River Study, N.J. & N.Y.

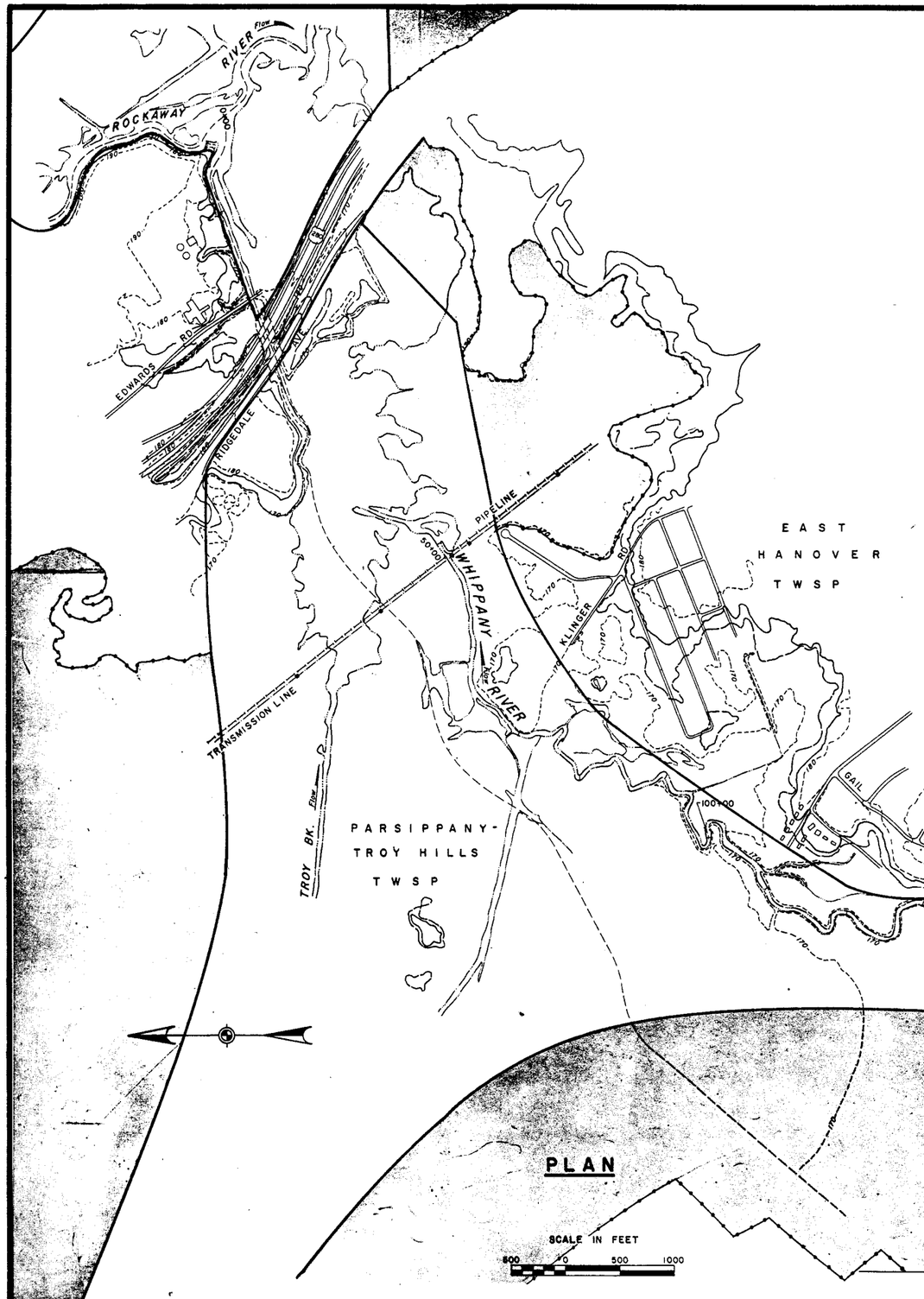
Deepavaal Brook

STA. 100+00 TO STA. 182+50

RECOMMENDED PLAN

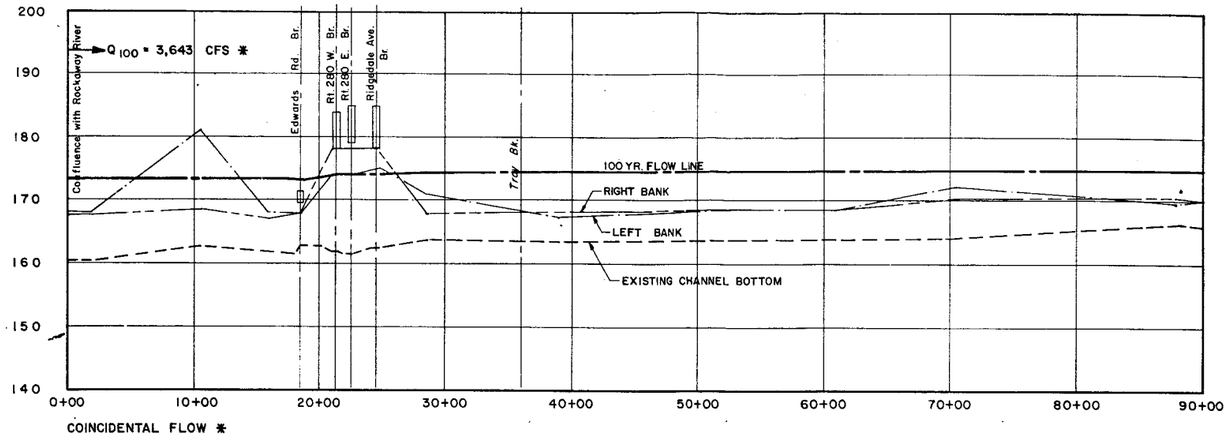
FIGURE No. C-120

600

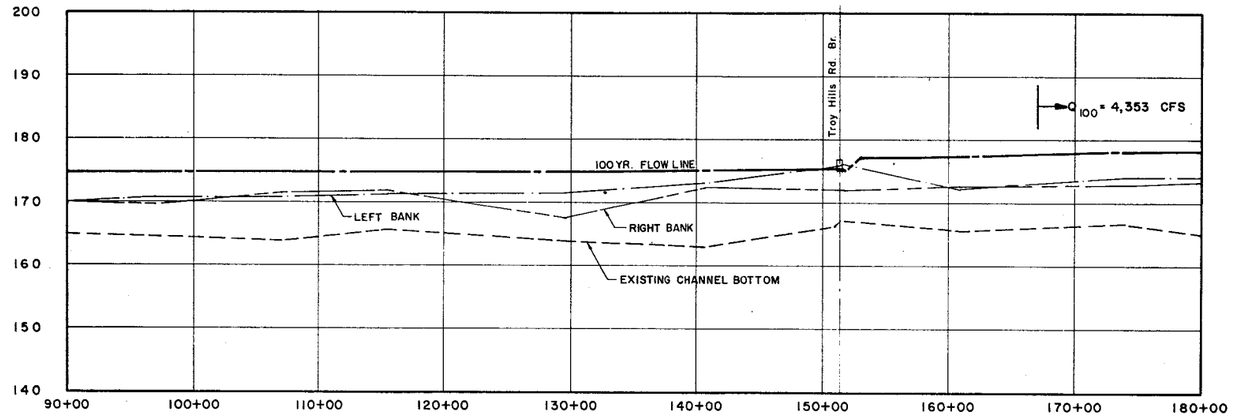


PLAN

SCALE IN FEET
500 0 500 1000



COINCIDENTAL FLOW *



PROFILE

SCALE IN FEET
HOR. 500 0 500 1000
VERT. 10 0 10 20

LEGEND

- ACQUISITION OF NATURAL STORAGE AREAS
- STATE DESIGNATED FLOODWAY
- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.

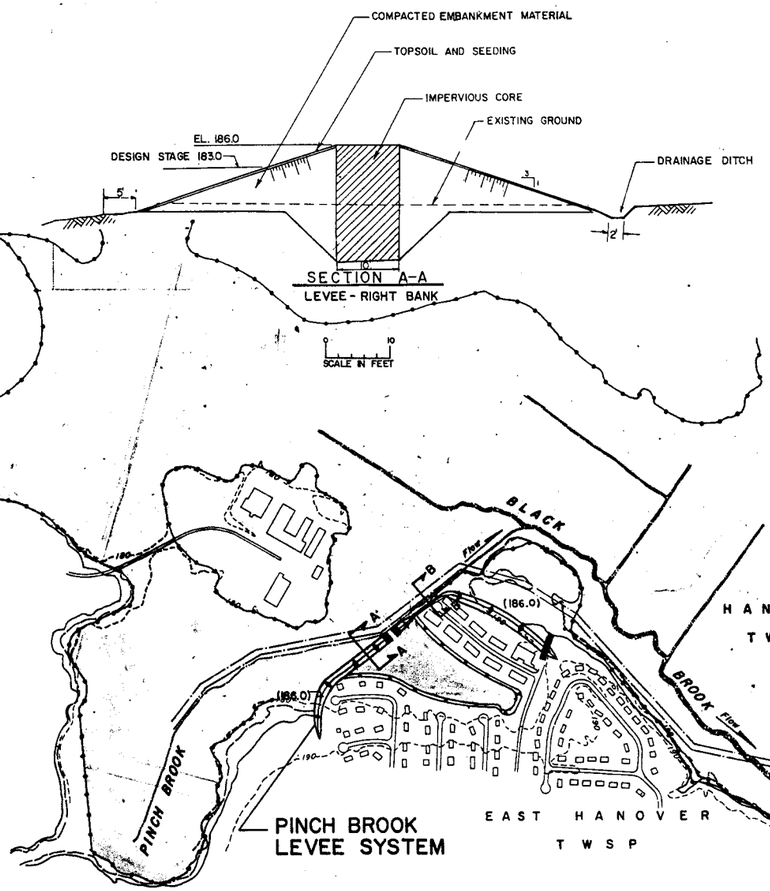
Passaic River Study, N.J. & N.Y.

Whippany River

STA. 0+00 TO STA. 180+00

RECOMMENDED PLAN

FIGURE No. C-121



PROFILE

SCALE IN FEET

HOR. 500 0 500 1000

VERT. 10 0 10 20

PLAN

SCALE IN FEET

500 0 500 1000

MATCH LINE 180+00 SEE FIGURE No. C-121

LEGEND

- FLOODWALL
- LEVEE
- PUMP STATION
- CHANNEL CUT
- PONDING AREA
- PRESSURE INTERCEPTOR
- GATED STRUCTURE
- 100 YR.
- 500 YR.
- STATE DESIGNATED FLOODWAYS
- ACQUISITION OF NATURAL NATURAL STORAGE AREAS

Passaic River Study, N.J. & N.Y.

Whippany River

STA. 180+00 TO STA. 270+00

RECOMMENDED PLAN

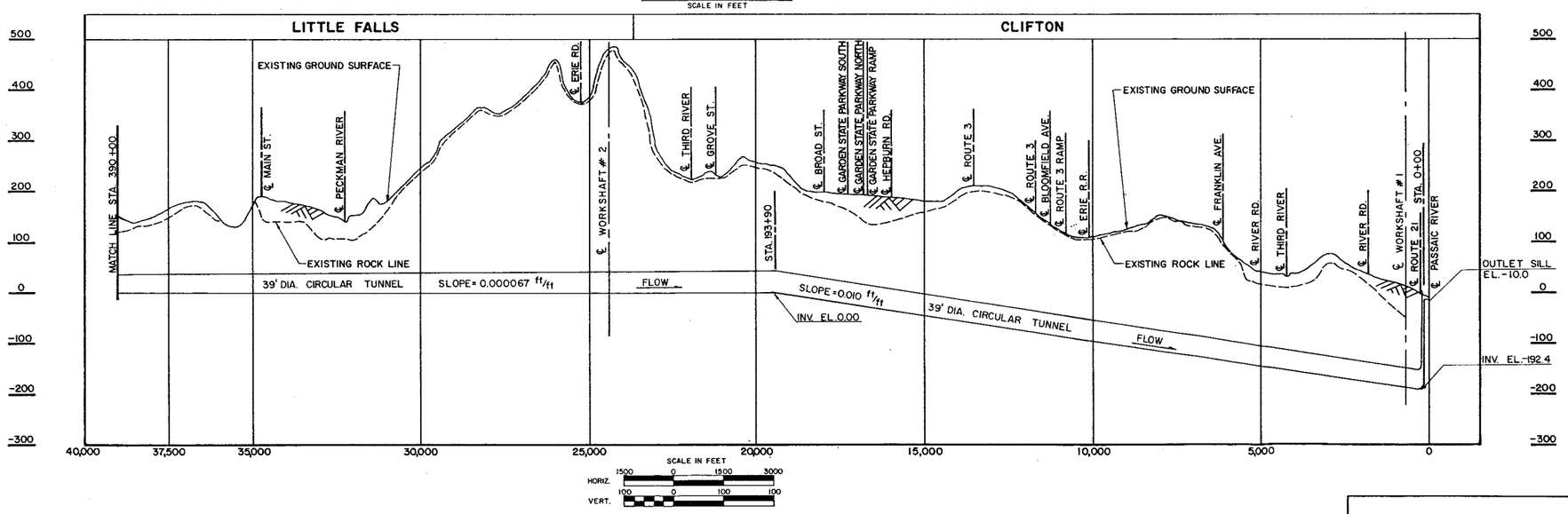
FIGURE No. C-122

602



PLAN

1500 0 1500 3000
SCALE IN FEET



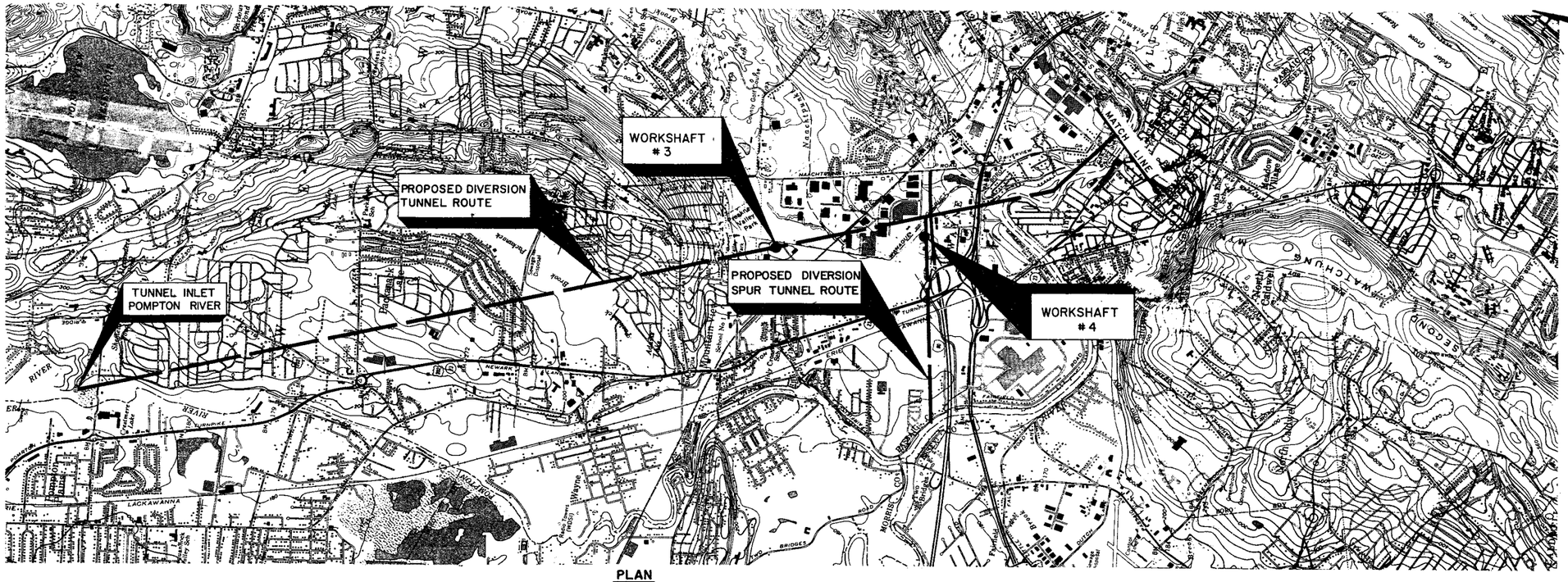
SCALE IN FEET
HORIZ. 1500 0 1500 3000
VERT. 100 0 100 100

PROFILE OF DIVERSION TUNNEL

Passaic River Basin, N.J. & N.Y.

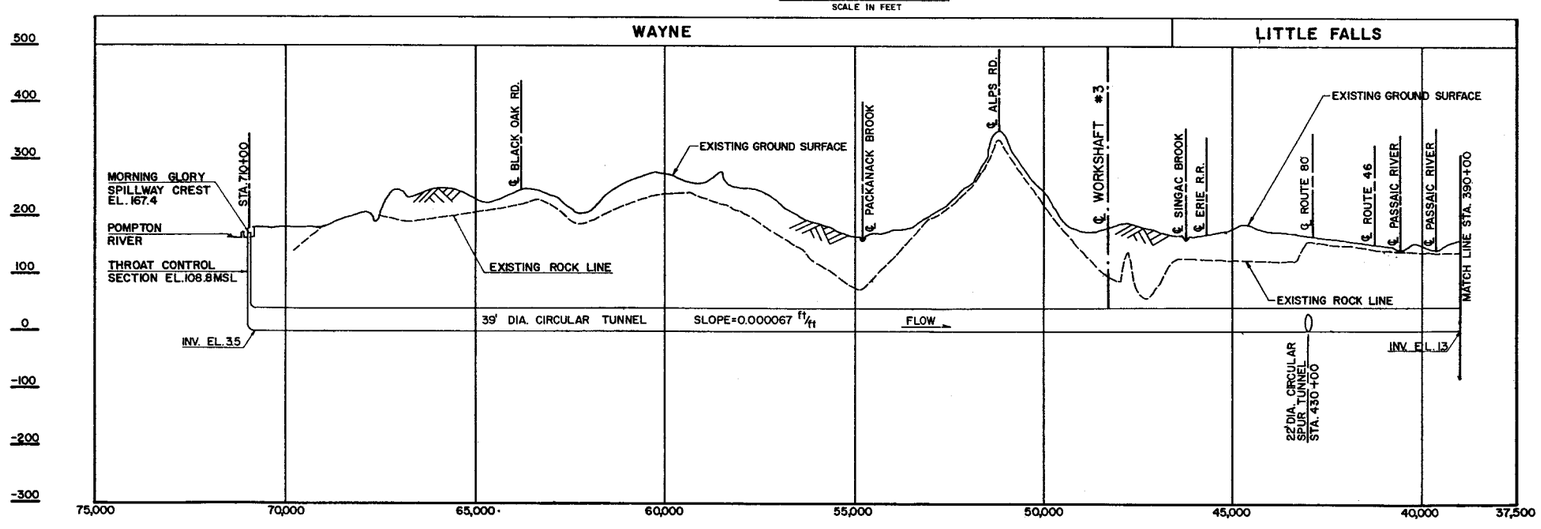
39 FOOT POMPTON RIVER TO PASSAIC RIVER TUNNEL PLAN & PROFILE (1 OF 2)

FIGURE No. C-123



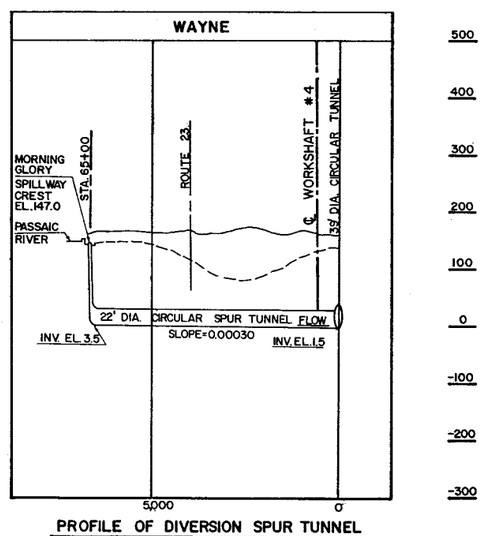
PLAN

1500 0 1500 3000
SCALE IN FEET



SCALE IN FEET
HORIZ. 1500 0 1500 3000
VERT. 100 0 100 200

PROFILE OF DIVERSION TUNNEL

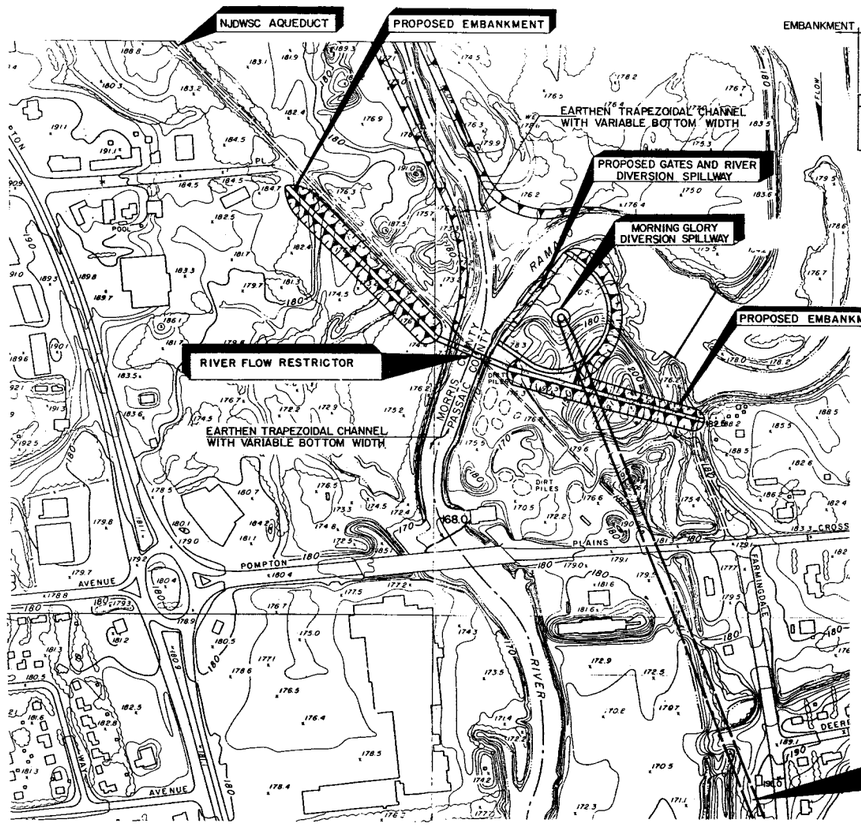


PROFILE OF DIVERSION SPUR TUNNEL

Passaic River Basin, N.J. & N.Y.

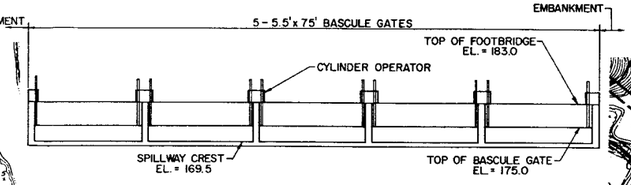
39 FOOT POMPTON RIVER TO PASSAIC RIVER TUNNEL, 22' SPUR TUNNEL PLAN & PROFILE (2 OF 2)

FIGURE No. C-124



INLET LOCATION

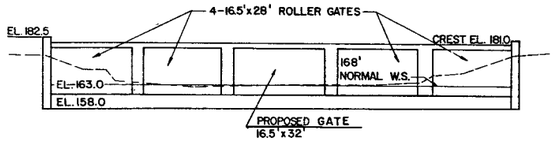
200' 100' 0 200' 400'



GATED DIVERSION SPILLWAY

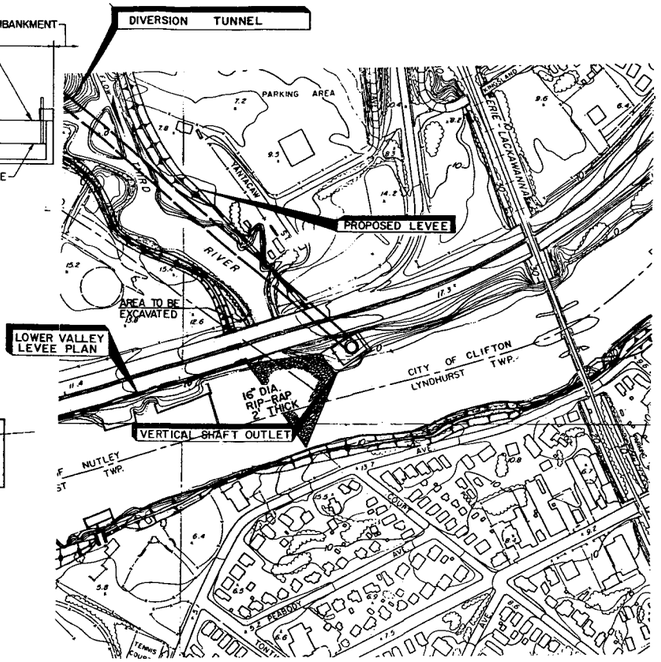
HORIZ. 40' 20' 0 40' 80'

VERT. 20' 10' 0 20' 40'



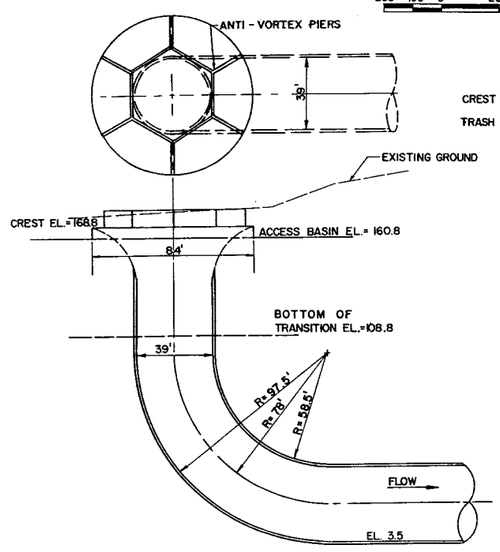
RIVER FLOW RESTRICTOR

20' 10' 0' 20' 40'



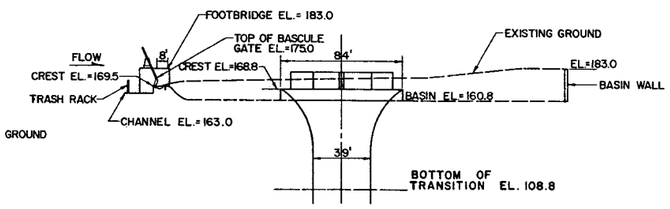
OUTLET LOCATION

200' 100' 0' 200' 400'



MORNING GLORY SPILLWAY

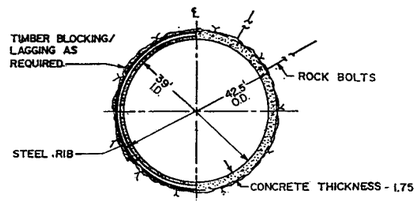
30' 20' 10' 0 30' 60'



DIVERSION INLET SECTION VIEW

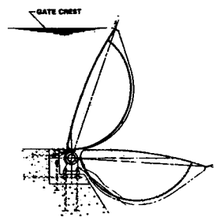
40' 20' 0 40' 80'

HORIZ.



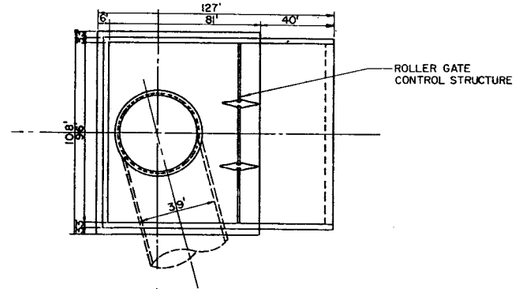
CIRCULAR TUNNEL SECTION

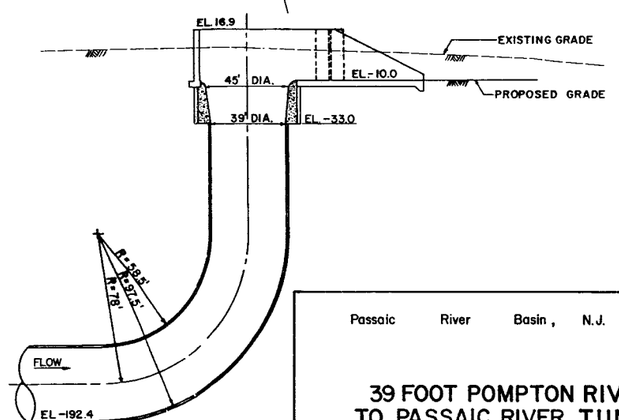
NOT TO SCALE



BASCULE GATE

N.T.S.





VERTICAL SHAFT OUTLET

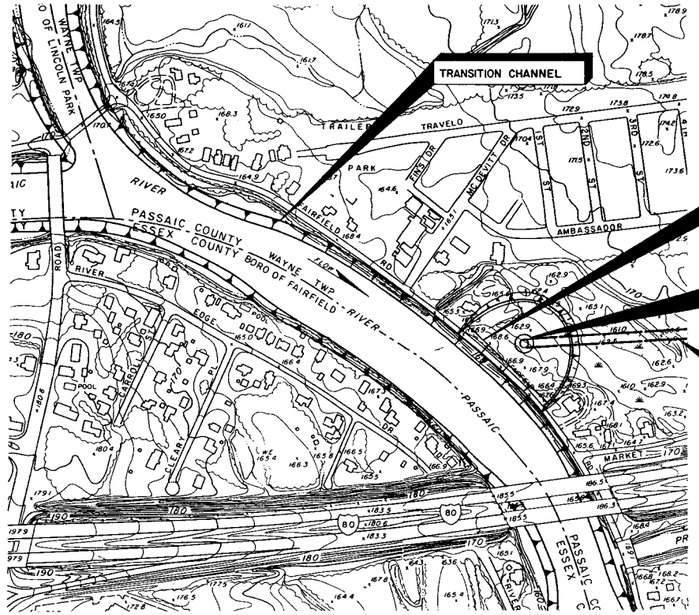
30' 20' 10' 0 30' 60'

Passaic River Basin, N.J. & N.Y.

39 FOOT POMPTON RIVER TO PASSAIC RIVER TUNNEL

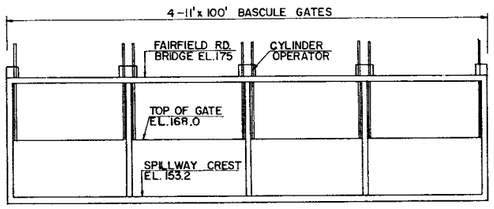
INLET & OUTLET SKETCHES

FIGURE No. C-125



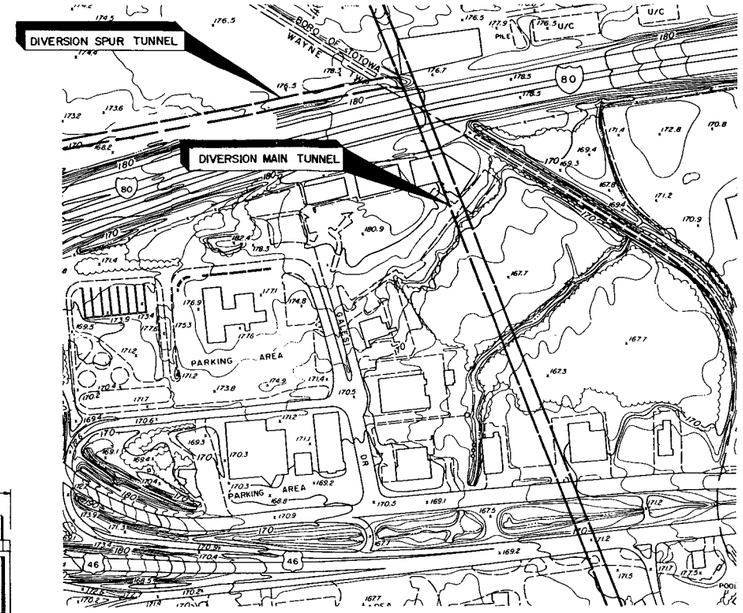
INLET LOCATION

200' 100' 0 200' 400'



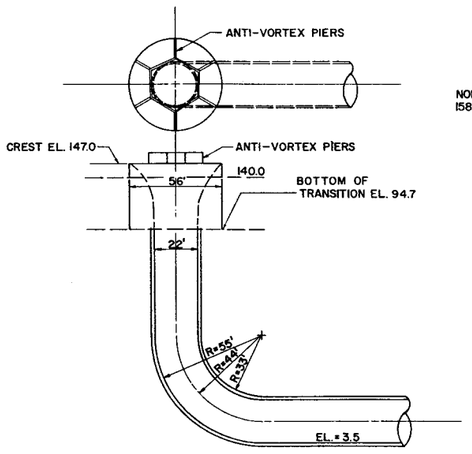
GATED DIVERSION SPILLWAY

NOT TO SCALE



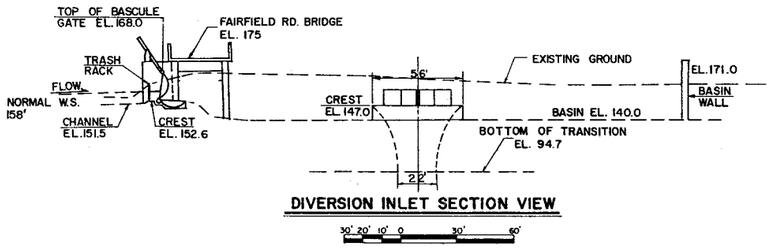
DIVERSION SPUR TUNNEL JUNCTION LOCATION

200' 100' 0 200' 400'



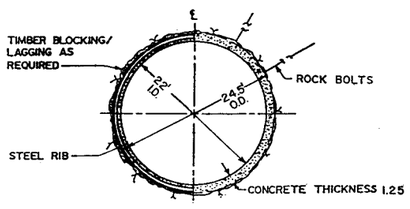
MORNING GLORY SPILLWAY

30' 20' 10' 0 30' 60'



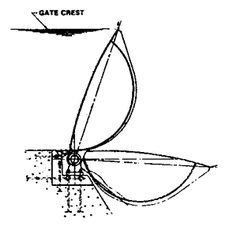
DIVERSION INLET SECTION VIEW

30' 20' 10' 0 30' 60'



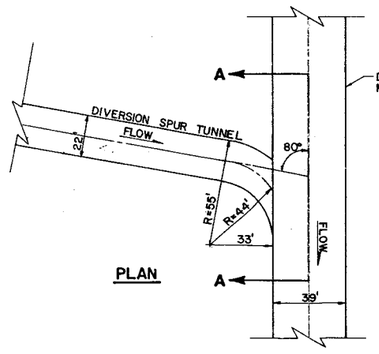
CIRCULAR TUNNEL SECTION

NOT TO SCALE

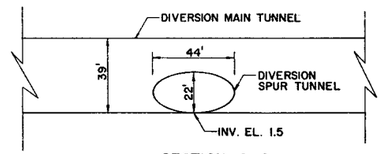


BASCULE GATE

NOT TO SCALE



PLAN



SECTION A-A

DIVERSION SPUR TUNNEL JUNCTION

30' 20' 10' 0 30' 60'

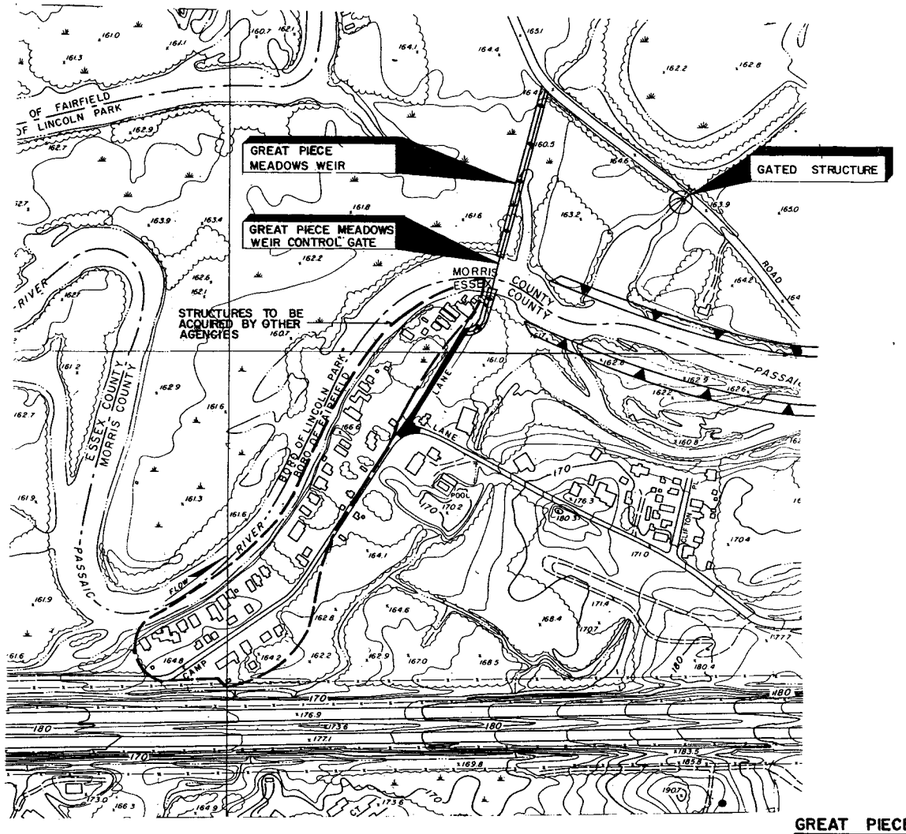
Passaic River Basin, N.J. & N.Y.

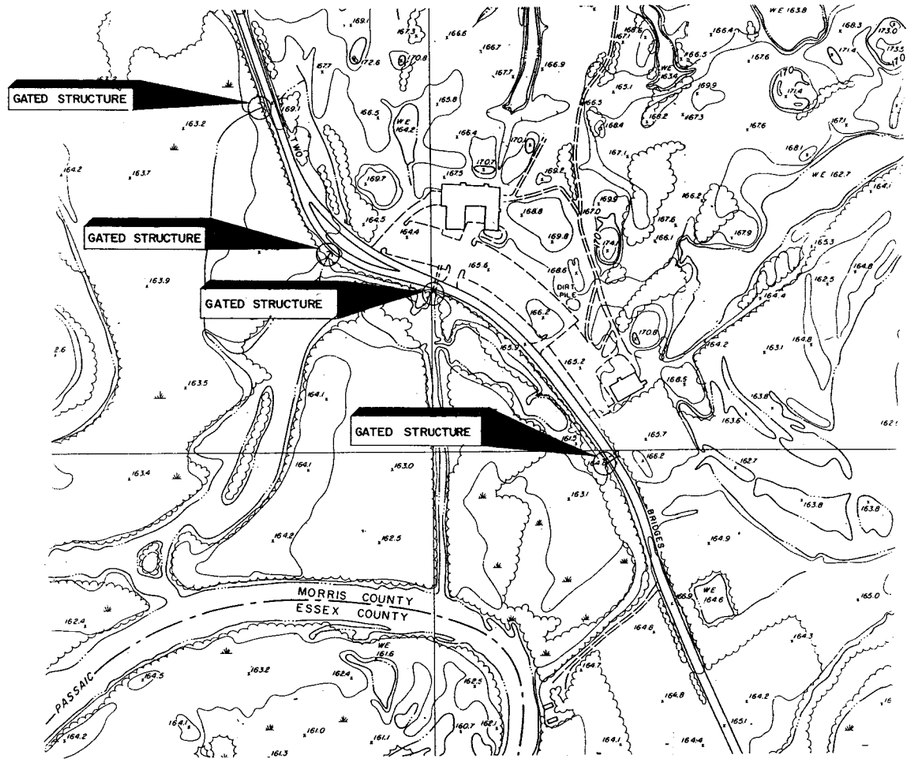
22 FOOT SPUR TUNNEL

INLET, JUNCTION DETAILS

FIGURE No. C-126

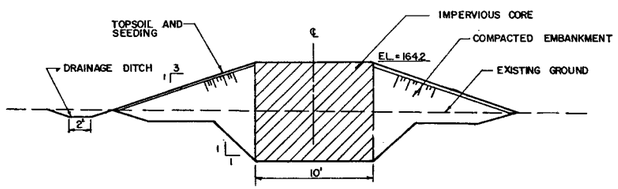
606





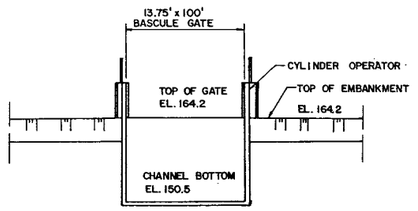
GREAT PIECE MEADOWS WEIR LOCATION

200' 100' 0 200' 400'



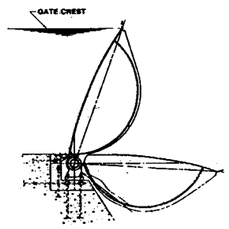
GREAT PIECE MEADOWS WEIR

SCALE = 1" = 5'



GREAT PIECE MEADOWS WEIR CONTROL GATE

SCALE: HORZ = 1" = 50'
VERT = 1" = 10'

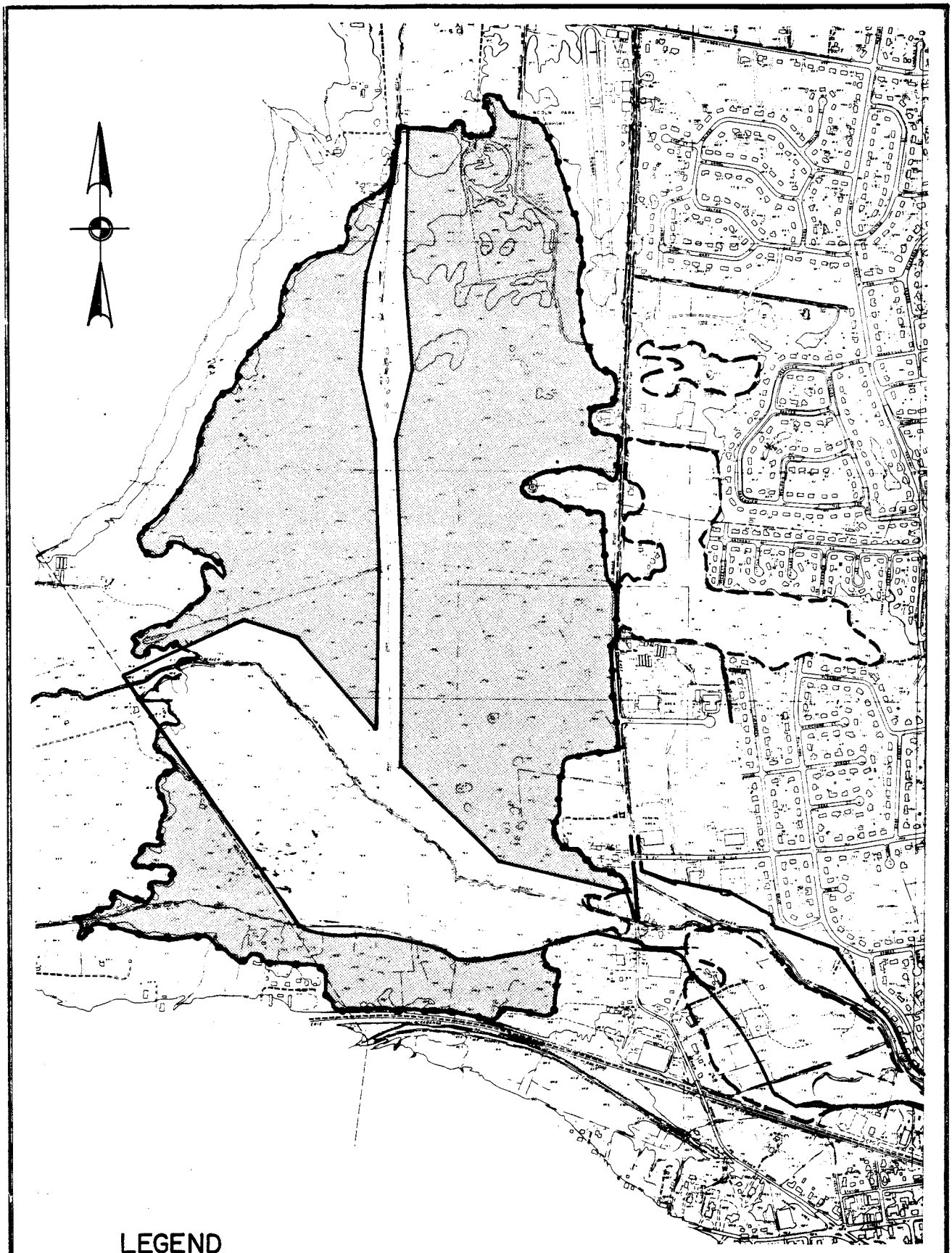


BASCULE GATE

NOT TO SCALE

Passaic River Basin, N.J. & N.Y.

GREAT PIECE MEADOWS WEIR DETAILS



LEGEND

NATURAL STORAGE AREAS

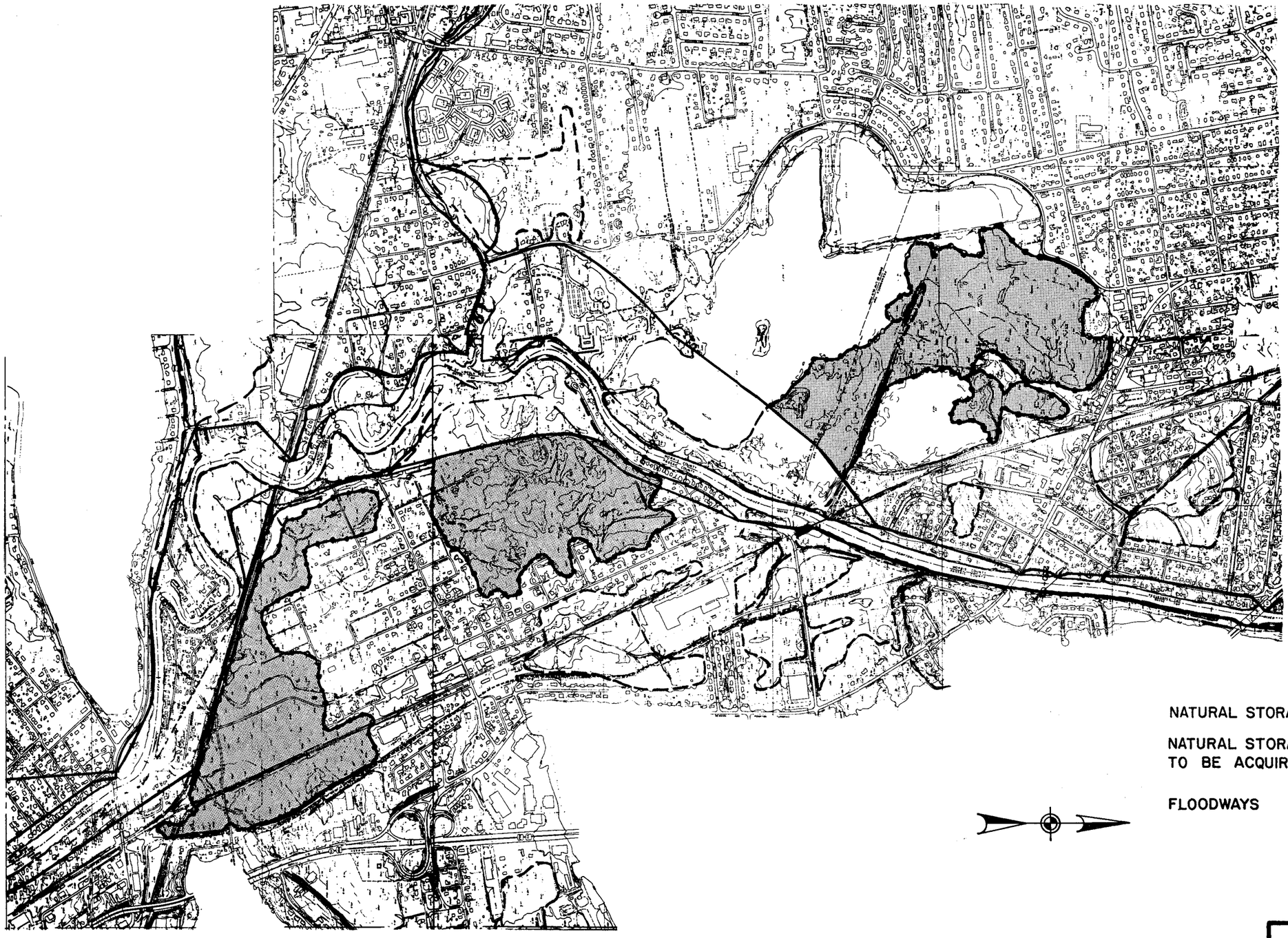
NATURAL STORAGE AREAS TO BE ACQUIRED

FLOODWAYS

Passaic River Study N.J. & N.Y.

NATURAL STORAGE AREAS

BOG & VLY MEADOWS



LEGEND

NATURAL STORAGE AREAS

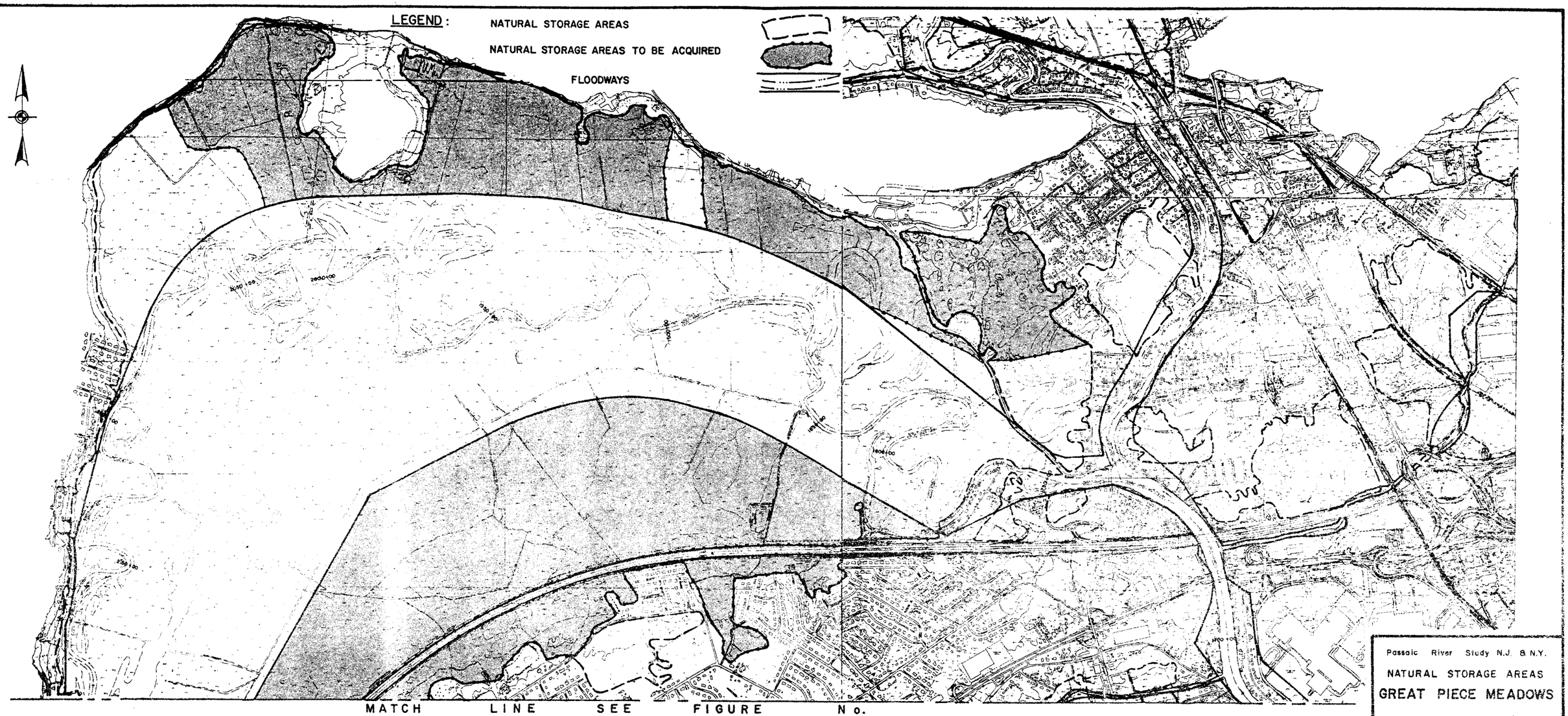
NATURAL STORAGE AREAS TO BE ACQUIRED

FLOODWAYS

Passaic River Study N.J. & N.Y.

NATURAL STORAGE AREAS

LOWER POMPTON VALLEY

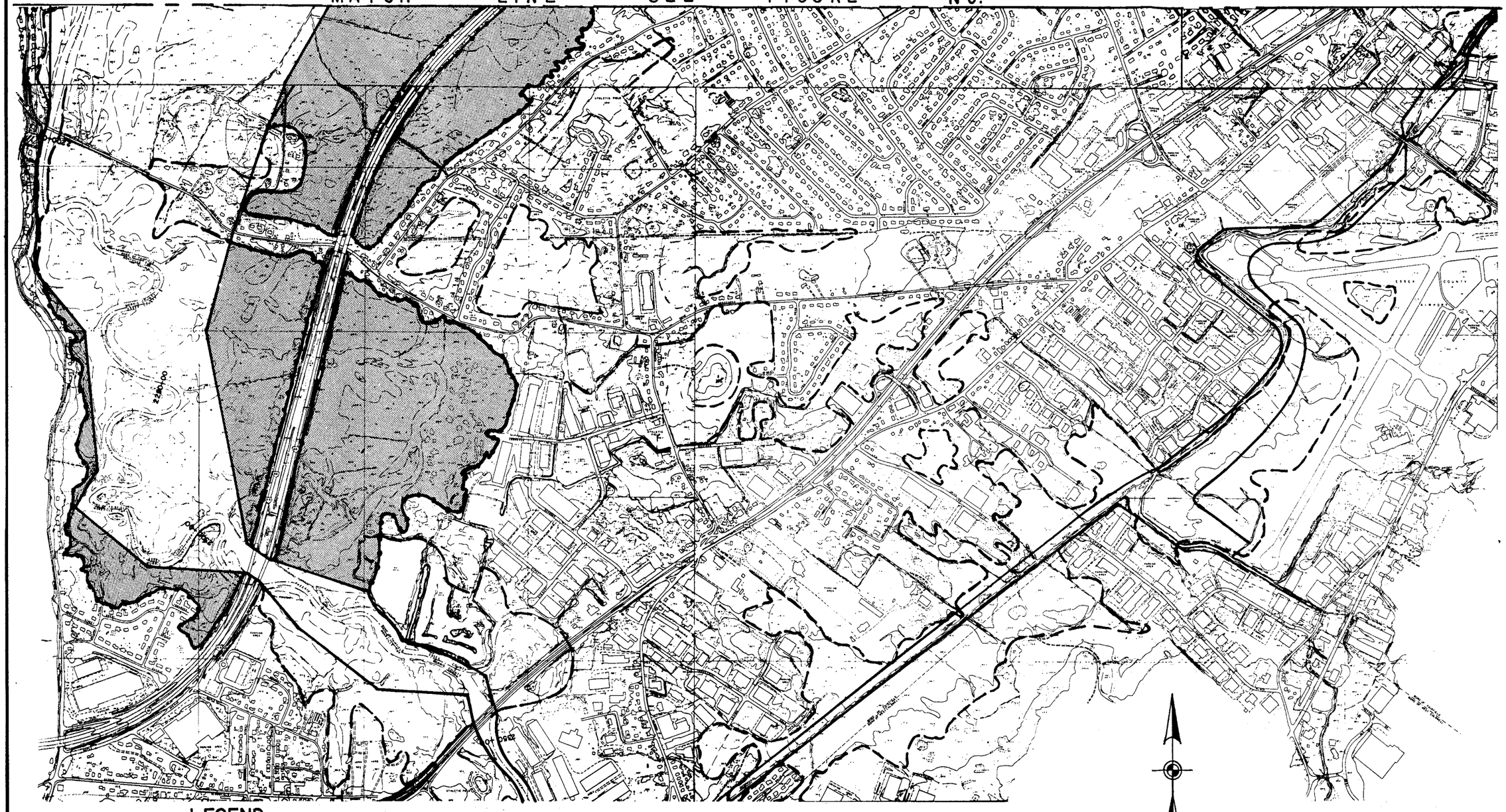


Passaic River Study N.J. & N.Y.
NATURAL STORAGE AREAS
GREAT PIECE MEADOWS

C-587

FIGURE C-130

MATCH LINE SEE FIGURE No.



LEGEND

NATURAL STORAGE AREAS

NATURAL STORAGE AREAS TO BE ACQUIRED

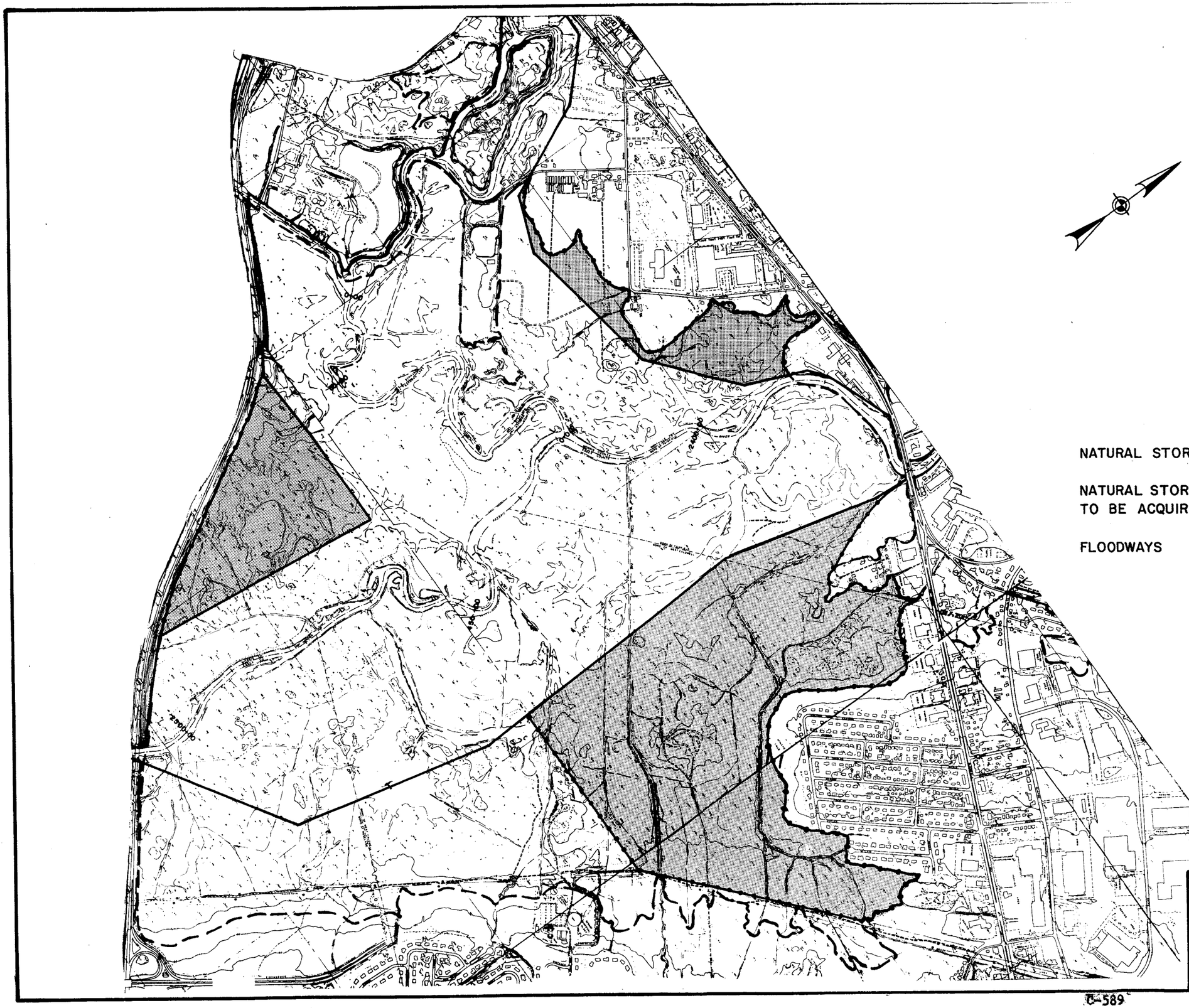
FLOODWAYS

Passaic River Study N.J. & N.Y.

NATURAL STORAGE AREAS

GREAT PIECE MEADOWS

FIGURE C-131 611



LEGEND

NATURAL STORAGE AREAS

NATURAL STORAGE AREAS TO BE ACQUIRED

FLOODWAYS

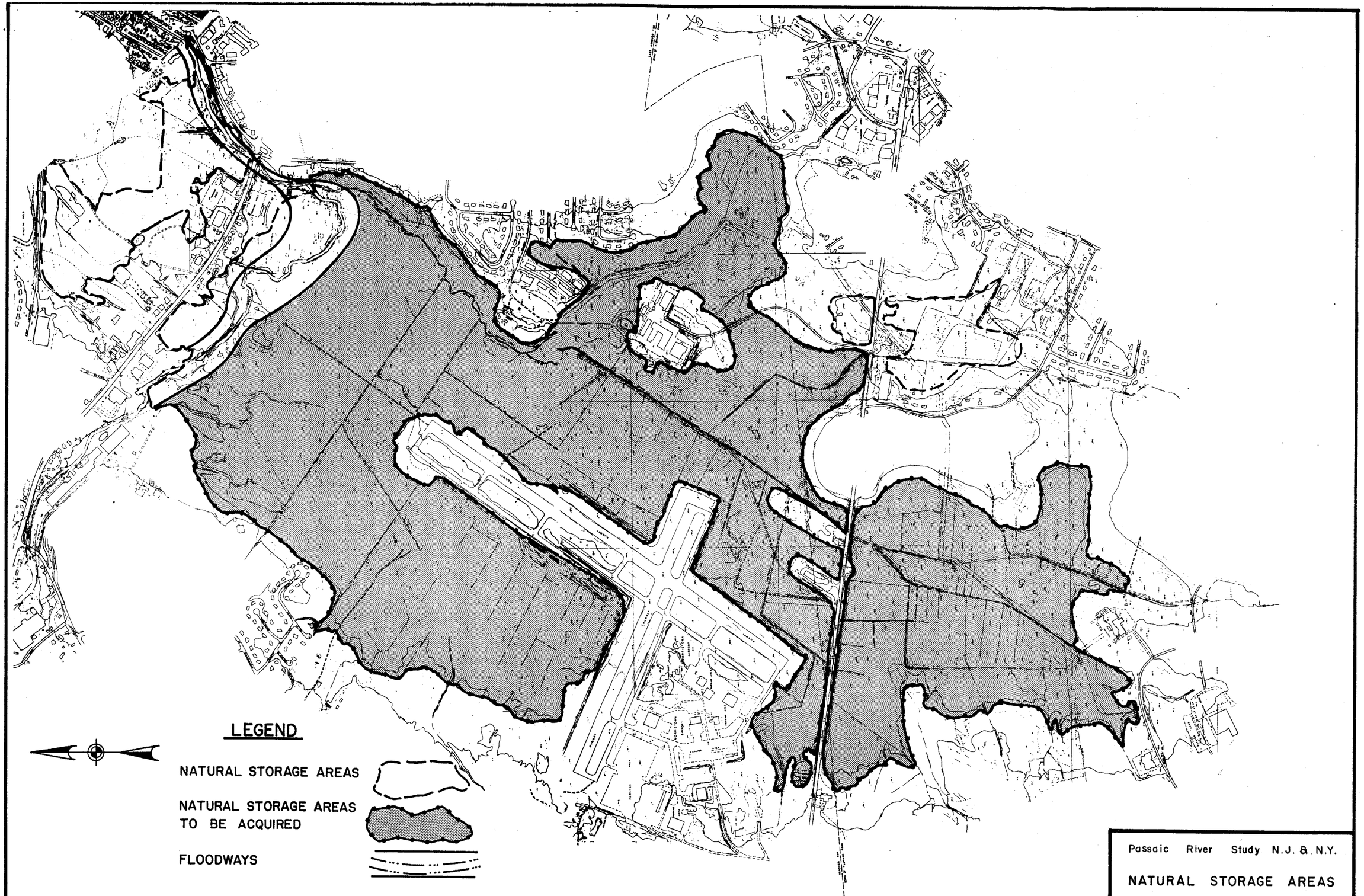
Passaic River Study N.J. & N.Y.

NATURAL STORAGE AREAS

HATFIELD SWAMP


LEGEND
NATURAL STORAGE AREAS
NATURAL STORAGE AREAS TO BE ACQUIRED
FLOODWAYS
Passaic River Study N.J. & N.Y.
NATURAL STORAGE AREAS
TROY MEADOWS

FIGURE C-133



Passaic River Study N.J. & N.Y.

NATURAL STORAGE AREAS

BLACK MEADOWS

FIGURE C-1|34

614

LEGEND

NATURAL STORAGE AREAS

NATURAL STORAGE AREAS TO BE ACQUIRED

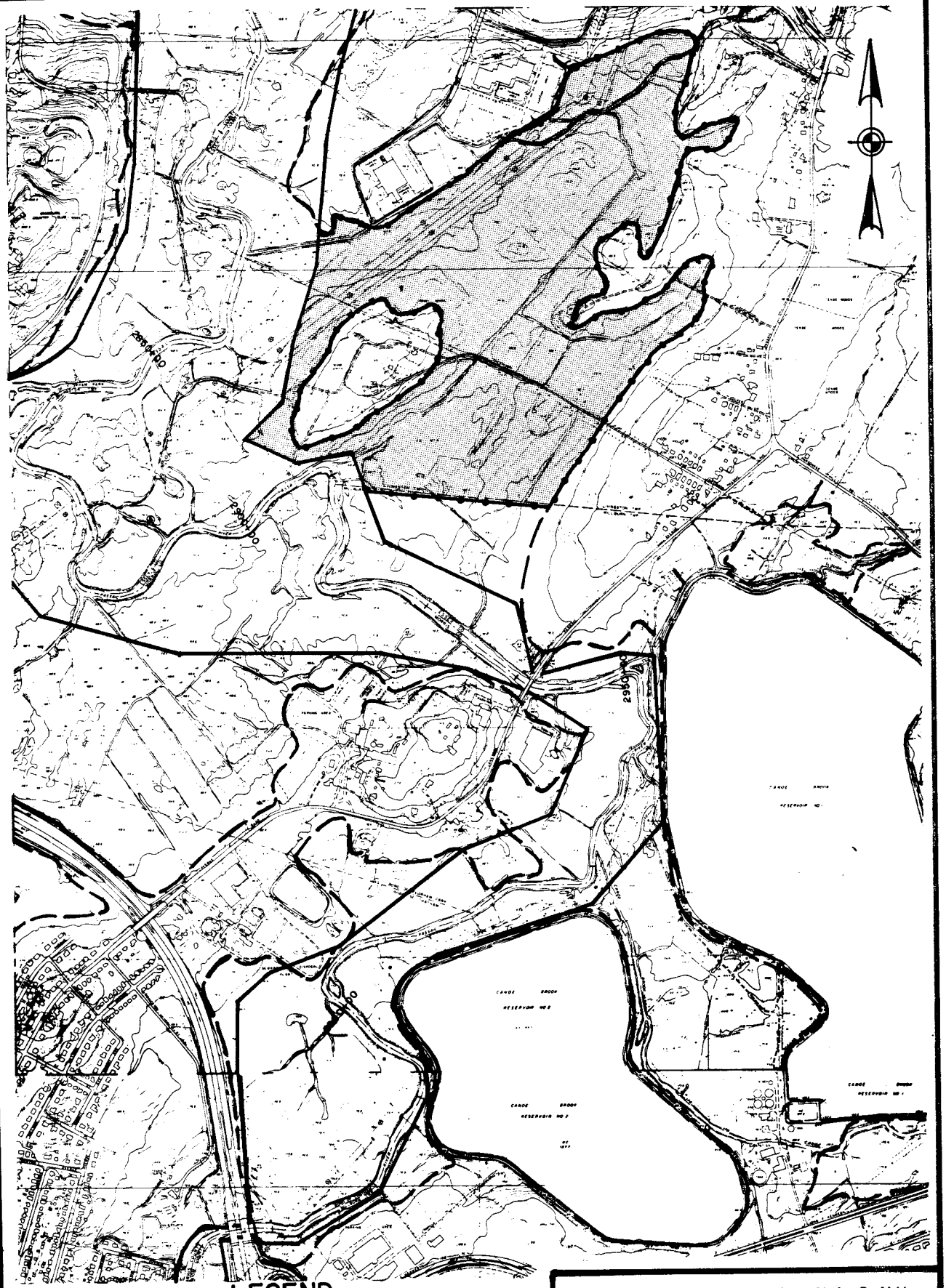
FLOODWAYS

Passaic River Study N.J. & N.Y.

NATURAL STORAGE AREAS

HATFIELD SWAMP SOUTH

FIGURE C-135



LEGEND

NATURAL STORAGE AREAS

NATURAL STORAGE AREAS TO BE ACQUIRED

FLOODWAYS

Passaic River Study N.J. & N.Y.

NATURAL STORAGE AREAS

CANOE BROOK