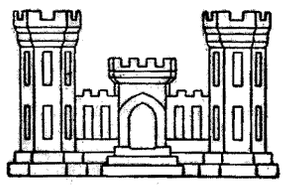
PASSAIC RIVER
NEW JERSEY

SURVEY REPORT FOR FLOOD CONTROL

VOLUME 1 - MAIN REPORT



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Serial No. 21
Passaic River, N.J. (S)

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, NEW YORK DISTRICT
NEW YORK, N. Y.

OCTOBER 1948

S Y L L A B U S

A serious flood problem exists within the Passaic River Watershed, particularly in the Lower Valley at Passaic and Paterson, New Jersey, because of severe losses which are inflicted by frequently recurring floods. The losses throughout the watershed are estimated at $2,700,000 annually under present conditions of development. A repetition of the record flood of 1903 would cause damages approximating $50,000,000.

A local flood protection project which would protect Passaic and Paterson against the maximum flood of record is justified. Such a project is estimated to cost $32,300,000, of which $24,600,000 would be Federal and $7,700,000 local costs.

A comprehensive solution of the flood problem on the main stream will require the construction of a Multiple-Purpose Reservoir at Two Bridges, New Jersey, with channel improvements downstream therefrom. The reservoir would provide flood detention storage for moderation of flood flows, supplemented by conservation storage primarily for affording additional water supply for northern New Jersey. The cost of this project would be approximately $96,300,000 of which $67,700,000 would be Federal and $28,600,000 local costs. This project has the support of the Department of Conservation of the State of New Jersey, but involves a conflict of interests between residents of the lower and upper valleys of the Passaic River. The project is economically justified. It should be constructed if the State of New Jersey approves the project and can guarantee the necessary local funds.

In addition, local protection works should be constructed on three tributaries, Weasel Brook, Saddle River and Molly Ann's Brook, subject to conditions of local cooperation; and the Federally-owned dams at Picatinny Arsenal should be reconstructed at Federal expense.

The plan, for the main stream together with the plans for protection on the three tributaries and at Picatinny Arsenal would cost an estimated $105,265,000, of which $74,835,000 would be Federal and $30,430,000 would be local. The annual costs of operation and maintenance are estimated at $125,600 Federal, and $146,500 non-Federal.

SURVEY REPORT FOR FLOOD CONTROL

PASSAIC RIVER, NEW JERSEY

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DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
OFFICE OF THE DISTRICT ENGINEER
NEW YORK DISTRICT
NEW YORK 5, N. Y.

NANGC 20 October 1948

SUBJECT: Survey Report for Flood Control of Passaic River, N. J.

TO: The Division Engineer
North Atlantic Division
Corps of Engineers
111 East 16th Street
New York 3, N. Y. NADGF

I. AUTHORITY

1. Act. This report is submitted in compliance with Section 6 of the Flood Control Act of 22 June 1936 (Public No. 738 - 74th Congress), which provides that:

> "The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control at the following-named localities . . Passaic River, New Jersey."

A preliminary examination report dated 19 December 1936, was submitted by the District Engineer under joint authorization of the foregoing Act and of the Act of 6 May 1936 (Public No. 574 - 74th Congress), which provides:

> ". . . . . That the Secretary of War is hereby authorized and directed to cause a preliminary examination to be made of the Passaic River in the State of New Jersey with a view to the control of floods, in accordance with the provisions of Section 3 of an Act . . . approved March 1, 1917. . . . . ."

2. After review of the preliminary report by the Board of Engineers for Rivers and Harbors, a survey was directed on 30 July 1937, by the Chief of Engineers, Department of the Army, under authority of the Secretary of the Army. Under date of 25 June 1947, based upon requests by the Ordnance Department, Department of the Army, and the New Jersey State Department of Conservation, the Chief of Engineers further directed that

consideration be given in this report to the adequacy of the existing Lake Denmark and Picatinny Lake spillways and the effect of possible failure of these structures upon Picatinny Arsenal and the Jersey City water supply dam at Boonton, New Jersey.

II. SCOPE OF SURVEY

3. Scope. This report is of survey scope and considers all phases of the flood problem within the Passaic watershed, with the object of determining the most suitable plan of improvement for flood control together with the economic justification thereof.

4. Surveys. Surveys and investigations were made for this report briefly as follows:

A topographic survey was made in 1938 of the main stream, the major tributaries, and several dam sites. A State riparian and stream survey of the main stream and tributaries was prepared in 1938 by the State of New Jersey and was supplemented by field reconnaissance and surveys by this office in 1946 and 1947. Supplemental data were also obtained from aerial photographs taken in 1936, 1942 and 1947. Subsurface investigations undertaken at the sites of proposed improvements, included core and auger borings, test pits and laboratory analysis of samples. These data were supplemented by local construction records and other existing soils survey data (Appendix D). Flood damages were evaluated by detailed field surveys to determine estimates of recurring damage at various flood stages (Appendix G). Field appraisals of the properties lying within the areas subject to flooding both along the main stream and its tributaries, and within possible reservoir areas, were prepared based on physical inspections supplemented by information obtained from local authorities and real estate interests. Assessed valuations were obtained from records of the local tax assessors (Appendix H). Pertinent data on past floods were obtained from newspaper files, published and unpublished records of the New Jersey State Water Policy Commission, and

the records of other State, Federal and local agencies. Several rain and stream gages were established and maintained in operation by the New York District during 1938 and part of 1939 (Appendix G).

5. Reports by Other Agencies. The flood problem on the Passaic River has been studied by local agencies since Revolutionary times. Numerous reports exist, of which the more noteworthy are tabulated in Appendix A. The most comprehensive of these reports, published in 1931 by the New Jersey State Water Policy Commission, undertook a careful inventory of the total flood control benefits which might be derived within the Passaic watershed, and concluded that the capitalized value of these benefits under contemporary conditions would aggregate $93,109,000. In this report numerous flood control plans were discussed, several were shown to be economically justified, but none was specifically recommended.

6. Consultation with Interested Parties. In order to determine the extent and type of improvements desired, two public hearings were held, one in 1936 and one in 1946. In addition, frequent conferences were held with various committees, organizations, and local governmental agencies representing interested parties. (Appendix A and paragraphs 100 to 108 of this report)

III. PRIOR REPORTS

7. Except for the preliminary examination report referred to in paragraph 1, there have been no prior reports rendered by the Department of the Army on flood control within the Passaic watershed. Concurrently with the foregoing report and under the identical authorization, the Secretary of Agriculture submitted a preliminary examination report on the Passaic River, New Jersey, in which it was concluded that the expenditure of Federal funds by the Department of Agriculture for runoff and waterflow retardation and soil erosion prevention was not justified.

IV. DESCRIPTION

8. General Description. The Passaic watershed has a total area of 935 square miles of which 787 square miles or 84 percent are in the northeasterly portion of the State of New Jersey, and the remainder in southerly portion of New York State. The watershed in New Jersey occupies 10.5 percent of the total State area including the greater part of Passaic County, half or more of Essex, Morris and Bergen Counties, and parts of Hudson, Somerset, Sussex and Union Counties. In the State of New York, it occupies parts of Orange and Rockland Counties. The watershed is located within a 35 mile radius of New York City. The area is shown on published quadrangle sheets of the Corps of Engineers, Army Map Service; U. S. Geological Survey; and the State of New Jersey, Department of Conservation. An index of these maps is given in Table A1, Appendix A. Five plates and thirty figures accompany this report, including an index map (Figure 1) and a watershed map (Figure 2), bound herein.

9. Topography. The watershed is roughly elliptical in shape, with a length of 56 miles and a greatest width of 26 miles. It is physiographically divided into three distinct regions known as the Highland Area, the Central Basin and the Lower Valley (Plate 1). The Highland Area, roughly 13 miles wide, 38 miles long and 489 square miles in area, is a heavily wooded mountainous region comprising the northwesterly half of the watershed. This area is characterized by a series of parallel ridges deeply dissected by transverse, steep-sided, narrow valleys, in which flow the five major tributaries, and in which are contained numerous lakes and reservoirs which have an aggregate water surface area of 22.9 square miles. The average elevation is 900 feet above sea level varying from about 1,200 to 1,400 feet in the uplands at the westerly edge of the watershed to 300 feet, in the valley at the easterly edge.

10. The Central Basin, containing 253 square miles, is a flat oval shaped depression about 10 miles wide and 30 miles long, extending in a

northeast-southwest direction from Millington to Little Falls. The low lying land bordering the river is largely composed of fresh water swamps and flat meadow lands, occasionally relieved by low rolling hills and several rocky outcrops. The aggregate swamp area in this region is 42.9 square miles, including the Great Swamp above Millington with an area of eight square miles, and the Great Meadow above Two Bridges with an area of 35 square miles. The Great Meadow includes a chain of low lands known locally as Black Meadows, Troy Meadows, Great Piece Meadows, Long Meadows, Bog and Vly Meadows, and Hatfield Swamp. The average elevation of the basin is 300 feet above sea level varying from about 500 feet along the southwesterly rim of the basin to 163 feet at the northeasterly edge.

11. The Lower Valley, containing 193 square miles, is a flat, densely populated and highly industrialized region in the southeasterly portion of the watershed, extending from Little Falls at the northeasterly edge of the Central Basin to the mouth of the Passaic River in Newark Bay (Plate 1). This roughly rectangular valley, about eight miles wide and 26 miles long, has rolling sides and a wide flat flood plain. The average elevation of the area is about 250 feet above sea level, varying from 500 feet along the westerly edge of the basin to tide level in Newark Bay. The tributaries in this area are short and steep, and enter the main stream at uniform intervals below Two Bridges.

12. Main Stream. The headwaters of the Passaic River have their source in Mendham Township, Morris County, New Jersey. The course of the stream is generally south by east for a distance of about nine miles to above the village of Millington where Great Swamp acts as a collecting basin for the headwater tributaries in this area. At Millington the stream flows through a narrow gorge traversing a high trap rock ridge, and then is sharply diverted to the northeast by the Second Watchung Mountain which forms the southeasterly limit of the watershed. From below Millington to Chatham, the stream flows for a distance of twelve

miles through a narrow corridor between two flanking ridges which limit the width of the watershed in this section to an average of about three miles. Beyond Chatham, the main stem continues in a northerly direction to the Great Meadow area in Caldwell where it turns sharply east through a rock gorge at Little Falls and thence northeast to Paterson. It then flows south a distance of about 23 miles to its mouth at the northerly end of Newark Bay. This bay is a tidal estuary about six miles long and 1¼ miles wide communicating with upper New York Bay through the Kill Van Kull and with Lower New York Bay through the Arthur Kill.

13. Tributaries. All of the major tributaries of the Passaic River rise in the Highland Area and enter the main stream within the Central Basin (Figures 1, 2 and 3). The Pompton River, together with its tributaries, the Pequannock, Wanaque and Ramapo Rivers, enters the main stream from the north at Two Bridges. The Rockaway, with its tributary the Whippany, enters the main stream from the west near Pine Brook. The Saddle River, the only large tributary downstream from Two Bridges, enters the main stream from the north opposite the city of Passaic.

14. Geology. The geology of the Passaic watershed is highly diverse. The entire Highland Area is underlain with crystalline schists, granites and gneisses, occasionally infolded with strata of sedimentary shales and conglomerates. The Central Basin and the Lower Valley, separated from the Highland Area by an inactive fault along the Ramapo River, are largely composed of sedimentary sandstones and shales intersected with long, narrow sills of basaltic trap rock. The watershed was overrun several times by the glacial ice sheet, and below Chatham, where the stream originally flowed into the Rahway watershed, heavy deposits of debris dammed the original channel and diverted the flow into the Passaic drainage system. The extensive wet lowlands in the Central Basin mark an ancient lake bottom which is underlain with thick strata of clay. This clay has been slightly consolidated by glacial overrun, and is now pro-

tected from surface erosion by the basaltic dikes at Little Falls. Detailed geology of the area is contained in Appendix D.

15. Stream Slopes. From its mouth in Newark Bay to Dundee Dam at Clifton, the Passaic River is tidal (Figure 3). In Newark Bay, the mean low water elevation is 2.4 feet below mean sea level, the extreme tide is 6.3 feet above mean sea level and the tidal range is 5.1 feet. At Gregory Avenue Bridge in Passaic (mile 13.8), the mean low water is 2.3 feet below mean sea level and the tidal range is 5.1 feet. Above the Eighth Street Bridge in Passaic (mile 15.0), which is the head of improvement for navigation, the river is shallow and the tide is increasingly affected by fresh water runoff of the Passaic River.

16. In the 80 miles of its course from Great Swamp above Millington to its mouth in Newark Bay, the Passaic River has a total fall of 220 feet of which about 113 feet occur in vertical falls as follows: 17 feet at Dundee Dam in Clifton, 63 feet at the Great Falls (S.U.M. Dam) in Paterson, and 33 feet at Beatties Dam in Little Falls. The elevation of the Great Meadows varies uniformly from 165 feet, m.s.l. to 180 feet, m.s.l. The Great Swamp has an elevation of 225 feet, m.s.l. at its lower end and an elevation of 240 feet, m.s.l. at its upper end. The gradients of the main river and tributaries are summarized in Table 1 and shown on Figure 3.

17. Channel Dimensions and Capacities. In the Lower Valley, flooding occurs as a result of insufficient channel capacity, due in part to the flat gradient and meandering character of the stream, but in a larger measure to flagrant encroachments by communities both in the flood plain and along the river banks. The process of land reclamation by deposition of earth fills adjacent to the river has materially reduced the original channel width, and has fed into the river, through the agency of scour, heavy deposits of silt which have shoaled the channel and formed islands in several localities. Throughout the Lower Valley,

TABLE I

STREAM SLOPES, PASSAIC RIVER WATERSHED, N. J.

Stream	Locality	Distance Above Mouth of Passaic River (miles)(a)	General Slope (ft. per mi.)
Passaic River	Mouth to Dundee Dam(Clifton)	0-17.4	Tidewater
	Dundee Dam to S.U.M. Dam (Great Falls)	17.4-25.2	2.0
	S.U.M. Dam to Beatties Dam (Little Falls)	25.2-29.7	1.9
	Beatties Dam to Below Chatham	29.7-58.7	0.3
	Chatham	58.7-61.5	10.6
	Chatham to Above Millington	61.5-81.0	0.9
	Above Millington to Headwaters	81.0-87.5	58.8
Major Tributaries			
Pompton River	Two Bridges to Pompton Lakes Dam	33.0-41.9	4.5
Pequannock River	Pompton Lakes to Oak Ridge Dam	39.7-59.2	33.9
Wanaque River	Pompton Lakes to Greenwood Lake Dam	41.8-58.4	25.9
Ramapo River	Pompton Lakes to Monroe	41.9-74.6	12.2
Rockaway River	Pine Brook to Petersburg	47.0-83.0	17.2
Whippany River	Pine Brook to Morristown	48.2-60.2	10.2
Other Tributaries			
Weasel Brook	Passaic to Clifton (Jewett Avenue)	14.2-16.7	26.0
Saddle River	Lodi to Upper Saddle River	15.5-33.0	8.0
Hohokus Creek	Ridgewood to Allendale	25.8-31.8	35.0
Diamond Brook	Fairlawn to Glen Rock	22.2-24.7	15.0
Goffle Brook	Hawthorne to Wyckoff	23.3-30.3	47.7
Molly Ann's Brook	Paterson to Franklin Lakes	25.8-32.3	63.1
Slippery Rock Brook	Paterson to West Paterson	26.1-28.1	225.0
Peckman River	West Paterson to Pleasentdale	28.2-34.3	44.0
Singac Brook	Singac to Preakness	31.8-35.8	10.5

Note: (a) 0.0 miles on the Passaic River is the intersection of the Hackensack and Passaic River channels in Newark Bay, approximately 4,000 feet downstream of Central Railroad of New Jersey bridge over the Passaic River.

numerous bulkheads jut into the waterway, constricting its width. Many of the bridges, built at low level to meet adjacent street grades, afford grossly inadequate waterways for the safe passage of floods; and many bridges, destroyed by the 1903 flood, have since been rebuilt with equal or smaller openings than existed before the flood. In the navigable section, the channel is further restricted by large flatirons and bridge-pier fenders built in midstream.

18. Under existing conditions the Passaic River varies in width from about 165 feet to 800 feet in the reach from Two Bridges to its mouth. In depth it varies over the same reach from 8 to 45 feet. The major tributaries in the lower reaches vary up to 510 feet in width and up to 24 feet in depth. The minor tributaries, largely in the Lower Valley, vary up to 80 feet in width and up to 7 feet in depth. The channel dimensions of the main stem through the Lower Valley are summarized as follows:

TABLE II

CHANNEL DIMENSIONS IN LOWER VALLEY, PASSAIC RIVER WATERSHED, N. J.

Reach	Miles Above Mouth	Width at Top of Banks (feet)			Thalweg Depth at Bankful Stage (feet)	
		Min.	Max.	Av.	Min.	Max.
Newark Bay to Clifton (navigable)	0-11.5	260	800	400	14	45
Clifton to Dundee Dam	11.5-17.4	200	730	330	14	33
Dundee Dam to Head of Lake Dundee	17.4-18.6	720	1,300	850	13	19
Lake Dundee to S.U.H. Dam	18.6-25.2	165	750	300	11	20
S.U.H. Dam to Beatties Dam	25.2-29.7	210	620	280	8	15
Beatties Dam to Two Bridges	29.7-33.0	200	390	290	10	12

Other data on cross-sectional dimensions of the main stream and tributaries are given in Appendix A.

19. Under present channel conditions, minor flooding occurs in the city of Paterson above Great Falls when the discharge at Great Falls is 3,100 cubic feet per second or more. Floods of this magnitude occur on an average twice yearly. Flooding in the river below Little Falls, as a whole, occurs when the discharge at Great Falls exceeds 7,700 c.f.s. (1.5-year frequency). Extensive flooding through the Lower Valley begins with discharges at Great Falls (S.U.M. Dam) of 11,700 c.f.s. (4 to 5-year frequency). Immediately upstream of Little Falls, flooding occurs as a result of backwater from Beatties Dam and from the narrow approach channel which extends upstream of the dam nearly to Two Bridges. In this section overflow occurs whenever the discharge of the Passaic River at Little Falls attains a value of 4,800 c.f.s. and inundation of meadowlands upstream therefrom occurs whenever the discharge exceeds 2,900 c.f.s. although limited overflow at scattered localities occurs at somewhat lower discharges. For this report bankful channel capacities of the main stream and its tributaries at indicated reference gages were assumed as given in Table III.

20. Drainage Areas. Drainage areas of the principal tributaries together with watershed areas at designated localities on the main stream are given in Table IV. Other drainage area data are given in Appendix A.

TABLE III

CHANNEL CAPACITIES, PASSAIC RIVER WATERSHED, N. J.

Stream	Locality	Distance Above Mouth of Passaic River (miles)	Bankful Channel Capacity (c.f.s.)
Passaic River	Mouth to Dundee Dam (Clifton) Gregory Ave. Bridge	0-17.4	7,400
	Dundee Dam to SUM Dam (Great Falls) Straight St. Bridge	17.4-25.2	9,500
	SUM Dam to Beatties Dam (Little Falls) Lincoln Bridge	25.2-29.7	11,700
	Beatties Dam to Two Bridges Route 23 Bridge, Singac	29.7-33.0	4,800
	Two Bridges to Chatham Route 6 Bridge, Pine Brook	33.0-51.5	2,900
Major Tributaries			
Pompton River	Two Bridges to Pompton Lakes Dam Lower Pompton Feeder Dam	33.0-41.9	3,200
Pequannock River	Pompton Lakes to Macopin Intake Pompton Lakes	39.7-50.2	600
Wanaque River	Pompton Lakes to Wanaque Dam Pompton Lakes	41.8-46.5	800
Ramapo River	Pompton Lakes to Oakland Pompton Lakes	41.9-44.0	500
Rockaway River	Pine Brook to Boonton Dam Pine Brook	47.0-55.5	900
Whippany River	Pine Brook to Whippany Pine Brook	48.2-54.2	400
Other Tributaries			
Weasel Brook	Passaic to Clifton Central Ave. Bridge, Clifton	14.2-16.7	330
Saddle River	Lodi to Paramus Railroad Ave. Bridge, Rochelle Park	15.5-27.0	1,600
Hohokus Creek	Ridgewood to Hohokus Grove St. Bridge, Ridgewood	25.8-29.8	440
Diamond Brook	Fairlawn to Glen Rock Oxford Ave. Bridge, Glen Rock	22.2-24.7	210
Goffle Brook	Hawthorne to Wyckoff Lafayette Ave. Bridge, Hawthorne	23.3-30.3	310
Molly Ann's Brook	Paterson to North Haledon Church St. Bridge, Haledon	25.8-29.8	430
Slippery Rock Brook	Paterson to West Paterson Murray Ave. Bridge, Paterson	26.1-28.1	80
Peckman River	West Paterson to Cedar Grove E. Main St. Bridge, Little Falls	28.2-31.2	500
Singac Brook	Singac to Preakness Preakness Ave. Bridge, Preakness	31.8-35.8	440

TABLE IV

DRAINAGE AREAS, PASSAIC RIVER WATERSHED, N. J.

Stream	Locality	Distance Above Mouth of Passaic R. (miles)	Drainage Area (sq. mi.)
Passaic River	Mouth at Newark Bay	0.0	935
	Passaic, above Saddle River	15.5	876
	Clifton, Dundee Dam	17.4	810
	Paterson, S.U.M. Dam	25.2	785
	Little Falls, Beatties Dam	29.7	762
	Two Bridges, below Pompton R.	33.0	741
	Chatham	64.5	103
	Millington	75.8	55
Major Tributaries			
Pompton River	Mouth at Two Bridges	33.0	378
Pequannock River	Mouth at Pompton Lakes	39.7	193
Wanaque River	Mouth at Pompton Lakes	41.8	108
Ramapo River	Mouth at Pompton Lakes Dam	41.9	160
Rockaway River	Mouth at Pine Brook	47.0	206
Whippany River	Mouth at Pine Brook	48.2	72
Green Pond Brook	Picatinny Lake Dam	75.8	9
Meadow Brook	Lake Denmark Dam	77.8	4
Other Tributaries			
Weasel Brook	Mouth at Passaic	14.2	7
Saddle River	Mouth at Garfield	15.5	61
Hohokus Creek	Mouth near Ridgewood	25.8	19
Diamond Brook	Mouth at Fairlawn	22.2	3
Goffle Brook	Mouth at Hawthorne	23.3	9
Molly Ann's Brook	Mouth at Paterson	25.8	9
Slippery Rock Brook	Mouth at Paterson	26.1	1
Peckman River	Mouth at West Paterson	28.2	10
Singac Brook	Mouth near Singac	31.8	12

21. Bridges. Several hundred bridges cross the Passaic River and its tributaries. In the Lower Valley below S.U.M. Dam 47 bridges or an average of one every half mile cross the river. Fourteen of these are railroad bridges and the remainder are mainly highway bridges with some footbridges and pipeline crossings. Data on the more important bridges in the watershed are listed in Appendix A.

V. ECONOMIC DEVELOPMENT

22. General. From an economic standpoint the Passaic River watershed is an integral part of the Greater New York metropolitan area. In the west and south the development is largely rural and suburban, with a rapid transition to intense industrial development in the easterly portion of the watershed approaching New York City.

23. Population. According to U. S. Census reports, the population of the Passaic watershed was 1,080,000 in 1940, or about 1,150 inhabitants to the square mile. Of this total, about 74 percent resided in urban centers of 10,000 persons or more, over 98 percent resided in the State of New Jersey, and nearly 80 percent was concentrated in the Lower Valley below Little Falls. In 1940, the Passaic area contained about 25 percent of the total population of the State of New Jersey. The population of the watershed has increased at an average annual rate of 1.7 percent since 1920 and 2.2 percent since 1910. Population densities vary from an average of 4,810 per square mile in the Lower Valley to an average of 137 per square mile in the Highland Area. Maximum density occurs in the city of Paterson with a value of 17,241 per square mile. The metropolitan character of the watershed, particularly of the Lower Valley, is evident when its population density is compared with the value of 1,411 persons per square mile for all metropolitan districts of the United States, and the value of 4,565 persons per square mile for the Greater New York metropolitan area as a whole. Newark, the largest city in the State of New Jersey, had a 1940 population of 429,760, of which about forty percent resided in the Passaic watershed. Communities located entirely within the Passaic area, together with their 1940 populations include the following: Paterson (139,656), Passaic (61,394), Clifton (48,827), Montclair (39,807), Bloomfield

(41,623), Belleville (28,167) and Garfield (28,044). Other communities which lie partially within the watershed together with the portion of their population included within the watershed limits, and the percent of the total population represented, are as follows: East Orange (41,300, 60%), Orange (21,400, 60%), and Kearny (19,733, 50%). The population of urban places within the watershed of 10,000 or more is given in Appendix A.

24. Occupation and Industries. Since colonial times, the Lower Valley of the Passaic has continuously developed industrially because of the accessibility to domestic and world markets through the Ports of New York and Newark, the availability of fuel and raw materials and the plentiful water supply and power resources of the Passaic River. The Passaic area now contains about 36 percent of the manufacturing establishments of the State of New Jersey, 32 percent of the wage earners and contributes 28 percent of the value of manufactured products. According to the 1939 Census there were 2,900 manufacturing establishments in the watershed employing 140,000 wage earners, paying annual wages amounting to $163,000,000 and producing goods valued annually at $950,000,000. This industrial activity is largely concentrated in the Lower Valley. The principal manufacturing centers are Paterson, Passaic, Clifton, Bloomfield, Garfield, Kearny and Newark. The major industries are engaged in dyeing and finishing of textiles, the manufacture of wearing apparel, food and kindred products and the production of textile machinery, chemicals, paints and varnishes, electrical equipment and leather goods. Business activity in the watershed, as indicated by the 1939 census, comprises about 1,700 retail establishments with annual sales of $440,000,000; 1,300 wholesale establishments with annual sales of $420,000,000 and 6,300 service establishments with annual receipts of $37,000,000.

25. Land Use and Development. The land use and development within the watershed is highly diversified. As previously indicated, intensively developed industrial and urban areas are located in the southeasterly portion of the watershed. Within the Central Basin, although development has been materially retarded in comparison with other areas by the existence of large expanses of swamp, the influence of metropolitan activity has been such as to cause the growth of numerous suburban communities, particularly where rail facilities afford commuting service. In addition many summer colonies have sprung up throughout the northerly portion of the Central Basin along its water courses. Much of the remaining arable land is devoted to truck farming. The mountainous and wooded Highland Area lying to the west of the Central Basin includes several large publicly owned reservations set aside for water supply use by the metropolitan communities to the east, and contains elsewhere a great number of summer recreational colonies bordering its streams and lakes. Picatinny Arsenal is located in the westerly portion of the Highland Area on Green Pond Brook in the headwaters area of the Rockaway River.

26. Agriculture. Based upon the 1940 U. S. Census there are about 2,500 farms in the Passaic Valley, valued at $35,000,000. Farm lands constitute about 20 percent of the total watershed area and lie largely in the Central Basin. The major produce consists of dairy products, poultry and fruits and vegetables. Their annual value is $10,000,000

27. Reservoirs. There are more than 200 artificial lakes, ponds and reservoirs within the Passaic River watershed used mainly for recreation and water supply purposes. About 130 of these are used for recreation, 35 for industrial water supply, 20 for potable water supply, and about 15, in whole or in part, for water power purposes. Data on the larger reservoirs are given in Table V. Except for Greenwood Lake, no data are given

TABLE V

PRINCIPAL EXISTING STORAGE RESERVOIRS, PASSAIC RIVER WATERSHED, N. J.

Reservoir	Operating Agency	Stream	Drainage Area (sq.mi.)		Elevation of Spillway Crest	Flash-boards	Reservoir Area at Spillway Level	Reservoir Storage to Spillway Level		Date of Construction	Purpose
			Gross	Net	(ft., msl)	(feet)	(acres)	(acre feet)	(inches) (6)		
Pompton Lakes		Ramapo	160.0	160.0	201	-	202	900(2)	0.1	1908(1)	Unused
Greenwood Lake	N.J. State Department of Conservation	Wanaque	27.1	27.1	619	-	1,920	21,100(2)	14.6	1928(1)	Recreation & Water Supply
Wanaque Res.	North Jersey District Water Supply Comm.	Wanaque	94.4(8)	67.3	300	2.0	2,310	85,960	17.1	1930	Water Supply
Canistear Res.	Newark Water Dept.	Pequannock	5.6	5.6	1,086	-	350	7,400	24.7	1900	Water Supply
Oak Ridge Res.	Newark Water Dept.	Pequannock	27.3	21.7	846(3)	-	482	12,200	10.5	1892	Water Supply
Clinton Res.	Newark Water Dept.	Pequannock	10.5	10.5	992	-	423	10,700	19.1	1892	Water Supply
Echo Lake	Newark Water Dept.	Pequannock	4.6	4.6	893	1.0	300	5,200	21.2	1927	Water Supply
Macopin Intake	Newark Water Dept.	Pequannock	63.7	-	584	-	12	100(4)	-	1892	Water Supply
Boonton Res.	Jersey City Water Dept.	Rockaway	119.0	113.4	305(5)	1.75	774	22,600	3.7	1904	Water Supply
Splitrock Pond Res.	Jersey City Water Dept.	Rockaway	5.6	5.6	835	-	566	9,520	31.9	(7)	Water Supply

(1) Originally constructed about 1837 to furnish water for the Morris Canal; reconstructed on dates indicated.
(2) Storage not used
(3) Crest raised 10 feet in 1918 to value shown; original reservoir area 383 acres.
(4) Dam used for collection and diversion purposes only.
(5) Provision exists to raise dam 19 feet above crest level given above, affording 16,100 acre feet additional storage.
(6) Over net drainage area except Wanaque Reservoir which is based on gross drainage area to include Greenwood Lake, 27.1 square mile.
(7) Under construction.
(8) Includes 4 square miles diverted from Post Brook.
(9) Formerly used for power purposes.

for recreation lakes or reservoirs not used for storage. Two small reservoirs, Lake Denmark and Picatinny Lake, constitute the principal source of industrial water for the operation of Picatinny Arsenal. These reservoirs are located on Meadow Brook and Green Pond Brook, respectively, in the upper Rockaway River watershed.

28. Water Supply. The Passaic River and its tributaries are the chief source of water supply for the municipalities in northern New Jersey. Prior to 1894, Jersey City, Newark and many other communities drew their potable water supplies from the lower river. Communities elsewhere used springs and wells. As demands increased through the years, three major water supply systems were developed in the Passaic Highland Area on the Rockaway, Pequannock and Wanaque Rivers (Plate 2). A fourth system, which drew its supply directly from the Passaic River at Little Falls, was constructed by private capital about 1899, and furnished potable supplies to Bayonne, Jersey City, Montclair, Kearny and several other communities.

29. The Pequannock River system which began operation in 1892 was originally built by private interests, but was acquired by the city of Newark in 1900. The present development is estimated to afford a minimum yield of 62 million gallons daily (96 c.f.s.). The supply is drawn from a watershed of 63.7 square miles above the collection point at the Macopin Intake on the Pequannock River. About 89 percent of this drainage area is now owned by the city of Newark for watershed protection purposes. Included in the supply system are the Oak Ridge, Clinton, Canistear and Echo Lake Reservoirs (Table V). Water is delivered by gravity from the Macopin Intake through two independent pipe lines to collecting and equalizing reservoirs near the city of Newark. The system is so operated that practically no dry season flow is contributed to the lower river from above the Macopin Intake.

30. The Rockaway River system was constructed in 1903 by a private company under contract with Jersey City to furnish a minimum yield of 50

million gallons daily (77 c.f.s.) for water supply purposes. The collection point for the 119 square miles of watershed is the Boonton Reservoir (Table V). Provision was made during construction to permit raising the level of the dam by 19 feet at some future date and thus increase the minimum watershed yield to 70 million gallons daily (108 c.f.s.). Delivery is made through 36 miles of aqueduct to Jersey City. In 1910 the works were acquired by Jersey City and operated since that date as a municipal system. In 1925 Jersey City began construction on a sewerage system to carry the sewage of upstream municipalities to a treatment plant below the dam. An additional storage reservoir at Splitrock Pond upstream from Boonton is now under construction. At present the Rockaway River supply furnishes water to Jersey City, Hoboken, Lyndhurst, Union Township and Ellis Island. The minimum summer flow below the Boonton Reservoir is about 3 c.f.s.

31. The Wanaque River system dates back to 1916 when the North Jersey District water Supply Commission was created by the State of New Jersey to act as agent for municipalities and other corporations in developing needed additional water supplies. Using funds provided by eight communities, in an amount of about $26,542,000, the North Jersey District Water Supply Commission undertook construction of the Wanaque Reservoir and aqueduct in 1920 and completed the work by 1930. The participating communities were: Newark, 40.5 percent; Paterson, 20.0 percent; Kearny, 12.0 percent; Passaic, 11.0 percent; Clifton, 6.75 percent; Montclair, 5.0 percent; Bloomfield, 4.0 percent; and Glen Ridge, 0.75 percent. The reservoir, constructed to its maximum capacity, controls a drainage of 94.4 square miles of the Wanaque watershed, including the area controlled by Greenwood Lake (Table V). The safe yield afforded by this system is estimated at 82 million gallons daily (127 c.f.s.). At present the average daily consumption of water from the Wanaque supply is about 90 million gallons (140 c.f.s.). The reservoir

is operated so that the minimum dry-season flow below the dam is 10 million gallons daily (15.5 c.f.s.) including the low water flow from Greenwood Lake which is passed through the Wanaque reservoir unimpeded. During periods of past flood the outflow below the Wanaque Dam has been reduced to as little as 6.4 c.f.s.

32. The fourth water supply system, that of the Passaic Valley Water Commission, is controlled by the cities of Paterson, Passaic and Clifton. This system draws its supply directly from the Passaic River at Little Falls where it is treated, augmented by the additional supply from the Wanaque River system referred to in paragraph 31, and pumped through a booster station to service Paterson, Passaic, Clifton, Prospect Park, Little Falls, Totowa and other communities. The system has an estimated minimum safe yield of 35 m.g.d., augmented by 37.75 m.g.d. through ownership rights of the cities of Paterson, Passaic and Clifton in the Wanaque River system. The Commission claims a right to divert up to 75 m.g.d. (116 c.f.s.) from the Passaic River.

33. The foregoing public water supply systems constitute approximately 65 percent of the supply for the Northern Metropolitan District (Table C8, Appendix C), which comprises the area generally south of the State line, west of the Hudson River and New York Bay, north of the Raritan River, and east of the Passaic River (Figure C7-1, Appendix C). The problem of additional water supplies to meet increasing present and future demands is very acute in this District. This district, comprising 635 square miles, and containing approximately three million persons, is served by water systems having a present safe yield of 350 m.g.d. The water demand in this district for the past several years has been in excess of this safe yield and has been met only because of favorable rainfall and runoff conditions. Actual demands (1947) are 375 m.g.d., continuing an average past annual increase of about 4 m.g.d. A study of the population trend and per capita consumption in this district indicates

that a total water consumption of 430 to 470 m.g.d. may be expected in the year 1975, the midlife of possible new reservoir storage (Figure C7-2, Appendix C). This demand would require an additional safe yield of 115 to 170 m.g.d. including a factor of reserve for abandonment of some of the existing smaller ground-water systems.

34. Numerous investigationshave been made during the past 25 years of possible additional water supplies for this area, and planning has centered on those watersheds draining into the New York Bay, of which the major watersheds are the Passaic, Hackensack and Raritan Rivers. The Passaic and Hackensack watersheds have received the greatest development to date, and further development would involve interstate problems or low level supplies requiring pumping. The watershed of the Raritan River is the least intensively developed of those major sources which can be developed to serve the Northern Metropolitan District. State water policy, as reflected in recommendations of the State Water Policy Commission to the New Jersey State Legislature in February 1945, favors the development of a North Jersey water supply project in the Raritan River basin capable of yielding 25 m.g.d. in its initial stage, 75 m.g.d. in its intermediate stage, and 145 m.g.d. at full development (paragraph C78, Figure C7-3, and Table C8, Appendix C). No funds have yet been appropriated for this project. In 1946, the North Jersey Water Supply Commission, because of increased demands on its system, made application to the New Jersey State Department of Conservation for a grant to divert a maximum of 100 m.g.d. during the wet seasons from the Ramapo River at a point below the existing dam at Pompton Lakes to the Wanaque Reservoir by pumping through a force main so as to develop an additional firm yield of about 25 m.g.d. This application was denied for technical reasons.

35. Water Power. The power resources of the Passaic watershed were utilized to a maximum during the latter part of the 19th Century when

more than 200 independent mills were operated on run-of-river flow. Practically all of these have been abandoned, however, in favor of larger power systems having higher generating efficiencies and reduced annual load factors. Flow diversions for potable use and for industrial processing have been an important contributing factor in this change. There are now only two important hydro plants on the Passaic River. These are on the main stem of the river at Little Falls and Great Falls. Data on these plants are given in Table VI. In addition, there are two other important sites which formerly were operated for power purposes but which subsequently have been abandoned. One of these, on the Ramapo River at Pompton Lakes, has been disused since 1942. The other, on the main stream at Dundee Dam, is now utilized only for the diversion of industrial processing water from the Passaic River.

TABLE VI

PRINCIPAL WATER POWER PLANTS, PASSAIC RIVER WATERSHED, N. J.

Locality on Passaic River	Owner or Operator	Drainage Area (sq. mi.)	Head (feet)		Dam Crest Elev. (ft.msl)	Installed Capacity (KW)
			Gross	Net		
S.U.M. Dam (Great Falls), Paterson	City of Paterson	786.8 a	70	67	114.5	4,600
Beatties Dam, Little Falls	Passaic Valley Water Commission	762.2 a	37	32	157.6	2,400
Total			107	99		7,000

a. Includes flow from about 250 square miles diverted to water supply purposes.

36. The site at Great Falls was originally developed by the Society for Establishing Useful Manufactures which was established in 1791 to promote industrial activity in the Passaic area. The plant is now owned and operated by the city of Paterson which sells its energy output to local industry. The plant has a total installed hydro capacity of 4,600 KW which is supplemented by 6,250 KW of steam generating capacity. In 1945, this plant generated a total of about 26.5 million kilowatt-hours.

37. The installation at Beatties Dam, originally constructed in 1867, is now utilized by the Passaic Valley Water Commission to pump water from the Passaic River and also as a booster plant for furnishing water supplies from the Wanaque system to customers in Paterson, Passaic and Clifton. Surplus energy developed at this site is floated into the lines of neighboring utility systems. In 1945, this plant generated a total of about 12.5 million kilowatt-hours.

38. Both the foregoing plants lack storage, and operate on run-of-river flow, generating secondary power mainly. The total annual output of these plants represents only about one percent of the power now used annually within the Passaic area.

39. By far the greater portion of the electrical energy consumed within the Passaic Valley is generated at steam plants. The energy generated by steam plants in 1947, for use within the Passaic and contiguous areas was 3,885 million kilowatt-hours. Data on these plants are given in Table VII.

TABLE VII

PRINCIPAL FUEL-BURNING GENERATING PLANTS SERVING THE PASSAIC RIVER WATERSHED, N. J.

Plant	Locality	Operating Company	Plant Capacity	
			Turbines (H.P.)	Generators (KW)
	New Jersey			
Kearny	Kearny	Public Service Electric & Gas Co.	455,000	339,600
Essex	Newark	Public Service Electric & Gas Co.	430,000	320,500
Marion	Jersey City	Public Service Electric & Gas Co.	302,000	225,800
Sewaren	Sewaren	Public Service Electric & Gas Co.	536,000	400,000 a
Whippany	Whippany	Jersey Central Power & Light Co.	26,800	20,000
Gilbert	Milford	New Jersey Power & Light Co.	74,000	55,000
	New York			
Hillburn	Hillburn	Rockland Light & Power Co.	13,800	10,300

a. Under construction

40. Public utility service within the watershed is furnished by the following systems; Orange and Rockland Electric Company, Rockland Light and Power Company, Public Service Electric and Gas Company, Jersey Central Power and Light Company, New Jersey Power and Light Company and the Butler Municipal Plant. All of these systems are interconnected except the Butler Municipal Plant.

41. It is apparent from the foregoing that the water power plants on the Passaic River carry an extremely small part of the present local power load. This condition is due in part to the low cost of competitive energy generated at the large tidewater fuel plants nearby, and in part to the high local value placed upon water for industrial processing and potable use as compared with its value for power generation. Today water power is not a major influence affecting the welfare of the Passaic area, nor is there sufficient potential power available to increase materially this influence in the future. The extent of coordination between possible flood control and water power development is therefore limited (Appendix J).

42. Transportation. The Passaic watershed is traversed by most of the important arterial highways connecting New York City with the hinterland to the north and west. State highways traversing the watershed from New York City include Route N. J. 17 proceeding north through the watershed to the Catskills and central New York State; Route U. S. 202 proceeding generally south from Suffern, N. Y. to Philadelphia, Pa.; Route N. J. 23 proceeding northwest to Port Jervis, N. Y. and Route N. J. 6 (U. S. 46) and connecting Routes N. J. 3 and 4 proceeding west through the watershed to Pennsylvania. U. S. Route 1 to Philadelphia and Washington crosses the Passaic River in the tidal section near its mouth. Many improved state and county roads have been constructed in Essex, Bergen and Passaic Counties, where bus lines constitute the most important medium of local passenger transport. Elsewhere in the basin adequate facilities for highway communications are available.

43. Seven railroads, carrying a large part of the national commerce, traverse the watershed and converge on the Newark and Jersey City area where freight classification and rail-to-ferry transfers are effected in the course of transportation of goods and passengers to and from New York City. Extensive treckage through the watershed is owned by the Erie and the Delaware Lackawanna & Western Railroads. The Erie main line extends from railhead in Newark, north through Ridgewood, Suffern and points beyond the watershed to Chicago. A branch line connects Hackensack, Pompton, Oak Ridge and points west of the watershed to Wilkes-Barre. Another branch from Greenwood Lake connects Paterson and Passaic to railhead in Jersey City. The main trunk line of the Delaware, Lackawanna and Western Railroad follows the Passaic Valley from Jersey City, through Passaic and Paterson, thence to Wharton and beyond the watershed to Buffalo.

44. Immediately south of the Passaic watershed is located the Newark Airport, a major terminus in the east for mail and passenger service. Regular service is maintained to all parts of the country from this field.

Within the Passaic watershed are eight airports. The largest is the Caldwell-Wright Airport (CAA-Class IV) located at Fairfield in Caldwell Township in the Central Basin. Next in size is the Morristown Airport (Class III) located three miles east of Morristown in the Black Meadow area of the Central Basin. The remaining six are small Class I airports of which four are located in the Central Basin in Passaic, Bergen, Morris and Somerset Counties, one in the Lower Valley in Bergen County and one in the Highland Area in Morris County. Future development contemplated by the New Jersey State Aviation Department and the Regional Airport Conference Plan provides for two additional Class II and eight additional Class I airports within the watershed, and also provides for the improvement from Class I to Class II of one existing airport. The location of existing and proposed airports, and further data on their CAA Classifications are contained in Appendix A.

45. Navigation. Since 1824, when the Morris Canal and Banking Company was chartered, navigation has played an important role in the development of the Passaic watershed. The Morris Canal was constructed in 1836 to accommodate vessels of 5-foot draft plying between the Lehigh Valley and New York City. The canal was 106 miles long, extending from its terminus in Jersey City through Paterson, Pompton Plains, Boonton, Dover and beyond the watershed to the Delaware River where it connected with the Lehigh Coal and Navigation Company's canal on the Lehigh River. Water supplies were drawn from Pompton Lakes, Greenwood Lake and Lake Hopatcong; and the 913-foot rise to summit level within the Passaic watershed was accomplished by twelve inclined railways and sixteen locks. Traffic on the canal attained its peak in 1866, and thereafter steadily declined. The property was taken over by the State of New Jersey in 1923, and the canal works dismantled. The water rights of the canal company were also acquired by the State. Sections of the canal are now used as a carrier of industrial water supplies.

46. At present the Passaic River is navigable, under a Federal project, from its mouth to the Eighth Street Bridge in Passaic. The present channel is part of a general project affording navigation facilities in Newark Bay and the Hackensack and Passaic Rivers, New Jersey. In the Passaic River, the existing project provides for a channel 30 feet deep at mean low water and 300 feet wide from Newark Bay to a point 3,000 feet above the Lincoln Highway Bridge in Newark, a distance of 2.6 miles; thence 20 feet deep and 300 feet wide to the Nairn Linoleum Works, about 4.4 miles; thence 16 feet deep and 200 feet wide to the Montclair and Greenwood Lake Railroad bridge, about 1.1 miles; thence 10 feet deep and 150 feet wide to the Eighth Street Bridge in Passaic, 7.3 miles; a total distance of 15.4 miles. The approach channel in Newark Bay is 30 feet deep with a minimum width of 400 feet. The existing project for the Passaic River alone was adopted by the River and Harbor Acts of 2 March 1907, 27 February 1911, 25 July 1912, 21 January 1927, 3 July 1930, and 2 March 1945. The total cost to the United States of all work in the Passaic River, Newark Bay and Hackensack River to 30 June 1948, was about $10,743,000, of which about $7,645,000 was for new work and $3,098,000 for maintenance. The latest estimated cost for annual maintenance of the entire project is $250,000. The existing project is about 63 percent completed, the 30, 16 and 10-foot channels in the Passaic River, and the 20-foot channel to Jackson Street, Newark, are completed. The cost for additional work to complete the 20-foot channel from Jackson Street, Newark, to the Nairn Linoleum Works in Kearny, based upon an estimate made in 1948, is about $750,000.

47. There are several publicly owned freight terminals and more than 100 usable private wharves and piers along the improved section of the Passaic River. The navigation season extends throughout the year. Commerce on the Passaic River in 1946 involved a total movement of 4,014,000 tons. The lower Passaic is also used for recreation purposes;

the number of pleasure craft docking along the river being about 200. Several yacht clubs, boat repair and storage yards provide landing and servicing facilities for these pleasure craft.

48. Mineral Resources. The mineral resources of the Passaic watershed are developed to only a limited degree. The most important produce is iron ore. A total of 1,263,537 tons of crude magnetite was produced in 1943 from underground mines in New Jersey, most of which came from mines located in Morris County. This represents about one percent of the total crude iron ore mined in the United States for that year. Granite and trap rock quarries and sand and gravel deposits are also extensively developed in the area.

49. Recreation. The Highland Area of the Passaic watershed is well adapted to all types of recreation. Extensive sub-marginal areas of scrub woodland exist which are unsuited to either lumbering or agriculture. Numerous lakes and ponds, periodically stocked by the New Jersey Fish and Game Commission, are scattered throughout the region. Many of these have been developed for boating and bathing. Nearly one-sixth of the nation's population is concentrated within three hours ride of the area. Large migratory populations from New York City and adjacent urban areas have established numerous summer colonies within the Pompton and Rockaway watersheds. Private fish and game preserves, exceeding 25,000 acres in Ringwood and adjacent localities, have been opened to the public. Many small mill ponds, which formerly furnished power to scattered industries, have in recent years been converted to recreational use. However, existing recreational facilities in this area have lagged considerably behind present requirements. This has been due partly to the heavy industrialization of the Lower Valley which placed business requirements above recreational needs, and partly to the mosquito nuisance which originates in the Great Meadow area. Although over 60,000 acres or about ten percent of the watershed is held in public ownership, relatively

little of this is available for unrestricted recreational use. More than 45,000 acres of woodland largely in the upper Pequannock watershed and in the vicinity of Wanaque watershed are being held by the city of Newark and other municipalities for the protection of its surface water supplies. Federal holdings in the Passaic area consist of about 2,600 acres at Picatinny Arsenal and the Morristown National Park. State park lands in Ringwood State Park and the Palisades Interstate Park aggregate over 12,000 acres, largely concentrated in the New York State section of the watershed. Approximately 30 municipal and county parks scattered throughout the area have an aggregate area of about 5,400 acres. Based upon permanent population figures and the accepted urban park standard of 10 acres per 1,000 inhabitants, it is estimated that an urban park deficiency of about 7,200 acres exists in this area.

50. It is estimated that an aggregate of over 130,000 persons annually use the summer recreational facilities in the upper Passaic area, and that the value of the recreation industry in this section is over $9,000,000 annually. Future increases in this activity are dependent upon the control of the mosquito nuisance and the further development of the water resources of the area for recreational purposes. A report on recreational resources of the area was prepared by the U. S. National Park Service and is contained in Appendix J.

51. Pollution. The problem of pollution of the Passaic River is not as serious a consideration today as it was formerly. This is due to the energetic control exercised by local authorities over the discharge of sewage and industrial waste into the stream. Until 1888, the Passaic River was used as a source of potable water supply for the cities of Newark and Jersey City, the point of intake being at Belleville. Population growth and increasing industrial activity through the years gradually changed the river from a clean and wholesome stream to virtually an open sewer. The heavy discharge into the river of domestic sewage, chemicals,

grease, oil and industrial waste soon exhausted the oxygen content of the water, destroyed all fish life and promoted a condition of menace to the public health. In 1902, the State Legislature enacted a law which forbade the discharge of untreated waste into the Passaic River from its mouth to Great Falls in Paterson. Many industrial plants installed treatment works for their effluents, and others changed their processes of manufacture so as to eliminate the discharge of wastes into the river. About twenty municipalities, tributary in whole or in part to the river in this section, organized the Passaic Valley Sewage District which undertook in 1907 to construct a main trunk sewer through Paterson and adjacent communities. Up to 1924 a total of $21,200,000 had been expended on this work. The communities now served are Newark, Belleville, Nutley, Passaic, Paterson, Clifton, Garfield, Rutherford, East Rutherford, Wallington, Lyndhurst, North Arlington, Kearny, Harrison, East Newark, Prospect Park, Haledon, Bloomfield, Glen Ridge, East Orange, Montclair and Orange. The sewerage system consists of a main trunk or intercepting sewer constructed along the west bank of the Passaic River from Great Falls to a pumping station on the Newark Meadows. Thence the sewage is pumped through mains under Newark Bay and across Bayonne to an outfall in upper New York Bay near Robbins Reef Light where the currents are sufficiently strong to diffuse the effluent. Before passing to the outfall the sewage is screened and a large portion of the solids is removed in settling basins. The system became fully operative in August, 1924. It has a capacity of 324 million gallons daily. Communities above Great Falls, those of East Paterson, Fairlawn and Hawthorne in the Lower Valley and those along the Saddle River, do not form part of the Passaic Valley Sewage District. These are dependent upon local treatment works which discharge their effluent directly into the river. Although a substantial degree of pollution abatement has been achieved by this sewerage system, residual pollution from the sections of the river not served by the

Passaic Valley Sewerage System and urban storm drainage, are sufficient to cause pollution of the lower reaches of the stream, particularly during the low flow period of the summer season. Even when a comparatively high minimum summer monthly average flow of 956 c.f.s. occurred, the dissolved oxygen content in the lower river fell as low as 2.0 p.p.m., less than 26 percent saturation. This quality of water is worse than the quality standard established for Newark Bay by the Interstate Sanitation Commission, namely a dissolved oxygen content of 30 percent saturation. It is considered that the quality of the water in the Passaic River should approach that required for Newark Bay. A report on the quality of water in the lower Passaic River was prepared by the U. S. Public Health Service and is contained in Appendix J.

52. Mosquito Control. The mosquito nuisance in the Passaic watershed is intimately related to the local water resources problem, and is an important factor controlling the value of property and the economic security of the inhabitants in the lower Highland Area and Central Basin. The growth of population in this area, under the impetus afforded by improved transportation facilities and the growing summer recreation industry which provides the major source of income to many of the permanent residents, make this problem more pressing of solution every year. The bulk of flight mosquitoes affecting the Passaic area are fresh-water species which breed in the Great Meadow and Great Swamp areas along the Passaic River from Little Falls to above Millington. Included in these species are those which transmit malaria to man, heartworm to dogs, meningitis to horses and fowlpox to chickens. The breeding season generally extends from May through September. The two prevailing mosquito types are those which breed upon or in close contact with stagnant water surfaces (principally culex and anopheles) and those which deposit their eggs on higher ground and await a period of inundation for incubation (principally aedes). Mosquitoes of the first type breed independently of

flood occurrences, but because of their short flight vector (1 to 2.5 miles) and their susceptibility to ordinary methods of control, they do not achieve great importance as pests. The second type accumulates in the ova stage above water level over periods of months or even years awaiting favorable conditions for further development. After periods of moderately prolonged rainfall, when the main stream and lower tributary channels above Little Falls become inadequate to carry off the runoff, extensive flooding over the lowlands occurs. Wherever such floods remain above normal level for eight days or more during the mosquito breeding season when temperatures are moderately high, vast swarms of adult mosquitoes are matured which circulate within a 10-mile radius of the incubation area and affect a population of over 1,500,000 in Essex, Union, Morris and Passaic Counties. These flood-nurtured mosquitoes live from three to five weeks, during which period little can be done to effect their control. When they finally disappear, ordinary local control of endemic varieties again becomes effective. Mosquito producing floods occur on the average of twice each year. Of particular severity in this respect were the floods of July 1935, July 1936, July 1938, and July 1945. Mosquito traps operated in Pine Brook and West Caldwell by the Morris County Mosquito Extermination Commission show the effect of these floods. The daily average count of all species of mosquitoes at Pine Brook for the period of June 1938 prior to the flood was 218; this increased fourfold to 830 during the month following the flood. Similarly at West Caldwell the flood of 1945 caused an increase from 122 to 500 in the daily average count. For the entire period of record at Pine Brook (1938-1942) the average daily count from June through September was 235. This indicates severe and continuous annoyance during the summer months.

53. Aside from the acute discomfort suffered by the inhabitants of this area from mosquito prevalence, the population is continually subjected to a serious health menace. The records for Pine Brook and West Caldwell

show that up to 10 percent of the mosquitoes are of the anopheline or malarial transmitting type. This number, which increases materially in close proximity to the swamps, is sufficient to start an epidemic under suitable conditions of contact with a malarial source. A further consideration, of great economic consequence, is the depressing influence exercised over real estate values by the mosquito nuisance. Real estate immediately adjacent to the lowlands is valued at from 50 to 70 percent of equivalent property situated beyond the mosquito flight vector. It has been estimated that the recoverable values in real estate alone, following a release from the mosquito nuisance, would amount to over $12,000,000 in the Passaic area. Prospective benefits to business in general and to the recreation industry in particular would be considerably greater than this. It is estimated by the Morris County Mosquito Extermination Commission that the benefits of mosquito control in the Passaic Valley, based upon costs of house screening and mosquito repellants, damage to business and a small nuisance factor, would be $2,900,000 annually. Actual expenditures by local interests for mosquito control in the Passaic Valley, from 1931 to 1946 inclusive, are estimated at $400,000 or about $27,000 annually. Since a large measure of mosquito prevalence is due to floods, the foregoing figures may be construed as an indirect flood damage.

54. To combat the mosquito menace, seven of the eight counties within the Passaic watershed have active mosquito extermination commissions which are invested with powers to trespass on private property and undertake action for the protection of the public health. Mosquito control work is under the authority of the State Board of Health and of the New Jersey State Agricultural Experiment Station. The methods employed include drainage and spraying, the former being considered most efficacious by authorities on the subject. Numerous attempts at drainage have been undertaken with local funds in the past, and much work has been done by the Works Progress Administration and Civilian Conservation Corps in clearing channels

and excavating ditches. A four-county mosquito extermination committee has formulated plans for the improvement of the upper Passaic River above Two Bridges, and some of the work under these plans has been performed.

55. Wild Life Conservation. The problem of wild life conservation is probably of greater relative importance in the Passaic area than in any other watershed in the Northeast. The Troy Meadows and adjacent marsh areas, comprising in all several thousand acres, are one of the most important and desirable fresh-water marsh habitats existing for wild life on the Atlantic Coast between tidewater and the Appalachian Mountains. The U. S. Fish and Wildlife Service considers that within the Great Piece and Troy Meadow areas "are some of the finest and most productive fresh-water swamps in the Northeast. They provide hunting for waterfowl, upland game, and big game for residents of northeastern New Jersey, and attract numerous sportsmen from the New York City area. These marshes have more than a local significance. They are of considerable importance with respect to the continental waterfowl population. Black ducks, wood ducks, blue-winged teals and mallards use the areas to rear their young and the marshes are important resting and feeding areas for migratory ducks of the Atlantic flyway. Pintails rest and feed in these meadows in large numbers during the early spring, and as many as 500,000 ducks of several species have been observed in the area at one time. In addition to the considerable utilization of the area by ducks, there is a heavy population of fur-bearing animals which are an important resource to trappers and landowners. Troy Meadows were formerly one of the outstanding snipe-shooting grounds in the east, and rails and woodcocks are numerous in many areas. The reported annual harvest of pheasants and deer in the area is high for that section of New Jersey". In the conservation of wild life, public opinion and sentiment are considered of greater consequence than is indicated by the monetary factors involved. As expressed by the U. S. Bureau of Biological Survey, "A wildlife refuge can hardly be evaluated in monetary terms. Its

convenient location makes it the principal outdoor wildlife laboratory for study by such large national organizations as the Linnaean Society, the National Association of Audubon Societies, the Isaac Walton League, and others from whom this Bureau has received protests over a period of several years against the disturbance of the natural conditions in Troy Meadows by flood control measures. Besides these, similar protests have been received from such State agencies and organizations as the New Jersey Board of Fish and Game Commissioners, Consolidated Sportsmen's Clubs of New Jersey, and many private citizens of the State interested in the preservation of this natural area. In addition to its value to the nation and to the State of New Jersey as a wildlife habitat, this tract is a haven for song and insectivorous birds and is visited often by local nature study groups. Moreover, it serves as a refuge for upland game birds and is of tremendous interest to local sportsmen". A report on fish and wild life in the Central Basin was prepared by the Fish and Wildlife Service, Department of the Interior and is included in Appendix J.

VI. CLIMATOLOGY

56. Climate. The climate of the Passaic area is moderate. The winters are mild with light snowfalls and with temperatures seldom sustained below freezing for more than a week at a time. The summers are long with occasional hot sultry weather and frequent thunderstorms. In the Central Basin and Lower Valley the air is relatively moist due to the proximity of the ocean, while in the Highland Area, on the southerly prong of the Catskill Mountains, the air is cooler and drier. The average annual temperature is 51 degrees, Fahrenheit, with extremes varying from 26° below zero in winter to 108° above zero in summer. The hours of sunshine are 60 percent of the total amount possible. The relative humidity is comparatively high, averaging about 70 percent. The average growing season is 169 days, decreasing with altitude. Prevailing winds are from

the northwest, shifting to the south and southwest during the summer. Additional climatological data are contained in Appendix B.

57. Rainfall Records. Precipitation data within and adjacent to the Passaic River watershed are available at 55 stations operated by the U. S. Weather Bureau and by local water-supply agencies. Of these, 39 are in operation at the present time. The location of these stations and their periods of record are shown on Figure B3, Appendix B. The longest continuous precipitation record available within the watershed is at Newark since 1843.

58. Annual Rainfall. The average annual precipitation over the watershed, is 47.8 inches. This precipitation is fairly uniform over the watershed, varying from 45.7 inches in the Lower Valley to 48.7 inches in the Highland Area (Figure B2, Appendix B). The maximum annual precipitation of record was 85.99 inches in 1882 at Paterson, and the minimum was 25.26 inches in 1930 at Morristown. The annual rainfall is fairly well distributed throughout the year, with a slight increase occurring in the summer months due to local thundershowers. The seasonal rainfall for the basin as a percent of the total rainfall is 24.5 in the spring (April-June), 29.3 in the summer (July-September), 22.9 in the fall (October-December) and 23.3 in the winter (January-March). Monthly extremes have varied from 25.98 inches in September 1882 at Paterson to 0.11 inches in October 1904 at Dover, N. J. The average annual snowfall over the basin is 35.8 inches, with a water equivalent of about four inches in depth. Further precipitation data are contained in Appendix B.

59. Storm Rainfall. The Passaic watershed lies at the southwesterly edge of the New England massif which juts into the ocean across the coastal storm paths and renders the area subject to frequent storm rainfalls of great intensity. The storms occurring over the Passaic River watershed may be classified as extra-tropical, hurricane, transcontinental and thunderstorm types. Extra-tropical storms are great summer and fall storms which

generally originate over the ocean to the southward and are precipitated by the sudden uprising of the moist tropical air masses in contact with hills and mountains or with colder air masses from the north and west. The storms of 1882, 1903 and 1945, were of this type. Of comparable magnitude are the hurricane or West Indian storms which draw their moisture from the Atlantic Ocean in low latitudes and strike northward most generally in the late summer and fall accompanied by violent winds and torrential rains. The storms of 1810, 1919 and 1938 were of this type. More moderate but of greater frequency are the transcontinental or cyclonic storms which originate in the West and Southwest usually in the spring and travel eastward. These storms are of widespread extent and of moderate intensity but occur frequently when the ground is frozen or covered with a blanket of snow and when flood runoff conditions are at their optimum. The storms of 1896, 1902 and 1936 were of this type. Thunderstorms largely occurring in the summer are of great intensity but of limited extent. They are flood producing mainly on the smaller tributaries. The storms of 1843 and 1865 over the watershed, and that of 1819 somewhat farther removed from the Passaic area were of this type. The storm of August 21, 1843 caused a precipitation of more than 9 inches over an area of about 200 square miles in the southern Passaic and northern Raritan watersheds with its center over Bound Brook, N. J. where about 12 inches of rain fell within a period of 12 to 14 hours. The storm of July 26, 1819 occurred over an area of about 50 square miles near Catskill, N. Y., and caused a maximum precipitation of 18 inches within 7.5 hours, of which about 10 inches was reported to have occurred within an hour.

60. Past Storms. A summary of the most notable storms of record over the Passaic River watershed is given in Table VIII. Comparable data for the Northeastern States are given in Table B6, Appendix B. A study of these storms indicates that any of these are as likely to center over the Lower Valley as over the Central Basin or the Highland Area.

TABLE VIII

LARGE STORMS OVER PASSAIC RIVER WATERSHED, N. J.

Period of Rainfall	Location of Max. Rainfall in Watershed	Type of Storm	Max. Storm Rainfall in Watershed (inches)	Average Rainfall over Watershed (inches)
22-24 Nov. 1810	--	Hurricane	--	8 a
21 Aug. 1843	--	Thunderstorm	--	9 a
16-17 July 1865	--	Thunderstorm	--	6 a
20-24 Sept. 1882	Paterson	Extra-Tropical	17.90	9.2
3-7 Feb. 1896	Charlotteburg	Transcontinental	5.61	4.4
25 Feb.-3 Mar. 1902	Ringwood	Transcontinental	3.46	2.6
7-12 Oct. 1903	Paterson	Extra-Tropical	15.51	11.4
19-23 July 1919	Boonton	Hurricane	12.97	7.8
11-22 Mar. 1936	Milton	Transcontinental	8.95	6.0
16-23 Sept. 1938	Chatham	Hurricane	9.73	7.0
15-23 July 1945	Midland Park	Extra-Tropical	14.73	8.5

a. Estimated

61. Standard Project Rainfall. The standard project rainfall for the Passaic watershed is defined as that which would result if the worst storm of record over the Northeastern States, corrected for elevation and moisture content, were to center over the watershed. The standard project rainfall is utilized in computing the standard project flood (paragraph 74). The derivation of this rainfall is contained in Appendix B. The standard project rainfall over the Passaic watershed for areas of 10 to 900 square miles for periods of 3 to 48 hours, is given in Table IX.

TABLE IX

STANDARD PROJECT RAINFALL, PASSAIC RIVER WATERSHED, N. J.

Area (sq.mi.)	Accumulated Depth of Rainfall (inches)						
	3 Hr.	6 Hr.	12 Hr.	18 Hr.	24 Hr.	36 Hr.	48 Hr.
10	9.8	13.4	17.0	17.6	17.8	--	--
50	8.8	11.9	15.5	16.8	17.3	--	--
100	7.8	10.5	13.7	15.5	16.6	--	--
200	6.4	8.7	11.6	13.7	15.1	16.1	--
500	4.2	6.1	8.8	10.9	12.5	14.6	15.5
900	2.6	4.3	7.1	9.5	11.5	13.9	14.9

62. Maximum Probable Rainfall. The maximum probable rainfall is defined as that which would result from a storm occurring over the Passaic area under the worst possible combination of meteorological and hydrologic conditions. The maximum probable rainfall is used to derive the maximum probable flood (paragraph 76). The maximum probable rainfall for the Passaic River watershed is given in Table X. Other data and details on the development of the maximum probable storm are given in Appendix B.

TABLE X

MAXIMUM PROBABLE RAINFALL, PASSAIC RIVER WATERSHED, N. J.

Area (sq.mi.)	Accumulated Depth of Rainfall (inches)						
	3 Hr.	6 Hr.	12 Hr.	18 Hr.	24 Hr.	36 Hr.	48 Hr.
10	19.5	23.5	28.2	29.0	29.3	--	--
50	17.5	21.5	25.9	26.7	27.0	--	--
100	15.4	19.6	23.3	24.3	24.6	--	--
200	12.8	17.0	20.2	21.1	21.5	21.9	--
500	9.0	13.0	16.0	17.2	17.9	18.6	18.9
900	6.4	9.6	12.4	14.0	15.0	16.4	17.1

VII. - RUNOFF AND STREAM FLOW DATA

63. Runoff Records. Stream flow data within the Passaic River watershed are available at 22 gaging stations operated by the U. S. Geological Survey and by local water supply agencies. Of these, 19 are in operation at the present time. In addition, 23 temporary staff gages and four automatic river stage recorders were operated by this office on the Passaic River and its tributaries during 1938-1939 for purposes of this report. The locations of these stations together with periods of observation are shown on Figure 53, Appendix B. Practically continuous records of stream flow are available for the Passaic River at Paterson from 1877 to date. No stream gaging records are available for many of the smaller tributaries on which flood conditions are known to exist.

64. Normal Runoff. The average annual runoff at Paterson (drainage area 785 sq. mi.) is 1.56 c.f.s. per square mile equivalent to about 21.2 inches depth over the total watershed area. This does not include 0.31 c.f.s. per square mile, equivalent to about 4.2 inches of runoff, diverted from the upper tributary areas for water supply purposes. The total average annual runoff of 25.4 inches at Paterson is equal to about 53 percent of the average annual rainfall. A summary of comparative runoff data is given in Table XI. Additional runoff data are contained in Tables B10 and B11, Appendix B.

VIII. - FLOODS OF RECORD

65. Flood Characteristics. Although the Passaic area is subject to relatively intense rainfalls, the overall characteristics of the watershed are not favorable to the occurrence of extremely large floods. Despite this condition, heavy flood damages frequently recur, due to the extensive urban development of the flood plain and its effect in seriously

TABLE XI

COMPARATIVE RUNOFF DATA

PASSAIC RIVER WATERSHED, N. J.

(Corrected for water supply diversions and storage)

Stream	Locality	Drainage Area (sq. mi.)	Period of Record Considered	Average Observed Runoff (cfs per sq. mi.)						Average Runoff for Period (cfs per sq. mi.)
				Daily		Monthly		Annual		
				Max.	Min.	Max.	Min.	Max.	Min.	
Passaic R.	Paterson	785.0	1897-1945	35.7	0.00	9.30	0.113	3.71	0.966	1.86
Passaic R.	Chatham	100.0	1903-1911	29.6	0.020	13.88	0.046	3.45	1.062	1.98
Rockaway R.	Boonton	119.0	1906-1945	29.4	0.00	9.17	0.139	3.35	1.01	1.83
Whippany R.	Morristown	29.4	1921-1945	35.0	0.143	7.31	0.251	2.86	0.912	1.66
Pompton R.	Pompton Plains	355.0	1940-1945	79.8	0.132	5.01	0.115	2.57	1.38	1.63
Pequannock R.	Macopin Dam	63.7	1922-1945	33.4	0.00	10.38	0.005	3.09	0.904	1.88
Wanaque R.	Wanaque Dam	90.4	1919-1945	40.2	0.035	9.86	0.009	2.66	0.887	1.73
Ramapo R.	Pompton Lakes	160.0	1921-1944	65.9	0.00	10.40	0.108	2.98	0.900	1.77
Ramapo R.	Mahwah	118.0	1922-1944	56.2	0.068	9.75	0.116	2.86	1.03	1.78
Saddle R.	Lodi	54.6	1923-1944	31.5	0.110	5.92	0.206	2.73	0.947	1.62

reducing the safe discharge capacity of the river. The main stem of the Passaic above Chatham is little affected by floods, partly because of its long, narrow watershed, and partly because of the moderating effect exercised by Great Swamp upon the flow of the stream below Millington. The Whippany River, and to a lesser extent, the Rockaway, have marked peaking characteristics in their upper reaches but in their lower reaches a high degree of natural valley storage in the Black and Troy Meadow areas materially reduces the flood peaks on these streams. During the 1903 flood, the natural storage in this section amounted to 2.4 runoff-inches (drainage area 205 square miles) and the flood peak at the mouth of the Rockaway River was reduced thereby to about 53 percent of its value upstream. The Pompton River, carrying the combined flow of the Pequannock, the Wanaque and the Ramapo Rivers, contributes the principal component of flow to the flood peak in the lower river. The three Pompton tributaries are only slightly desynchronized in the timing of their flood peaks, and the limited valley storage above Mountain View, amounting to about 1.4 runoff-inches (from a drainage of 377.3 square miles) during the 1903 flood, tends to reduce this desynchronization without materially increasing the flood peaks. The Wanaque River, which for its size is the flashiest stream in the Passaic watershed, delivers its flood peak several hours before the Pequannock and Ramapo. Although the lower section of the Pequannock below the Macopin Dam is equally flashy, the peak on this stream is considerably reduced by the relatively flat gradient of the upper watershed. The Ramapo, which contributes the largest volume of flood flow to the Pompton, has the longest period of rise.

66. All of the foregoing streams discharge into the Great Meadow area above Little Falls. The bottom lands in this section act as a natural detention reservoir in reducing flood intensities downstream. Generally the Pompton River contributes the preponderant flood inflow to the Great

Meadow area, filling the available storage space at a faster rate than can be discharged at Little Falls, and for a period of 6 to 8 hours causing the flood waters to flow upstream in the lower reaches of the Rockaway, Whippany and upper Passaic Rivers. The Great Meadow area floods on an average twice each year. During the larger floods, inundation extends over an area of nearly 35 square miles affording a storage capacity of about 20,000 acre feet (0.5 runoff-inch) for each foot of rise over the meadowlands. Due to the progress of the flood wave downstream, the maximum depth of flooding over the meadows does not occur simultaneously throughout the area, and therefore the volume under the maximum flow line is somewhat greater than the actual volume of flow retained at any given time. During the 1903 flood, the volume beneath the maximum flood level in the Great Meadow area was about 146,000 acre feet, equivalent to a depth of about 3.6 inches over the 762.2 square miles of watershed above Little Falls. The maximum volume of water retained over the meadows at any one time during this flood is estimated at 2.29 runoff-inches (93,000 acre feet), or 35 percent of the total flood runoff at Little Falls. Had the Great Meadows not been available for flood detention, it is estimated that the 1903 flood peak at Paterson would have been nearly 55 percent greater than actually occurred, and the flood damages inflicted thereby would have been almost doubled. It is clear, therefore, that the future security of this valley against catastrophic floods is entirely dependent upon the assurance that the Great Meadows will continue in the future as in the past to be available for the storage of excess runoff during periods of unusual flood.

67. Due to desynchronization of the flood crests in the upper watershed, the amount that each tributary contributes to the flood peak at Paterson, is not proportional to the individual peaking characteristics given below. Actually the proportions vary with every flood depending upon the direction of travel and the location of the center of the storm,

For the 1903 flood, flow computations indicate that the separate components of flow in the peak at Paterson are approximately as follows: main stem, 8 percent; Rockaway, 10 percent; Whippany, 7 percent; Ramapo, 31 percent; Pequannock, 16 percent; Wanaque, 24 percent; and the main stem of the Pompton, 4 percent. From these data, it follows that in the 1903 flood peak at Paterson, the Pompton watershed (378.1 square miles) contributed 75 percent of the flow, and the remaining area above Paterson (406.9 square miles) contributed only 25 percent.

68. The tributaries of the Lower Valley, which are distributed along the entire length of the main stem, are short, flashy streams controlling relatively small steep drainage areas. These streams peak much earlier than the main stream and are capable of producing a flood peak on the main stem independent of that produced by the upper valley. The peak from the lower tributaries may be greater or smaller than that from the upper valley depending upon whether the storm is centered over the upper or lower portions of the watershed. In either case the peak from the Lower Valley is sharp and of short duration, while that from the upper watershed is rounded and of long duration. Flood stages on the main stem below Dundee Dam are affected by the tides from Newark Bay.

69. The relative peaking characteristics of each of the principal tributaries in the Passaic basin are given in Table XII. These data represent in each case the flood which would result from a rain excess of 1 inch in 12 hours for major tributaries, and a rain excess of 1 inch in 6 hours for the minor tributaries.

70. The effects of existing water-supply reservoirs upon flood discharges at Paterson are almost negligible, except for lesser floods of long duration and uniform intensity which are wholly or largely retained in the reservoirs. Farther upstream the reservoir effects are somewhat more marked. There are several reasons why the water-supply reservoirs in the Passaic area have little influence over larger floods

TABLE XII

COMPARATIVE FLOODS RESULTING FROM RAIN EXCESS OF 1 INCH,

PASSAIC RIVER WATERSHED, N. J.

Stream	Locality	Drainage Area (sq.mi.)	Peak Discharge		Relative Peaking Characteristic K^b	Period of Rise (hours)	Flood Duration (days)
			c.f.s.	c.f.s. per sq.mi.			
	MAJOR TRIBUTARIES (RAIN EXCESS 1 INCH IN 12 HOURS)						
Passaic R.	Millington	55.4	415	7.5	56	34.0	8.0
Passaic R.	Chatham	100.0	1238	12.4	124	15.0	6.5
Rockaway R.	Above Boonton	116.0	1688	14.5	157	25.5	4.7
Whippany R.	Morristown	29.4	825	28.0	152	20.0	4.0
Ramapo R.	Pompton Lakes	160.0	2270	14.2	179	28.0	5.5
Wanaque R.[a]	Wanaque	90.4	2023	22.4	213	12.0	6.0
Pequannock R.	Macopin Dam	63.7	825	13.0	103	16.0	6.0
Saddle R.	Lodi	54.6	1222	22.4	165	28.0	5.0
	MINOR TRIBUTARIES (RAIN EXCESS 1 INCH IN 6 HOURS)						
Weasel Brook	Passaic	7.1	495	69.7	186	8.7	2.0
Hohokus Creek	Paramus	19.4	585	30.1	133	13.0	3.1
Diamond Brook	Fairlawn	3.1	245	78.5	139	8.1	2.0
Goffle Brook	Hawthorne	8.9	538	60.2	180	9.7	2.0
Molly Ann's Brook	Paterson	8.6	536	62.0	182	9.5	2.0
Peckman River	W. Paterson	9.8	635	65.0	204	9.6	2.0
Singac Brook	Wayne Twp	11.5	622	54.1	183	10.4	2.0

a. Natural condition of watershed without Wanaque Reservoir.
b. Coefficient in formula $Q = K\sqrt{A}$ where Q is discharge (c.f.s.) and A is drainage area (sq. mi.).

in the Lower Valley. Both the Rockaway River above Boonton Reservoir and the Pequannock River above Macopin Dam are definitely out of phase with the main stem and hence have little effect on its peak. On the Pequannock, such contributions as are received in the peak are derived almost exclusively from the flashy section of the watershed below Macopin Dam. In the case of the Wanaque, somewhat different conditions govern. This reservoir is operated primarily for water supply purposes, and to insure adequate supplies and to obtain the necessary head to deliver gravity supplies through the distribution system, the reservoir is kept as nearly full as possible. Storage is necessarily repleted from the earliest runoif, and in consequence when a flood finally occurs, only the surcharge above spillway crest is ordinarily available for flood retention. Furthermore, in order to discourage plant and algae growth around the reservoir the water surface in the reservoir is maintained at as nearly a constant level as conditions of draft permit. Hence a flood surcharge is undesirable, and excess flood waters are therefore passed downstream as rapidly as possible. Such storage effects as are exercised by the Wanaque Reservoir retard the time of peak on the Wanaque River by several hours and increase the synchronization of this stream with the Pequannock and Ramapo. Under these conditions any reduction in flood discharge which may be effected on the Wanaque is largely offset by a change in the time of its peak. Inasmuch as the present system of operation cannot be modified, with a view to providing incidental flood control, without seriously jeopardizing the minimum assured water supply yield of the system, it is not anticipated that the flood conditions below these reservoirs in the future will be materially different from those in the past.

71. Flood Discharges. The peak discharges which have occurred during the ten worst known floods on the Passaic River are summarized in Table XIII. These data are based partly upon stream flow observations and

TABLE XIII

MAXIMUM FLOOD DISCHARGES, PASSAIC RIVER WATERSHED, N.J.

Stream and Locality	Drainage Area (sq.mi.)	Estimated Peak Discharge (c.f.s.) Present Condition of Watershed									
		7-12 Oct. 1903 1	22-24 Nov. 1810 2	16-17 July 1865 3	25 Feb. 3 Mar. 1902 4	15-23 July 1945 5	11-22 March 1936 6	20-24 Sept. 1882 7	3-7 Feb. 1896 8	Dec. 1878 9	Feb. 1886 10
Passaic River											
Dundee Dam	809.9	35,800	-	-	24,000	22,300	19,700	-	-	-	-
S.U.M. Dam	785.0	33,700	27,000[a]	22,500	22,500	19,500[a]	19,400[a]	18,260	17,220	16,590	12,450
Beatties Dam	762.2	32,700	-	-	21,200	16,000	19,100	-	-	-	-
Chatham	100.0	5,150	-	-	-	890	2,050	-	-	-	-
Pompton River at Mountain View	377.3	34,000	-	-	17,900	11,400	17,700	16,000	13,900	-	18,500
Pequannock River at Pompton	84.7	6,830	-	-	4,600	-	-	4,460	5,500	-	-
Ramapo River at Pompton Lakes	160.0	15,800	-	-	7,050	8,581[a]	12,300[a]	10,500	8,730	-	12,000
Rockaway River below Boonton Reservoir	119.0	9,500[bd]	-	-	4,590[ab]	1,280[a]	3,770[a]	4,850[ab]	5,500[ab]	-	-
Wanaque River at Pompton	108.1	14,100	-	-	5,090	-	-	5,600	6,110	-	-
Whippany River at Morristown	29.4	3,200	-	-	2,100	366	1,500	-	2,600	-	-
Weasel Brook at mouth	7.1	1,830	-	-	-	780	-	-	-	-	-
Saddle River at Lodi	54.6	7,000	-	-	4,500	3,500[a]	2,200[a]	-	-	-	-
Hohokus Creek at mouth	19.4	3,000	-	-	-	1,700	-	-	-	-	-
Diamond Brook at mouth	3.1	880	-	-	-	480	-	-	-	-	-
Goffle Brook at mouth	8.9	2,200	-	-	-	1,180	-	-	-	-	-
Molly Ann's Brook at mouth	8.6	2,180	-	-	-	1,120	-	-	-	-	-
Slippery Rock Brook at mouth	0.9	307	-	-	-	1,550[c]	-	-	-	-	-
Peckman River at mouth	9.8	2,190	-	-	-	1,550	-	-	-	-	-
Singac Brook at mouth	1.5	2,780	-	-	-	1,520	-	-	-	-	-
Volume of Runoff in inches at S.U.M. Dam		6.29	-	-	5.20	4.96	5.99	3.77	3.18	-	-

a. Observed

b. Not corrected to present conditions of storage and diversion.

c. Due to dam failure, discharge under normal conditions 245 c.f.s.

d. Observed average maximum daily discharge, equal to 7560 c.f.s.

partly upon computations from flood marks and collateral information. In general, the 1903 flood discharges were the maximum of record at all localities in the watershed. Additional data are given in Appendix B.

72. Flood Stages. Peak flood stages, corrected to suit present conditions of the watershed, for the October 1903, March 1936 and July 1945 floods, are given in Table XIV.

TABLE XIV

FLOOD STAGES, PASSAIC RIVER WATERSHED, N. J.

Location	Flood Elevation (ft., m.s.l.)		
	7-12 Oct. 1903	15-23 July 1945	9-22 Mar. 1936
Passaic River			
Gregory Avenue Bridge, Passaic	17.7	11.6	10.9
Dundee Dam, Clifton	33.4	31.4	30.9
S.U.M. Dam, Paterson	124.6	122.05	121.04
Beatties Dam, Little Falls	169.1	164.1	165.2
Chatham	180.0	--	173.2
Pompton River at Boonton Road Bridge, Mountain View	174.3	168.9	170.5
Pequannock River at Macopin Intake	587.4	585.2	585.9
Ramapo River at Pompton Lakes	--	204.0	204.6
Rockaway River below Boonton Reservoir (U.S.G.S. gage)		200.7	203.7
Whippany River at Morristown	269.7	--	266.3
Weasel Brook at Monroe Street Bridge (u.s.)	26.4	21.4	--
Saddle River at Borig Place Bridge (u.s.)	38.2	34.4	25.4
Hohokus Creek at Grove Street Bridge (d.s.)	68.5	66.8	--
Diamond Brook at Oxford Avenue Bridge (d.s.)	74.0	72.0	--
Goffle Brook at Wagaraw Road Bridge (u.s.)	44.0	42.8	--
Molly Ann's Brook at Preakness Avenue Bridge (u.s.)	135.5	134.1	--
Slippery Rock Brook at Murray Avenue Bridge (u.s.)	131.7	130.5	--
Peckman River at East Main Street Bridge (u.s.)	157.2	156.3	--
Singac Brook at Preakness Avenue Bridge (u.s.)	203.0	202.4	--

(u.s.) - Upstream side (d.s.) - Downstream side.

73. Flood Frequencies. Computed flood stage and discharge frequencies for the main stream and tributaries, corrected to present conditions of flow and reservoir storage, are given in Tables XV and XVI. Method used for determination of the frequency data is contained in Appendix B.

TABLE XV

FLOOD STAGE FREQUENCIES, PRESENT CONDITIONS - PASSAIC RIVER WATERSHED, N. J.

Flood	Passaic River					Pompton River
	Wallington and Passaic	Clifton and East Paterson	Paterson and Hawthorne	Paterson and West Paterson	Singac and Wayne	Lincoln Park and Pompton Plains
	Stage (ft.,m.s.l.) At Gregory Ave. Bridge (mile 13.8)	Stage (ft.,m.s.l.) Above Crooks Ave.Bridge (mile 18.2)	Stage (ft.,m.s.l.) Above Straight St. Bridge (mile 24.1)	Stage (ft.,m.s.l.) Above Lincoln Ave. Bridge (mile 26.4)	Stage (ft.,m.s.l.) Above Route No.23 Bridge (mile 31.0)	Stage (ft.,m.s.l.) At D.L. & W. R.R. Bridge (mile 35.6)
Zero Damage	6.0	28.0	38.0	117.0	159.0	165.0
50% Frequency	6.1	28.8	38.7	120.2	163.9	168.5
20% Frequency	7.4	29.3	40.2	121.4	164.8	170.2
10% Frequency	8.7	29.9	41.7	122.3	165.9	172.8
5% Frequency	10.2	30.5	43.2	123.3	167.0	173.1
2% Frequency	12.4	32.4	46.5	125.4	168.5	175.0
Flood of October, 1903	17.7	33.6	48.5	128.0	171.1	178.0
Standard Project Flood	23.3	35.9	52.5	131.6	175.0	181.3
Maximum Probable Flood	31.3	39.0	58.3	136.2	178.8	188.0

TABLE XVI

FLOOD DISCHARGE FREQUENCIES, PASSAIC RIVER WATERSHED, N. J.

Stream and Locality	Drainage Area (sq. mi.)	Discharge (c.f.s.)									
		Frequency (percent chance of occurrence)								Floods	
		100	50	20	10	5	2	1	0.5	1903	1945
Passaic River at											
Dundee Dam, Clifton	809.9	7,000	9,400	12,700	15,800	19,200	24,600	29,500	34,900	35,800	22,300
S.U.M. Dam, Paterson	785.0	6,700	8,800	11,900	14,700	18,000	23,100	27,900	33,100	33,700	19,500
Beatties Dam, Little Falls	762.2	6,300	8,500	11,550	14,250	17,430	22,300	26,880	32,100	32,700	16,000
Chatham	100.0	1,040	1,470	2,120	2,600	3,050	3,650	4,000	4,400	5,150	890
Pompton River at Mountain View[a]	377.3	3,800	6,000	9,400	12,520	16,400	21,800	25,700	29,500	34,000	11,400
Rockaway River at Boonton	116.0	1,120	1,580	2,340	3,050	3,900	5,200	6,300	7,400	9,500	1,540
Whippany River at Morristown	29.4	590	800	1,170	1,500	1,900	2,500	3,000	3,500	3,200	366
Ramapo River at Pompton Lakes	160.0	2,300	3,500	5,500	7,350	9,450	12,600	14,700	16,800	15,800	8,581
Saddle River at Lodi	54.6	800	1,200	1,880	2,600	3,400	4,900	6,300	7,900	7,000	3,500
Saddle River above Hohokus Creek	23.3	420	620	950	1,300	1,710	2,450	3,150	4,000	3,550	1,850
Hohokus Creek at Mouth	19.4	360	530	820	1,120	1,500	2,150	2,800	3,600	3,000	1,700
Weasel Brook at Clifton	4.4	240	310	430	530	650	830	990	1,170	1,300	438
Diamond Brook at Mouth	3.1	180	230	325	400	490	620	740	860	880	480
Goffle Brook at Mouth	8.9	420	550	760	940	1,150	1,450	1,720	2,000	2,200	1,180
Molly Ann's Brook at Mouth	8.6	400	520	730	910	1,100	1,420	1,690	1,910	2,180	1,120
Slippery Rock Brook at Mouth	0.9	60	90	120	150	180	240	280	330	307	1,550[b]
Peckman River at Mouth	9.8	460	590	820	1,010	1,230	1,570	1,880	2,200	2,190	1,550
Singac Brook at Mouth	11.5	510	680	930	1,160	1,400	1,800	2,120	2,500	2,780	1,520

a. With Wanaque Reservoir

b. Due to dam failure. Discharge under normal condition 245 c.f.s.

IX. PROJECT FLOODS

74. Standard Project Flood. The standard project flood as developed for this report represents a flood that would be exceeded in magnitude only on rare occasions but which would normally be much less than the maximum probable flood (paragraph 76). This flood represents the standard for which protection works would be provided if designs were determined solely on the basis of the flood potentialities of the affected drainage area without regard to economic or other practicable limitations of the project. This flood was derived from the standard project rainfall (paragraph 61). The elements of the standard project flood are given in Table XVII. The standard project flood at Great Falls in Paterson is 50,850 cubic feet per second or about 1.5 times greater than the 1903 flood. This flood was derived on the premise that the Great Meadow area will function, as at present, as a natural flood detention basin. Additional data on the standard project flood are given in Appendices B and C.

75. Design Flood. Although the standard project flood represents the objective toward which the design of flood protection works is ordinarily directed, topographic and economic limitations may not permit the complete attainment of this objective. The flood against which protection is actually provided under any given plan, designated as the design flood, represents the maximum practicable degree of protection which can be provided, and is ordinarily less than the standard project flood. The design flood is discussed subsequently with each of the projects as presented.

76. Maximum Probable Flood. The maximum probable flood represents the largest flood which reasonably might occur in nature if the worst conditions of rainfall, ground saturation and storm position were to occur coincidentally. For purposes of this report, this flood is utilized primarily for design of dam spillways. The maximum probable flood to be expected within the Passaic River watershed was developed for the tributaries

TABLE XVII

STANDARD PROJECT FLOOD, PASSAIC RIVER WATERSHED, N.J.

Stream	Locality	Drainage Area (sq.mi.)	Maximum Floods of Record				Standard Project Flood at Each Locality[a]					
			July 1945 Peak Discharge		October 1903 Peak Discharge		Peak Discharge		Time of Peak (hours)	Rainfall (inches)	Runoff (inches)	K[b]
			c.f.s.	c.s.m.	c.f.s.	c.s.m.	c.f.s.	c.s.m.				
Passaic River	Dundee Dam	809.9	22,300	27.5	35,800[c]	44.2	50,900	62.8	70.0	15.06	8.94	1,790
Passaic River	S.U.M. Dam	785.0	19,500	24.8	33,700	42.9	50,850	64.7	68.0	15.08	9.00	1,815
Passaic River	Beatties Dam	762.2	16,000	21.0	32,700	42.9	50,800	66.6	66.0	15.10	9.06	1,842
Passaic River	Chatham	100.0	890	8.9	5,150	51.5	15,600	156.0	22.5	16.60	12.31	1,560
Pompton River	Feeder Dam[a]	353.8	12,000	33.9	36,000	101.8	50,700	143.3	39.0	15.76	9.39	2,700
Ramapo River	Pompton Lakes	160.0	8,581	53.6	15,800	98.8	27,700	173.1	39.0	16.25	11.39	2,190
Rockaway River	Boonton	116.0	1,540	13.3	9,500[d]	81.9	22,250	191.8	38.0	16.5	12.33	2,070
Whippany River	Morristown	29.4	366	12.4	3,200	108.8	13,100	445.6	26.0	17.62	14.57	2,420
Weasel Brook	Clifton	4.4	438	98.0	1,300	292.0	7,300	1,640	16.0	17.65	14.77	3,455
Saddle River	Paramus	23.3	1,850	79.4	3,550	152.0	12,600	541.0	22.5	17.75	14.34	2,620
Hohokus Creek	Paramus	19.4	1,700	87.5	3,000	154.0	10,700	550.0	22.5	17.8	14.37	2,425
Diamond Brook	Fairlawn	3.1	480	154.0	880	282.0	4,450	1,427	14.5	17.58	14.96	2,512
Goffle Brook	Hawthorne	8.9	1,180	132.0	2,200	246.0	9,420	1,052	19.0	17.75	14.74	3,150
Molly Ann's Brook	Paterson	8.6	1,120	130.0	2,160	252.0	10,300	1,190	17.0	17.75	14.75	3,160
Slippery Rock Brook	Paterson	0.9	245	269.0	307	338.0	1,950	2,140	14.0	18.00	15.58	2,055
Peckman River	West Paterson	9.8	1,550	159.0	2,190	224.0	10,000	1,023	19.5	17.68	14.74	3,200
Singac Brook	Wayne Twp.	11.5	1,520	132.0	2,780	242.0	12,500	1,088	18.5	17.8	14.8	3,690

a. Modified By Wanaque Reservoir
b. Coefficient in the equation $Q = K\sqrt{A}$, where Q is the flood peak in c.f.s. and A is the drainage area in square miles.
c. Observed peak discharges
d. Observed average maximum daily discharge - 7,560 c.f.s.

in the Highland Area or Lower Valley from the maximum possible rainfall in Table X applied to unit hydrographs obtained from gaging data observed during recent floods, or synthesized from topographic data in ungaged areas. For the Central Basin and main stem in the Lower Valley this flood was developed by flood routing. The elements of the maximum probable flood in the Passaic area, are listed in Table XVIII. The maximum probable flood discharge at S.U.M. Dam, (Great Falls) in Paterson was determined as 84,400 cubic feet per second, or about 2.5 times as great as the maximum flood of record (1903) observed to date. This figure is based upon the premise that the Great Meadow area will function, as at present, as a natural flood detention reservoir. Should this land be reclaimed from inundation, it is estimated that the maximum probable flood at Paterson would be increased thereby to 120,000 c.f.s. Additional data on the maximum probable flood under present conditions are given in Appendices B and C.

X. EXTENT AND CHARACTER OF FLOODED AREA

77. Passaic River and Major Tributaries. The territory subject to flooding along the main stem of the Passaic River, and its major tributaries, the Pompton, Ramapo, Rockaway and Whippany Rivers, lies in three well defined areas as follows:

a. A highly developed business, industrial and residential area in the Lower Valley from Newark to Little Falls.

b. A suburban area upstream therefrom, composed largely of scattered residential developments and summer bungalow colonies in the northerly portion of the Central Basin along the Passaic River from Little Falls to Two Bridges and along the lower reaches of the Pompton and Ramapo Rivers.

c. An agricultural and swamp area, sparsely developed with summer bungalows in 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.

TABLE XVIII

MAXIMUM PROBABLE FLOOD, PASSAIC RIVER WATERSHED, N. J.

Stream	Locality	Drainage Area (sq. mi.)	Maximum Probable Flood at Each Locality					
			Peak Discharge		Time of Peak (hours)	Rainfall (inches)	Runoff (inches)	K[a]
			c. f. s.	c. s.m.				
Passaic River	Dundee Dam	809.9	84,500	104.3	59.0	17.38	14.39	2,970
Passaic River	S. U. M. Dam	785.0	84,400	107.5	56.0	17.50	14.50	3,015
Passaic River	Beatties Dam	762.2	84,000	110.2	55.5	17.55	14.55	3,040
Passaic River	Chatham	100.0	29,000	290.0	21.0	24.58	23.04	2,900
Pompton River	Feeder Dam	353.8	95,000	268.5	37.5	20.00	17.68	5,050
Ramapo River	Pompton Lakes	160.0	49,050	306.6	39.0	22.77	20.87	3,880
Rockaway River	Boonton	116.0	40,000	344.8	31.5	24.08	22.46	3,710
Whippany River	Morristown	29.4	24,400	830.0	26.0	28.22	26.71	4,510
Weasel Brook	Clifton	4.4	15,800	3,560.0	16.5	29.72	28.34	7,500
Saddle River	Paramus	23.3	23,200	996.0	22.5	28.55	27.65	4,820
Hohokus Creek	Paramus	19.4	19,200	988.0	22.0	28.70	27.24	4,350
Diamond Brook	Fairlawn	3.1	8,200	2,630.0	12.5	29.80	28.49	4,650
Goffle Brook	Hawthorne	8.9	18,800	2,100.0	18.8	29.28	27.82	6,290
Molly Ann's Brook	Paterson	8.6	19,800	2,290.0	18.0	29.30	27.84	6,740
Slippery Rock Brook	Paterson	0.9	3,859	4,240.0	14.5	34.5	33.63	4,050
Peckman River	W. Paterson	9.8	20,500	2,100.0	20.0	29.22	27.76	6,560
Singac Brook	Wayne Twp.	11.5	23,900	2,080.0	18.5	29.20	27.69	7,050

a. Coefficient in the equation $Q = K A$ where Q is flood peak (c.f.s.) and A is drainage area (sq. mi.)

78. The most critical flood condition in the Passaic watershed occurs in the Lower Valley below Little Falls, where flooding occurs as a result of insufficient channel capacity (paragraph 19) and where the flood plain extends generally 500 to 1,000 feet beyond both banks of the river. The principal focal points of damage are the city of Paterson below Great Falls and the city of Passaic below Dundee Dam. Extensive losses which formerly were suffered in the section of the river below Passaic were relieved in a large measure by channel enlargement undertaken under the existing Federal navigation project. During a flood recurrence of 1903 magnitude approximately 3,000 acres of metropolitan area would be subject to inundation in this section, comprising parts of the urban centers of Paterson, Passaic and numerous other communities. In all there are 18 communities bordering this 21 mile reach of waterway having a total population of 433,000, and producing annually goods having an estimated value of $790,000,000, according to the 1939 Census of Manufactures.

79. The flood plain in the northerly portion of the Central Basin varies from one-half to three miles in width, and contains about 5,000 acres of land subject to flooding of which about 1,600 acres are swampland. The principal damage center immediately upstream of Little Falls is the village of Singac, the lower half of which would be completely inundated under a recurrence of a flood of 1903 magnitude. Farther upstream, the principal flood damage occurs along the Pompton River from Mountain View to Pompton Plains. In this section, comprising the communities of Lincoln Park, Wayne, Pequannock, Pompton and Pompton Plains, a heavy fringe of one-story summer cottages has been built along the low river banks practically in the bed of the stream. The slightest freshet inundates these properties, and a flood of 1903 magnitude would cover them to depths of 10 to 14 feet. Such a flood, occurring in the late summer when occupancy is nearly at a maximum, might cause great loss of life. Such a flood, occurring at any

season of the year, might dislodge hundreds of cottages from their foundations and carry them to the lower river where numerous debris dams could form and tremendous damages result. This condition in the Pompton area, therefore, is more than a flood problem in itself; it is an acute flood menace endangering the security of the entire Lower Valley. Elsewhere in the Pompton area, considerable sections of bottom lands well within the flood plain have been subdivided by real estate interests with a view to the development of residential communities, but flood inundation has retarded the exploitation of these lands and tied up the funds invested therein. Most noteworthy in this category is the wide expanse of bottom land in lower Wayne on the left bank of the Pompton River upstream of Mountain View where an extensive street system has been laid out and a number of houses already erected despite the fact that the area was inundated to depths of 8 to 10 feet during the 1903 flood. Under a continuance of existing conditions this area probably will ultimately be developed in spite of the flood menace, and the property sold to unsuspecting individuals who will discover too late that their community is another flood-problem area which will require protection. Certain other sections of the flood plain, particularly in Pompton Plains, have already been developed as high-grade residential communities which suffer relatively frequent flood losses.

80. The flood plain in the upstream or southerly portion of the Central Basin extends for a width of from one to two miles over adjacent swamp and lowlands between Two Bridges and East Hanover, a distance of 15 miles. Above East Hanover, the flood plain becomes narrower varying from 1,000 to 4,000 feet in width. About 27,000 acres of which 18,000 are swampland, are inundated in this area, a condition largely responsible for the mosquito problem in the Passaic area.

81. Minor Tributaries. The areas flooded on minor tributaries which entex the Passaic River below Two Bridges are shown on Figure G2,

Appendix G. The flood plains of these streams are generally narrow, and flood damage results more from scour than from inundation. Several exceptions, however, occur. For example, the Saddle River flood plain is about a thousand feet wide and increases to as much as a mile in width over lowland areas in the vicinity of Rochelle Park and Paramus. At the latter locality the Hohokus Creek flood plain widens to more than a thousand feet above its junction with the Saddle River. The flood areas of Molly Ann's Brook, Peckman River and Singac Brook widen to as much as 3,000 feet near the mouths of the streams where they are affected by backwater from the Passaic River. The character of the flooded areas varies widely. Portions of Weasel Brook, Saddle River, Goffle Brook and Molly Ann's Brook traverse scattered industrial and commercial developments. Urban communities and moderately developed residential areas are located elsewhere along portions of Weasel Brook, and on Molly Ann's Brook, Slippery Rock Brook and Peckman River. High grade suburban communities are located along sections of Saddle River, Hohokus Creek, and Diamond Brook. A portion of Goffle Brook traverses a landscaped park. Open farm lands and undeveloped lands are located along a large portion of the flood plain of Peckman River and Singac Brook. In total, approximately 3,800 acres are inundated by flooding on the smaller tributaries of which much is intensively developed suburban property.

82. Flooded Areas. The areas inundated during the 1903 flood in the Passaic Valley (Figure G2, Appendix G), together with the maximum depths of flooding, are given in Table XIX.

TABLE XIX

AREAS INUNDATED DURING 1903 FLOOD IN PASSAIC AREA, N. J.

Stream	Locality	Maximum Depth of Flooding (feet)	Area Inundated			Swamp Area Included in Foregoing (acres)
			Right Bank	Left Bank	Total	
Passaic R.	Mouth to Dundee Dam	14.5	620	909	1,529	-
Passaic R.	Dundee Dam to Great Falls	9.9	386	460	846	-
Passaic R.	Great Falls to Little Falls	10.2	323	438	761	-
Passaic R.	Little Falls to Two Bridges	11.1	384	1,180	1,564	538
Passaic R.	Two Bridges to Chatham	14.2	7,250	8,850	16,100	11,240
Passaic R.	Above Chatham	12.0	-	-	11,000	6,500
Pompton R.	Two Bridges to Pompton Lakes	14.5	2,122	1,078	3,200	1,022
Total		-	-	-	35,000	19,300

Within the 1903 flood area at the present time there are about 9,500 dwellings, 2,600 business establishments, 180 industrial plants and 160 utility plants and public institutions. Similarly, during the 1936 flood there were inundated, in whole or in part, 1,500 dwellings, 600 business establishments, 25 industrial plants and 20 utility plants.

83. Value of Flooded Area. The 1946 assessed valuation of all improved private property below 1903 flood levels is $71,702,000. A breakdown of these valuations by streams is given in Table G3, Appendix G. The 1948 true value of improved real estate in the 1903 inundated area is $195,000,000 (Table XX). Of this total, $156,200,000 or 80.1 percent is concentrated below Little Falls. If allowance is made for railroads, highways, bridges, utilities, industrial equipment, supplies and personal property not included in the foregoing local grand list figures, the total value of all property subject to flood damage at about 1903 flood levels is estimated at $300,000,000.

TABLE XX

REAL VALUE OF PROPERTY INUNDATED,

PASSAIC RIVER WATERSHED, N. J.

Stream	Real Value
Passaic River	
Mouth to Dundee Dam	$ 63,700,000
Dundee Dam to S. U. M. Dam	46,300,000
S.U.M. Dam to Beatties Dam	15,625,000
Beatties Dam to Two Bridges	7,875,000
Upstream from Two Bridges	11,500,000
Tributaries	
Pompton River	11,167,000
Ramapo River	930,000
Rockaway River	1,865,000
Whippany River	1,445,000
Weasel Brook	6,132,000 [b]
Saddle River	12,659,000
Hohokus Creek	4,831,000
Diamond Brook	2,250,000
Goffle Brook	1,518,000
Molly Ann's Brook	3,155,000 [b]
Slippery Rock Brook	1,475,000
Peckman River	1,620,000 [b]
Singac Brook	1,007,000 [b]
Total - Passaic River Watershed	$195,054,000 [a]

a. If the figure included value of railroads highways, bridges, utilities, industrial equipment, supplies and personal property it would equal $300,000,000.

b. Value of property affected by backwater in lower reach of stream included in Passaic River valuations.

84. Flood Conditions. Flood conditions within the Passaic Valley, particularly on the main stem below Two Bridges and on its major tributaries are best exemplified by the October 1903 flood which was the highest of record on this stream. Earlier floods, particularly prior to 1865, did not cause material damage because of the relatively unimproved condition of the valley. The 1903 flood resulted from a 3-day rain which caused the Passaic to overflow its banks on October 8th, and to remain in flood until October 19th. The extended period of inundation, which is characteristic of the lower river, was in a large measure responsible for the extensive damage inflicted by this flood. In the headwater regions, where the runoff was flashy, damage was particularly severe on the Ramapo River. Nearly every bridge and dam on this stream was washed away, and widespread destruction was visited upon every settlement in the flood plain. On the Pequannock and Wanaque Rivers, where almost all ponds and reservoirs were full at the commencement of the flood, heavy damage was inflicted upon highways and bridges. Damage was also severe in Wayne Township. In the Great Meadow area, barns and crops were swept away, livestock was drowned, and an area of nearly 20,000 acres was inundated. Lower Singac was under 10 feet of water and the Erie Railroad tracks on the Greenwood Lake Division were washed out. Damage during this flood at the Little Falls pumping station was not as severe as during the flood of March 1902, when ice conditions caused the water to rise several feet over the floor of the plant, stopping all operations and damaging the equipment. In 1903, a number of manufacturing plants were inundated in Little Falls, and two cemeteries were badly gutted. The city of Paterson suffered the worst effects of the flood, nearly 200 acres of highly developed industrial and residential area being inundated up to depths of 10 feet. Over 10 miles of city streets were rendered impassable, and over 1,200 persons temporarily had to abandon their homes. Foundations were undermined and several houses collapsed. The West Broadway Bridge, the first below

Great Falls, was completely inundated, forming a barrier for floating debris until the structure failed. The Arch Street Bridge, built in 1902 to replace an earlier structure which was carried away by the March flood of that year, was also destroyed. Other bridges destroyed in whole or in part were the Straight Street, Hillman Street, Moffet, Wagaraw, Fifth Avenue, East 33rd Street and Broadway Bridges. In this area, considerable damage was inflicted by all of the small brooks tributary to the Passaic River. Heavy industrial losses, caused by overflow of the main stream, were sustained by the silk processing and textile industry. Individual plants in this section suffered individual losses up to $1,350,000. Water rose nearly 8 feet over the first floors of several large mills, interrupting their operations for a period of seven days and retarding production over a period of several months. In the city of Passaic, flood damages were nearly as severe as in Paterson. Flood levels rose 4.5 feet above the earlier levels experienced during the March 1902 flood. Over 800 houses were inundated and a number of mills ceased operations, throwing 8,000 employees out of work. The entire stock of three lumber yards was swept downstream, forming a dam at the Erie Railroad (Passaic Park) Bridge and endangering that structure, and water rose 10 feet over the tracks on the east bank. In the lower section of the river, it was reported that 20 three-story houses floated downstream or lodged against the bridges. At Belleville, flood waters were 11 feet deep on Main Street, and buildings on River Road were inundated to the second story. Numerous industries were affected and much machinery and stock damaged beyond reclaim. The city almshouse and isolation hospital were flooded, gas mains burst and large sections were without heat or light. Telegraphic communications were everywhere disrupted, and the entire valley was isolated for a period of over a week. The Dundee Canal overflowed into Weasel Brook, causing considerable damage to bridges and culverts.

85. Loss of life was not as great as might be expected, due to the slow rise of the flood waters. In 1903, a total of five lives were lost, three of which were in Paterson. One life was lost as a result of the 1902 flood.

86. The most serious general flood in the Passaic Valley since 1903 occurred in March 1936. Although this was of much smaller magnitude than the earlier flood, the damage inflicted was relatively severe due to the high state of development of the inundated area. Relatively heavy damage was suffered by bungalow colonies along the Pompton River from Two Bridges to Pompton Lakes, in sections where the river banks are low and overflow occurs semi-annually. Many of these properties were flooded to depths of seven feet or more over the ground floors, preventing occupancy for a period of several weeks. In Wayne Township alone, the police reported the rescue of 108 families. The state highway along the Pompton River was flooded to a depth of 4 feet for a distance of 1.5 miles. In Oakland, 75 persons were driven from their homes, and at Lincoln Park the Erie Railroad tracks were under several feet of water, and service to New York was temporarily discontinued. Along the lower Pequannock River damage was heavy among many small houses which are built alongside and almost in the bed of the stream only a few feet above normal summer water levels. At Singac and Little Falls, the sewage disposal plants were severely damaged, and the sewerage system clogged with silt and debris. At Little Falls, 40 persons were quartered in the municipal building for a period of four weeks, and many others were temporarily lodged by neighbors. In Paterson about 600 buildings were flooded, and heavy damage was inflicted upon pavements, sewers and parks. A large section of the city, particularly on the left bank of the river, was under two to three feet of water. Hundreds of persons were thrown out of work, and communications were everywhere disrupted. Emergency relief work was undertaken by the American Red Cross, the Civilian Conservation Corps, the Works Progress Administration and State and local agencies. The W.P.A. expended nearly

$23,000 upon construction of sand-bag levees, the removal of persons and goods from the path of the flood and cleaning of debris from the flood area.

87. Flood conditions on the smaller tributaries, below Two Bridges are best exemplified by the July 1945 flood, and are generally summarized as follows: On Weasel Brook, nine bridges were damaged and approximately ten industrial plants and 230 residences and small business establishments were flooded. On Saddle River and Hohokus Creek, six bridges were damaged and 11 destroyed. Approximately ten industrial plants, 80 small business establishments and 500 residences were flooded. Two suburban communities were seriously inundated when three small private dams failed on Hohokus Creek. On Goffle Brook, two bridges and five dams were damaged. Six industries and approximately 100 residences and small business establishments were flooded. Five industries near the mouth of the brook had nine feet of water over their first floor levels. On Molly Ann's Brook, flooding caused extensive damage to several communities north and west of Paterson. Twelve bridges were damaged and two were completely destroyed. Part of one industrial building was washed out. Other industrial commercial and residential buildings were inundated to depths of four feet. Approximately 500 homes in Paterson and Haledon alone were flooded. On Slippery Rock Brook, flood conditions were augmented enormously by failure of a dam which, it is reported, released 55 million gallons of water. One bridge was washed out, service was disrupted on the Delaware, Lackawanna and Western Railroad, scores of homes were inundated, and utilities were damaged. On Peckman River, conditions were aggravated by the temporary impounding action and final failure of a high embankment of the Erie Railroad at Cedar Grove. Traffic on this line was suspended 3.5 months. Six bridges were damaged on this stream and one was destroyed. Approximately 150 residences and small business establishments were flooded along the course of this stream. The large plant of the Little Falls Laundry

suffered severe damage from flood waters four feet in depth. On Singac Brook four bridges were damaged and one was destroyed. Approximately 150 residences and small business establishments along the lower portion of this brook were flooded.

88. Two persons lost their lives in this flood. A child was drowned after falling into Weasel Brook, and a woman was lost when her home on Peckman River was swept from its foundations.

XI. FLOOD DAMAGES

89. Flood Damages. A summary of estimated recurring, preventable flood damages within the Passaic River watershed as a result of the 1903, 1936 and 1945 floods is given in Table XXI. These data are based on flood damage surveys made in 1938, and 1946, and have been adjusted to 1948 price levels by application of a price factor based on indices of the U. S. Bureau of Labor Statistics. Details of the methods used in evaluating the losses and itemized distribution of damages by reaches classified as to type of damage are contained in Appendix G.

90. Average Annual Flood Damages. A summary of the average annual recurring and preventable flood damages within the Passaic River watershed as of 1948 is given in Table XXII. The values are based on floods up to the standard project flood (paragraph 74) and were computed from discharge-frequency data of Appendix B in conjunction with stage-discharge and stage-damage relations of Appendix G.

91. In view of the expected future increase in the development of the watershed, as projected from past records, the average annual damages were computed allowing for such future increase as might reasonably be expected to occur under existing flood conditions. In order that the benefits from flood control works might be representative of average conditions over the assumed 50-year life of the proposed structures, the average annual damages were evaluated for the anticipated state of development in the year 1975. This is equivalent to one-half the life of the structures

TABLE XXI

SUMMARY OF RECURRING, PREVENTABLE FLOOD DAMAGES

PASSAIC RIVER WATERSHED, N. J.

Floods of October 1903, March 1936 and July 1945

(1948 Conditions and Price Levels)

Stream	Total Flood Damages in Dollars		
	Oct. 1903 Flood	March 1936 Flood	July 1945 Flood
Passaic River			
Mouth to Dundee Dam	16,902,200	550,700	1,181,500
Dundee Dam to Great Falls	10,862,400	1,625,400	4,366,200
Great Falls to Little Falls	1,655,200	226,200	289,000
Little Falls to Two Bridges	1,542,500	376,800	399,000
Two Bridges to Chatham	472,200	161,800	180,000
Total - Passaic River	31,434,500	2,940,900	6,415,700
Pompton River	3,346,400	588,100	418,100
Ramapo River	173,600	149,600	131,500
Rockaway River	350,400	61,300	22,800
Whippany River	166,800	69,500	71,600
Weasel Brook	1,559,400	233,000	614,400
Saddle River	3,748,600	238,300	1,537,800
Hohokus Creek	1,123,800	238,600	740,400
Diamond Brook	213,200	32,000	90,000
Goffle Brook	262,100	40,900	131,900
Molly Ann's Brook	2,268,100	369,800	1,153,000
Slippery Rock Brook	196,400	19,800	133,400
Peckman River	866,400	43,200	445,800
Singac Brook	173,000	82,800	150,100
Total - Tributaries	14,448,200	2,166,900	5,640,800
Grand Total -- Passaic River Watershed	45,882,700	5,107,800	12,056,500

assuming 1950 as the date of construction. A summary of the average annual recurring preventable flood damages as of the median life period of the proposed works is given in Table XXII. The values are based on 1948 price levels, projected to 1975 by use of past records of growth in real property records. The methods used in determining future damages, together with an itemized distribution of damages by reaches are contained in Appendix G.

TABLE XXII

SUMMARY OF AVERAGE ANNUAL, RECURRING, PREVENTABLE FLOOD DAMAGES

PASSAIC RIVER WATERSHED, N. J.

Stream	Total Average Annual Damages in Dollars	
	1948 Conditions and Price Level	1975 Conditions and 1948 Price Level
Passaic River		
Mouth to Dundee Dam	640,300	968,000
Dundee Dam to Great Falls	460,600	631,100
Great Falls to Little Falls	115,600	202,400
Little Falls to Two Bridges	154,200	309,000
Two Bridges to Chatham	98,600	215,300
Total-Passaic River	1,469,300	2,325,800
Pompton River	205,000	332,500
Ramapo River	139,400	145,100
Rockaway River	18,000	40,900
Whippany River	52,900	114,600
Weasel Brook	196,300	234,000
Saddle River	219,200	238,900
Hohokus Creek	111,100	123,100
Diamond Brook	16,400	18,700
Goffle Brook	26,400	27,100
Molly Ann's Brook	183,700	201,800
Slippery Rock Brook	12,400	12,600
Peckman River	43,100	50,800
Singac Brook	22,100	49,800
Total-Tributaries	1,246,000	1,589,900
Grand Total-Passaic River Watershed	2,715,300	3,915,700

XII. EXISTING FEDERAL (CORPS OF ENGINEERS) PROJECTS

92. There is no existing Federal project for flood control on the Passaic River or its tributaries. The existing Federal navigation project which extends for 15.4 miles upstream from Newark Bay is described in paragraph 45.

XIII. IMPROVEMENTS BY OTHER FEDERAL AND NON-FEDERAL AGENCIES

93. No comprehensive improvement for the control of floods in the Passaic River watershed has been undertaken by any agency.

94. The problem of flood control on the Passaic River has been the subject of investigation and agitation by local interests since Colonial times. Early emphasis was placed upon the drainage of farm lands in the Central Basin above Little Falls where agricultural losses due to flooding were relatively frequent and severe. Channel excavation and construction of drainage ditches in this area were first undertaken in 1782, and work has continued at intervals until the present. Frequent objections have been directed against Beatties Dam at Little Falls on the grounds that it aggravated flood conditions upstream, and for a period from 1772 to 1805 the structure was removed, but it was later rebuilt. In 1869 plans were formulated for the installation of gates in Beatties Dam and for channel improvement upstream. Work was started on the channel improvement in 1889 but the project was abandoned shortly thereafter.

95. Subsequent flood control activity was confined largely to investigation and preparation of reports. In 1904 the Northern New Jersey Flood Control Commission investigated numerous projects with a view to providing flood control on the Passaic River. The Commission concluded that a reservoir on the Pompton River at Mountain View would afford the most practicable means of flood control for the Passaic Valley. These conclusions were concurred in by the Passaic River Flood District Commission in a report rendered in 1906, and again received support in 1908 from the New Jersey State Water Supply Commission which was engaged in a study of potable water supplies for the Passaic area. In 1905 the New Jersey State Geologist recommended in his annual report that a permanent lake and flood storage reservoir be constructed in the Great Meadow area by erection of a dam at Little Falls. This project was again

advanced in 1919 in a report by the New Jersey Department of Conservation and Development. This agency, in 1928, advanced an additional plan involving the construction of a dam at the mouth of the Rockaway River (Whippanong site) with a view to providing a permanent recreation lake having surcharge storage for flood control. This project also included the installation of flood gates in Beatties Dam and channel improvement downstream. In 1931 the New Jersey State Water Policy Commission undertook an exhaustive study of flood control possibilities on the Passaic River, and advanced a combined project involving construction of a flood detention reservoir on the Ramapo River at Oakland, construction of a reservoir at the Whippanong site on the lower Rockaway River, and channel excavation at downstream localities. The Whippanong project was revived in 1934 when a survey was conducted with Emergency Relief funds with a view to obtaining a Federal aid grant through the Public Works Administration. Application was made in 1935 for funds in an amount of $6,000,000 for the first year's operations and $18,000,000 for expenditure during the succeeding ten years. The project was considered to be self-sustaining from income to be derived from sale and rental of recreational facilities. No allotments were approved for this project.

96. A large number of channel improvement projects designed to afford local flood relief on the smaller tributaries throughout the Passaic area have been prosecuted by local agencies and individual property owners at various times. The most recent of these were constructed during the period 1933 to 1941, under the sponsorship of various Federal emergency relief agencies. Under this program Weasel Brook was improved by construction of a masonry and reinforced concrete conduit approximately 10 feet high and 18 to 23 feet wide extending for a distance of 2,000 feet from a point 0.3 mile above the mouth to Monroe Street in Passaic; by construction upstream therefrom of an open flume with masonry walls and reinforced concrete bottom approximately 10 feet high and 20 to 30 feet

wide extending for 1,100 feet between Monroe and Sherman Streets in Passaic, and thence, similar construction, with somewhat lesser cross-sectional area for a distance of 1,200 feet from Highland Avenue to Center Street in Clifton. Hohokus Creek was improved by construction of a masonry wall about six feet high extending for 250 feet on the left bank and 100 feet on the right bank between Grove Street and Spring Avenue in Ridgewood, and by construction of rubble masonry walls about 4 feet high for about 1,000 feet along both banks of the stream through the municipal part in Ridgewood. In the same stream, subsequent to the 1945 flood, private interests undertook channel clearing and widening in a 2,000-foot reach between Pine Lawn Bridge and First Street in Ridgewood. Peckman River was improved by the straightening and widening of the channel for 1,300 feet between Bradford and Ozone Avenues in Cedar Grove and for 5,800 feet between the Bronze Mill Dam and Bloomfield Avenue in Verona. In addition, masonry walls about six feet high were constructed on both banks of the stream for a distance of 500 feet from Bloomfield Avenue to Verona Lake in Verona. Second River was also improved by channel widening and by construction of continuous masonry walls 10 feet high along both banks of the stream for a distance of about 5,000 feet from Willet Street to Bloomfield Avenue in Bloomfield. Downstream, a 5,000-foot reach through Belleville Park between Washington Boulevard and Franklin Avenue in Belleville was improved by widening and by construction of an open flume with reinforced concrete walls about eight feet high and a paved bottom.

97. Several other smaller tributaries in the watershed were also improved by minor channel clearing projects. It is estimated that Federal relief funds approximating $1,500,000, and local funds approximating $200,000, were expended on the entire flood program.

98. Although not accomplished primarily for flood control, certain drainage improvements of an extensive nature have been initiated by the local county mosquito control commissions in the swamp and meadow areas

of the Central Basin. This work was effectively initiated in 1925, and during the period 1933 to 1941, received material aid through various Federal emergency relief grants. Operations are still being prosecuted under a comprehensive plan utilizing local funds. Up to the present time, work accomplished included the clearing of obstructions and debris from 33 miles of channel of the main stream between Two Bridges and Passaic Township, for a distance of about 11 miles below Swinefield Bridge in East Hanover, and for a distance of about 1.5 miles below the lower Chatham highway bridge. Channel clearing operations were also carried out along the lower Rockaway River and the Whippany River for a total distance of about 6.7 miles. In addition, ditching of a large portion of the adjacent meadows was completed. This work is under continuous prosecution jointly by the counties of Essex and Morris, and when completed will provide general bottom widths in the main stream of 90 feet in the section between Two Bridges and the mouth of the Rockaway River at Pine Brook, and 55 feet upstream therefrom to lower Chatham. During the period 1925-1947, approximately $900,000 has been expended on this work, of which about $550,000 was Federal relief funds. Approximately $38,000 is being expended annually by the two counties on the current dredging operations.

99. While all of these improvements provide some degree of local protection against minor floods, they have negligible effects upon major flood occurrences in the watershed.

XIV. IMPROVEMENT DESIRED

100. Local interests are sharply divided upon the improvements desired for flood control, depending upon whether their concern lies above or below Little Falls. At public hearings held on 29 September 1936 and 25 April 1946 in the city of Paterson, with a view to developing the local flood problem in the Passaic Valley and in subsequent letters, expressions of opinion were rendered by municipal, state and federal officials, and by business, civic and social interests. A digest of the public hearings is

contained in Appendix A. A summary of the improvements desired is given below.

101. In general, flood control reservoirs or local channel improvements or a combination of both were advocated by various local interests desiring flood relief along the main stem of the Passaic River. Below Little Falls most interests were primarily in favor of obtaining relief in the Lower Valley by means of flood retardation in headwater reservoirs. The city of Passaic was adverse to channel improvement alone, due to possible flooding of that city and danger to the Dundee Dam. Representatives of the city of Paterson indicated that no satisfactory solution of the overall flood problem in the Passaic Valley would be possible without the construction of flood control reservoirs. Residents of Totowa and Little Falls expressed a desire for flood relief by impounding of flow in upstream reservoirs.

102. Industrial and power interests of the Lower Valley both concurred in recommending channel improvements below Little Falls, but the latter were strongly opposed to any improvement upstream which would adversely affect the usable flow of the river. The Passaic Valley Water Commission indicated that it was interested in the preservation of its hydraulic power plant at Little Falls, and would be in accord with channel improvement downstream from Great Falls, or with any project that entertains as part of its program the development of a water supply on the Passaic River. The Commission suggested the inclusion of conservation storage in any flood control reservoir which might be constructed in order to increase the low water flow of Passaic River during the critical summer months for potable and industrial use. Individuals concerned with pollution in the lower river were opposed to any plan which would eliminate the flushing action of spring floods and the aeration of high waters passing over the dam at Great Falls.

103. Above Little Falls in the Central Basin several communities objected to any reservoir project which would remove large areas from local tax lists with consequent loss of income to these municipalities. These interests advocated local channel improvements exclusively. Between Little

Falls and Two Bridges some interests desired that the outlet of the Great Meadow area be enlarged by installation of gates in Beatties Dam and by channel excavation upstream therefrom. Agricultural interests above Little Falls concurred in this recommendation which would permit the drainage of the Great Meadow.

104. Property owners in the Pompton area in Wayne, Lincoln Park and Pompton expressed a desire for channel improvement on the Pompton and Pequannock Rivers, together with a means whereby ice gorges might be eliminated downstream. The strongest exponents for flood relief in this section were property owners whose bungalows are closely crowded upon the low banks of the river, and real estate interests who have invested heavily in flood-arrested developments in the flood plain. Objection was registered to any plan which would remove large areas from local tax lists, particularly in Wayne and Lincoln Park, with consequent loss of income to those municipalities. The Regional Plan Association, organized for the coordinated development of the New Jersey-New York-Connecticut Metropolitan Region, favored a flood detention reservoir and strongly advised against any developments which would foster residential growth in areas unsuited to such use, at the expense of other more suitable areas which are now available.

105. Wild life interests were in favor of flood detention reservoirs and permanent flooding if regulated, but were opposed to any unregulated land drainage of the Great Meadow area which might alter the present condition of the area and render it unsuited to wild life conservation. The mosquito extermination interests presented a program involving the improvement of the Passaic River from Little Falls to Two Bridges, the installation of gates in Beatties Dam, and the partial drainage of wet lands upstream. It was claimed that this improvement would afford only sufficient discharge capacity to eliminate the smaller, more frequent mosquito-producing floods in the Great Meadow area, without materially altering the present moderating role exercised by the Great Meadows over

the larger floods. These interests also favored flood detention reservoirs in the upper watershed, or any reservoir which would cause permanent flooding over the Great Meadows provided that the depth of flooding was sufficient to discourage mosquito breeding. The Passaic Valley Flood Control Commission recommended the immediate construction of a combined recreation lake and flood control reservoir at the Whippanong site on the lower Rockaway River with permanent pool level at elevation 190 feet, m.s.l. It was also suggested that suitable legislation be enacted to enforce the provision of flood control storage in existing reservoirs, particularly by drawdown of water surfaces in anticipation of a flood when watershed conditions so warrant. Because of the acute need for an additional water supply for the Northern Metropolitan District (Pars. 33 and 34), interested water supply agencies and the New Jersey State Department of Conservation indicated an interest in the inclusion of a conservation pool for water supply in any possible flood control reservoir which might be developed in the Passaic watershed. In addition, a representative of the North Jersey District Water Supply Commission favored inclusion of conservation storage in flood control reservoirs and recommended investigation of a combined water supply and flood control reservoir on the Ramapo River to be operated in conjunction with a modification of the Wanaque Reservoir for water supply and flood control. Bergen County objected to any damming of the Ramapo River due to residential and recreational uses of the land in that valley.

106. Individuals and representatives of communities along the tributaries of Passaic River generally expressed a desire for some form of channel improvements at localities subject to serious flooding.

107. With respect to the Lake Denmark spillway, the Division of Water Policy and Supply of the New Jersey State Department of Conservation has recommended ".....in the interest of good engineering and absolute safety that the existing loose rock spillway be paved and lengthened....." Arsenal authorities have also expressed concern over the safety of not only the Lake Denmark spillway but also of the Picatinny Lake spillway, two miles downstream, and the serious damages

which might be inflicted on Picatinny Arsenal as a result of failure of these dams.

108. In addition to the two public hearings, conferences were held with representatives of the New Jersey State Department of Conservation, Division of Water Policy and Supply, the Paterson Chamber of Commerce, the Passaic Valley Flood Control Commission, the New Jersey Conservation Department Flood Control Committee and the Four County Committee for Mosquito Control. At these conferences various possible plans of improvement, the problems of cooperation and objections of local interests to the plans were discussed. The New Jersey Conservation Department favored a multiple-purpose reservoir, including conservation storage for water-supply, together with channel improvement downstream of the dam, and the commissioner indicated willingness to recommend such a project to the state legislature.

XV.- FLOOD PROBLEM AND SOLUTIONS CONSIDERED

109. In the Passaic River watershed, although a considerable degree of flood control for the main stream below Little Falls has been provided by nature in the Great Meadow flat swamp area which acts as a natural retarding basin, channel restrictions, encroachments and bridges with inadequate clearances have reduced the safe channel capacity of the main stream below Little Falls to such an extent that losses from major floods in the highly populated Lower Valley are excessive and frequent. The principal focal points of damage in this reach are the city of Passaic below Dundee Dam and the city of Paterson below Great Falls (S.U.M. Dam).

110. Immediately upstream of Little Falls flooding occurs as a result of backwater from Beatties Dam and from the narrow approach channel which extends upstream from the dam nearly to Two Bridges. Flood conditions in this area are at times augmented by ice conditions. The principal damage center in this reach is the village of Singac. Upstream

from Two Bridges, the major flood losses are agricultural due generally to direct crop loss and to a lesser extent to loss of fertility through deposition of silt when flood stages persist for an extended period. Floods in this area are also largely responsible for the mosquito nuisance in the Passaic area.

111. Along the Pompton River and the lower Rockaway and Whippany Rivers, backwater from Beatties Dam is also partly responsible for flood conditions, but the major contributing factors are the flat gradients of the streams and the low banks. The principal flood damage occurs along the Pompton River from Mountain View to Pompton Plains including the communities of Lincoln Park and Wayne. In this section a heavy fringe of one-story summer cottages has been built along the low river banks. Along the lower Ramapo River in the vicinity of Oakland, there are also a large number of cottages and summer pleasure resorts which suffer damage chiefly because of their location on the low banks of the stream.

112. In the upper reaches of the Rockaway River, while flood losses presently are not of magnitude, the inadequate capacity of the spillways of the Government-owned Picatinny Lake and Lake Denmark Dams in Picatinny Arsenal constitutes a threat to the safety of the Arsenal. This problem is further discussed in paragraph 115 f.

113. On the minor tributaries, flood conditions are caused by backwater from the main stream; and above this backwater influence, generally by inadequate natural channel capacities aggravated by encroachments in the channels, inadequate bridge clearances, and failures of small dams. Along the lower portion of Weasel Brook particularly, built-up communities in Passaic and Clifton have encroached on the stream and bridges afford inadequate clearances for the passage of even minor floods. Along the lower portion of the Saddle River at Lodi, industrial developments encroach upon the channel within the flood plain. Upstream therefrom in Saddle River Township, Rochelle Park Township and Fairlawn, high grade

suburban developments have been constructed on the low banks of the river. Along Hohokus Creek and Diamond Brook, conditions similar to those along the residential developments of Saddle River prevail. In the upper portion of Goffle Brook in Midland Park, industrial establishments encroach on the banks of the stream. On Molly Ann's Brook, encroachments on the stream by industrial and residential developments in the highly populated section of Haledon augment flood conditions. On Slippery Rock Brook, flood conditions were aggravated by the failure of Barbour Pond Dam during the 1945 flood. It is now planned by local interests to reconstruct the dam with a slightly lowered spillway. Reconstruction of this dam should eliminate the danger of a recurrence of the greater portion of this flood damage. Along the Peckman River in the vicinity of East Main Street at Little Falls, commercial developments are located within the flood plain. On Singac Brook, above the influence of backwater from the main stream, most of the losses are occasioned by damage and destruction of bridges with inadequate clearances and by washout of roads along the low river banks.

114. With respect to the main stream and methods of flood protection there is conflict between the interests of property owners below Little Falls and those above. At present the heavily settled Lower Valley which suffers the bulk of the flood damage in the Passaic area, is afforded a measure of protection by the natural flood detention storage in the Great Meadow area above Little Falls. Without this protection, floods below Little Falls would be from 30 to 55 percent in excess of those which occur at present, and flood damages would be almost doubled thereby. It is in the majority interest, therefore, that the flat lands above Little Falls continue to serve in their present role. Minority interests in the meadow area, however, are increasingly desirous of reclaiming and utilizing these lands. Development of this area, particularly along the

Pompton River has been accelerated during recent years despite the fact that many of these improved properties lie well below the 1903 flood level; and there is reason to believe that this growth will continue.

115. Of the many solutions of the flood problem studied for this report, only a limited number, considered to be the most feasible, are discussed herein. These solutions involve two general principles employed separately or in combination; either that the flood waters in excess of channel capacity be retained in suitable storage reservoirs to be later released as down-river flows permit, or that the flood waters be accelerated to Newark Bay, without damage, by the construction of enlarged channels. Solutions studied are as follows:

a. Headwater Reservoirs. Flood flow detention in numerous headwater reservoirs, designed to provide the highest degree of protection to the areas both above and below Little Falls, represents a plan most generally acceptable to local interests. Of the numerous flood control reservoirs in the upper Passaic area that have been studied by previous investigators, four of the most practical sites namely, Oakland, Newfoundland, Powerville and Millington were selected for preliminary study in connection with this report. After eliminating those reservoirs which were of insufficient size to exercise a material influence over floods in the lower river, it was found that only the Oakland Reservoir, when combined with the Whippanong Reservoir in the Great Meadow area, afforded benefits which would warrant further study. In addition, a study was also made of existing lakes and reservoirs with a view to providing surcharge storage for flood control above existing spillway levels. In no case was such storage found to be feasible. At

Wanaque Reservoir, where a flood surcharge would be of greatest benefit, physical conditions preclude obtaining additional storage except at exorbitant cost. Allocation of a portion of the existing water supply storage of the Wanaque Reservoir for flood control and substituting therefor an equivalent storage for water supply in the Oakland Reservoir, was also found not to be economically feasible.

b. Reservoirs in the Great Meadow Area. Four sites for flood detention reservoirs in the Great Meadow Area, namely, Two Bridges, Mountain View, Whippanong, and Swinefield were given preliminary study in connection with this report. It was soon apparent that only the Two Bridges Reservoir, and the Whippanong Reservoir when combined with the Oakland Reservoir in the headwaters warranted detailed study and that the Two Bridges Reservoir afforded the greater benefits when compared with the costs. In accordance with the desires of the Passaic Valley Water Commission, a study was made of the introduction of a conservation pool in the Two Bridges Reservoir to increase the low water flow at Little Falls and furnish additional water supply during the dry period of the year. Plans were also considered for introduction of conservation storage in the reservoir for low water flow regulation in order to increase the dependable energy output and capacity of hydro plants downstream, and also to further stream pollution abatement.

c. Main Stream Channel Improvement. Acceleration of flood flow on the main stream by enlargement of the existing channel would be provided under a number of solutions, all of which are complicated by high costs and excessive interference with highway communications. The most feasible of these solutions, which involves channel improvement

from the mouth of the river to Two Bridges is complicated because of various existing conditions. Channel widening is generally impractical because of the high value of property along the bank, particularly in the narrowest sections of the river where the abutting properties are intensively developed. Channel deepening is rendered costly by reason of the extensive rock excavation required in certain sections of the river and the heavy underpinning required beneath abutting structures. An extensive levee project would require raising or reconstruction of a large number of bridges, and great expense would be entailed in providing the necessary street approaches in heavily built-up areas. The most practical channel improvement project would consist of a combination of channel deepening and levee and wall construction along the portions of the river which are most susceptible to these types of improvement, and most in need of protection. Above Two Bridges along the Passaic River, the scattered local flood damages do not warrant channel improvement beyond minor drainage work. Along the Pompton River consideration was given to a local protection project from Two Bridges to the Newark Pompton Turnpike (Old Route 23) involving levee construction with channel clearing and widening.

d. Diversions. In view of the desires of local interests for a solution of the flood problem by means of a diversion tunnel or diversion channel from Little Falls to below Dundee Dam and from Great Falls (S.U.M. Dam) to below Market Street in Paterson, several plans of this nature were considered. However, these solutions would involve costs considerably greater than those which would provide equivalent discharge capacity in the existing channel, and therefore, have been rejected. (Appendix E)

e. Reservoir and Main Stream Channel Improvements. In order to provide a balanced and economic plan for flood protection from the mouth to Two Bridges, consideration was given to a plan involving a combination of channel improvement and reservoir control. The plans studied include:

(1) The construction of flood detention reservoirs on the Ramapo River at Oakland and on the lower Rockaway and Whippany Rivers near Pine Brook, the provision of an improved channel having a 25,000 c.f.s. capacity at Paterson and extending from Two Bridges to the mouth of the Passaic River, the installation of a flood gate in Beatties Dam and levee construction to accommodate a flood of about 28,000 c.f.s. at Two Bridges along the Pompton River from Pompton Lakes to Two Bridges.

(2) Construction of a flood detention reservoir on the Passaic River above Two Bridges, diversion of the Pompton River into the reservoir, provision of levees and walls along the Pompton River along the proposed diversion channel and around the Lake Hiawatha development, and the Commonwealth and East Orange water supply developments, and provision of an improved channel having a 16,000 c.f.s. nominal capacity at Paterson, and extending from Two Bridges to the mouth.

(3) Construction of a multiple-purpose reservoir on the Passaic River above Two Bridges with an improved channel downstream therefrom, with a 16,000 c.f.s. nominal capacity at Paterson. The other features of this plan are identical to those noted above for the detention reservoir plan except for the provision of a conservation pool for water supply, power and pollution abatement uses. The two latter plans would provide the most practicable degree of protection along the main stream and on the lower reaches of the major tributaries within backwater influence of the main stream.

f. Improvements on Tributary Streams in Central Basin and Highland Area. The scattered character of the flood losses along the Ramapo, Rockaway and Whippany Rivers preclude provision of flood protection

along these streams within any reasonable degree of economic justification. With respect to the upper Rockaway River, consideration was given to reconstruction of the spillways of the Federally-owned Lake Denmark and Picatinny Lake Dams in Picatinny Arsenal.

(1) Lake Denmark, located on Meadow Brook 0.2 mile upstream from its junction with Green Pond Brook, is about 2.0 miles upstream from Lake Picatinny Dam. Lake Picatinny, located on Green Pond Brook in the industrial area of Picatinny Arsenal, is about 21 miles upstream from Boonton Reservoir, a part of the Jersey City water supply system. Both of these lakes are utilized to store water for industrial use in the Arsenal.

(2) The dam at Lake Denmark consists of an embankment composed of a rock and earth fill structure. (Figures 28 and 29). The spillway located near the right abutment consists of a dumped rock fill section with an average top elevation only about 1 foot lower than the top of the dam. In the spillway channel are five six-foot diameter concrete pipes. Normal lake level at three feet below the top of dam is maintained by leakage through the rock fill composing the spillway and by discharge through two outlet pipes. Lake Denmark at normal level has a water surface of 174 acres and a capacity of 920 acre feet (4.10 inches on the 4.2 sq. mi. drainage area above dam). The estimated maximum discharge capacity of the spillway and outlet works combined is 160 c.f.s. This discharge corresponds to a flood inflow to the reservoir of about 600 c.f.s. as compared to the estimated flows from the largest flood of record (October 1903), the standard project flood, and the maximum probable flood of record (October 1903), the standard project flood, and the maximum probable flood of 1,000 c.f.s., 5,600 c.f.s., and 11,750 c.f.s. respectively.

(3) Picatinny Lake Dam consists of an earth embankment with a concrete spillway. The embankment is approximately 500 feet long and 17 feet high, and is surmounted by a concrete wall with top elevation at 713.5 feet, m.s.l. The concrete spillway, trapezoidal in section, has a center section 37 feet long with a crest elevation of 708.7 feet, m.s.l., and two side sections each 12 feet long with crest elevation 710.4 feet m.s.l. Flashboards are provided on the spillway to maintain a normal lake level at elevation 712.4 feet, m.s.l. Lake Picatinny at normal level has a water surface of 115 acres and a capacity of 275 acre feet equal to 0.59 inches on 8.7 square mile drainage area above it. The estimated maximum discharge capacity of the spillway with the water surface at the top of the curb and the flashboards out is 1,114 c.f.s. This discharge corresponds to a flood inflow to the reservoir of about 1,530 c.f.s. as compared with the estimated values of the largest flood of record (October 1903), the standard project flood, and the maximum probable flood of 1,720 c.f.s., 7,800 c.f.s., and 15,400 c.f.s. respectively.

(4) The existing spillways at these dams do not conform to conservative standards of design, and failure might occur under a recurrence of a great flood. Failure of either of these dams would cause virtually complete cessation of activities at the Arsenal through direct damage by flood to buildings, equipment and utilities, including the loss of the industrial water supply. The effect at Boonton Reservoir, 18 miles downstream, is not readily determinable. Boonton Dam (Table V) is a stone masonry structure constructed in 1904 with a spillway length of 300 feet, a crest elevation of 305.4 feet, m.s.l., a flat crested overfall and a freeboard to top of dam of five feet. The estimated discharge capacity of the spillway with one foot freeboard below top of dam,

is 7,300 cubic feet per second. This capacity would be adequate to accommodate a flood of 1903 magnitude, the largest of record, with but small margin of safety. In the event of failure of both Arsenal dams, whatever flood wave were released thereby would traverse the flat meadowland immediately below Lake Picatinny and along the Rockaway River for a distance of 20 miles. Although the wave would be slow in traversing this area and would be desynchronized from the main flood peak and attenuated by the natural valley storage contained therein, the discharge rate at Boonton might be materially increased over the natural flood intensity at the dam.

(5) In view of the consequential damages which might result under these conditions, reconstruction of the dams at Lake Picatinny and Lake Denmark appears to be the most economic and practicable solution to the local flood problem.

g. Improvements on Tributary Streams in the Lower Valley. Acceleration of flow on the minor tributaries could be obtained by channel improvement on individual tributaries. These improvements, designed to protect largely against localized storms over the Paterson area, are treated individually in this report on their own merits and independently of the main river problem. Solutions considered for protection along the tributaries below Two Bridges are summarized as follows: On Weasel Brook, consideration was given to channel improvements and small detention areas in the headwater area. Utilization of small detention areas above Jewett Avenue either alone or in combination with channel improvement was found impracticable because of the limited flood storage available. However, a channel improvement project alone would provide a practicable degree of protection along the main stream from Monroe Street in Passaic to Jewett Avenue in Clifton.

(1) On Saddle River, consideration was given to protection at the points of major damage by channel improvement from the mouth at

Saddle River Avenue in Garfield through Lodi, Rochelle Park, and Paramus to Union Street in Fairlawn; local protection between Grove Street and Ridgewood Avenue in Ridgewood and at greenhouses near Allendale Avenue and the State fish hatchery south of Pleasant Avenue in the town of Saddle River. Preliminary studies indicated that only in the highly developed urban area in Lodi were the costs for protection reasonably comparable with the benefits.

(2) On Hohokus Creek, local protection projects involving channel widening and deepening and walls and levees from the vicinity of Grove Street in Glen Rock and Ridgewood to above North Maple Avenue in the borough of Hohokus were considered but were found not to be economically justified.

(3) On Diamond Brook, consideration was given to increasing the capacity of the outlet through the plant of the Wright Aeronautical Corporation near the mouth of the stream and local protection along the Boulevard between Grandview Avenue and Oxford Place in Glen Rock. Preliminary studies indicated that improvement of this stream was not practicable because of the high costs compared with the benefits afforded.

(4) On Goffle Brook, local protection was considered for residential properties at Rea Avenue and First Avenue in Hawthorne; along the stream in the reach between Goffle Hill Road to above Lake Avenue in Hawthorne and Ridgewood; and in the vicinity of Granite Place and Greenwood Avenue in Midland Park. Plans for flood protection along this stream were also eliminated from detailed study because preliminary estimates indicated that the benefits were not reasonably comparable with the costs.

(5) On Molly Ann's Brook, a channel improvement project from below Preakness Avenue in Paterson through Haledon to Oldham Pond in North Haledon was studied and found to be practicable. It was further found that reconstruction of the Squaw Lake Dam to provide a detention basin combined with a channel improvement project would not add to the practicability

and economic justification of the channel improvement plan. The flooding of the lower portion of the stream from Preakness Avenue down to the mouth is caused primarily by backwater from the Passaic River under existing conditions and by overflowing its banks if the Two Bridges Reservoir were to be constructed. Two plans were considered to provide protection against flooding under existing conditions and under conditions as modified by the Two Bridges Reservoir. These plans were found not to be economically justified.

(6) On Slippery Rock Brook, local interests are considering a plan for lowering the spillway of Barbour Pond and strengthening the earth non-overflow section to assure safety of the structure against destruction from future floods. This project will reduce materially the flood hazard along this brook since past damages resulted primarily from failure of the dam. Preliminary studies indicate that the flood damages under natural conditions after reconstruction of the dam would not be sufficient to justify economically a local protection project.

(7) On Peckman River, consideration was given to a channel improvement project from below East Main Street to Francisco Avenue in Little Falls Township. Flood losses along this reach are largely non-recurring because of replacement of the railroad embankment and culvert of the Erie Railroad crossing at Cedar Grove by a steel trestle. The flood losses under natural conditions with the existing steel trestle at Cedar Grove would not be sufficient to justify economically a local protection project.

(8) On Singac Brook, upstream from the junction of Singac Brook and Naachtpunkt Brook consideration was given to local protection involving bridge reconstruction, and walls and levees in the vicinity of Riverview Drive and Valley Road, at Preakness Avenue and at Ratzer Road in Wayne Township. Improvement along this stream was found impracticable

because of the high costs involved. Protection of the lower portion of the brook from the mouth of Naachtpunkt Brook down to the Passaic River, flooding of which is caused by backwater from the Passaic River, was included in plans considered for improvement of the main stream.

XVI. FLOOD CONTROL PLANS

116. General. The most practicable plans of improvement finally developed for the Passaic watershed are designed to provide flood control (1) for the main stem of the Passaic River, (2) for tributaries of the Passaic River below Two Bridges and (3) for Picatinny Arsenal on the upper Rockaway River. Data on hydraulic design for all plans are contained in Appendix C. These plans are described in the following paragraphs. Other plans of improvement are discussed in Appendix E.

117. The most feasible plans for flood control on the main stem of the river consist of the following:

Plan I. Dry detention reservoir on the Passaic and Pompton Rivers in the vicinity of Two Bridges together with channel improvement downstream of the dam.

Plan II. A multiple-purpose reservoir in the vicinity of Two Bridges together with channel improvement similar to that provided under Plan I.

Plan III. Local protection works by channel enlargement and rectification in critical areas of concentrated flood damage downstream from the S.U.S. Dam in Paterson.

118. The most feasible plans for flood control on the tributaries below Two Bridges include local protection projects involving channel improvement and wall and levee construction along Weasel Brook, Saddle River, and Molly Ann's Brook.

119. The most feasible plan for protection of Picatinny Arsenal on the upper Rockaway River requires reconstruction of the Lake Denmark and Picatinny Lake Dams.

120. Plan I.-Two Bridges Detention Reservoir with Channel Improvement. This plan which is shown on Plate 3 provides for the construction of a dry detention reservoir and dam in the Central Basin upstream from Two Bridges, and channel improvement on the Passaic River downstream from the reservoir. The dam and reservoir structures for this plan (Figures E1 to E4, Appendix E) are similar to those described for Plan II (paragraph 121 and Figures 4 through 8) except for the deletion of a conservation pool contained in the latter plan, and the change in elevation of the various control works involved therein. The channel improvement downstream from the reservoir is similar to that described for Plan II (paragraph 134 and Figures 9 through 15). Pertinent data on the dam and reservoir for this plan are given in Table XXIII. The degree of protection afforded by Plan I would be the same as that afforded by Plan II (paragraph 122), but the economic justification of the former plan is less than for the latter. A summary of cost and benefit data for this plan is given in Tables XXIX, XXXIV, XXXVII, XXXIX and XLI.

121. Plan II-Two Bridges Multiple-Purpose Reservoir with Channel Improvement. This plan provides for the construction of a reservoir and dam in the Central Basin upstream from Two Bridges (Plate 4). About 30 percent of the reservoir would be maintained as a conservation pool, and the remainder as a dry detention basin. In addition the plan provides (a) for channel excavation in the Pompton River and for the excavation of a new channel to divert the flow of the Pompton River into the conservation pool one mile above the dam site; (b) for the improvement of Deepavaal Brook to divert the upper Passaic River past the conservation pool; (c) for the construction of levees and walls to protect the Commonwealth Water Company reservoirs and wells at Canoe Brook, the East Orange wells and pumping station, the Braidburn, Dickinson and Slough Brook wells, the Caldwell, Livingston and Chatham sewage disposal plants, three power plants and other utilities located in the reservoir area, the

community of Lake Hiawatha at Troy Hills, and the communities of Lincoln Park, Pequannock and Pompton Plains bordering the Pompton River diversion channel; and (d) for the improvement of the Passaic River downstream from the proposed reservoir by excavation of the channel above Beatties Dam, by installation of three tainter gates in Beatties Dam, by the construction of walls and levees on both sides of the stream to provide local protection for two critical damage areas in Paterson and Passaic, by excavation of the lower river channel below Dundee Dam, and by establishment of encroachment lines to preserve existing channel capacity, where necessary. Pertinent data for various features of the reservoir and channel improvement are shown on Figures 4 through 15 and contained in Tables XXIII and XXIV.

122. The plan would provide flood protection for the communities bordering the main stream below Two Bridges, the lower Pompton River from Two Bridges to Pompton Plains, and the lower Rockaway River at Troy Hills, against a flood 20 percent in excess of the 1903 flood. This design flood of 40,500 c.f.s. at Paterson would be reduced to 14,100 c.f.s. through reservoir regulation. Residual damage areas noted above would be protected by channel improvement including local protection works. It is also designed to provide, by means of the conservation pool, a minimum dry season flow of 114 c.f.s. below the dam in addition to a diversion of 186 c.f.s. for water supply use.

123. The main dam would be located on the Passaic River in the Township of Caldwell and the Borough of Lincoln Park, 0.3 mile upstream from Two Bridges. In addition to the main structure (designated as the Passaic Section), there are proposed two auxiliary dams, of which one (designated as the Conservation Section) would separate the conservation pool from the dry flood detention reservoir, and the other (designated as the Pompton Section) would effect diversion of the Pompton River into the reservoir. Fixed spillway level would be at elevation 184.5 feet, m.s.l. The reservoir area at this level would be 21,225 acres and the

TABLE XXIII

PERTINENT DATA FOR DAMS AND RESERVOIRS

PLANS I AND II
TWO BRIDGES DETENTION RESERVOIR AND
TWO BRIDGES MULTIPLE PURPOSE RESERVOIR
WITH CHANNEL IMPROVEMENT

PASSAIC RIVER WATERSHED
(See Table XXIV for pertinent data for channel improvement)

Item	PLAN I Two Bridges Detention Reservoir			PLAN II Two Bridges Multiple Purpose Reservoir				
Watershed								
Area controlled (sq.mi.)	735.2			735.2				
Percent of area above Paterson	93.8			93.8				
Reservoir	Spillway Pool	Maximum Pool		Conservation Pool		Spillway Pool	Maximum Pool	
Elevation (ft., m.s.l.)	181.25	193.2		176.5		184.5	192.9	
Area (acres)	19,550	24,950		6,280		21,225	24,750	
Storage (acre feet)	214,800	481,000		70,000		278,000 (1)	471,000 (1)	
Storage (inches)	5.48	12.27		1.79		7.09 (1)	12.01 (1)	
Elevation of property taking line (ft.,m.s.l.)	185.0			187.5				
Dam	Passaic Section	Pompton Section		Passaic Section		Pompton Section	Conservation Dam Section	
Embankment - Type	Earth	Earth		Earth		Earth	Earth	
Foundation	Earth	Earth		Earth		Earth	Earth	
Length, exclusive of spillway (feet)	17,800	11,500		17,800		11,500	14,250	
Maximum height above stream bed (feet)	46	45		46		45	25	
Top width (feet)	20.0	20.0		20.0		20.0	80.0	
Top elevation (ft., m.s.l.)	200.0	200-202		200.0		200-202	187.5	
Spillway								
Type	Concrete ogee	-		Concrete ogee		-	Concrete ogee	
Foundation	Hardpan	-		Hardpan		-	Earth	
Effective crest length (feet)	400	-		600		-	1200	
Spillway crest elevation (ft., m.s.l.)	181.25	-		176.5-184.5		-	176.5	
Maximum surcharge on crest (feet)	12.0	-		16.4 - 8.3		-	8.0	
Spillway design discharge (c.f.s.)	62,500	-		73,720		-	-	
Spillway design reservoir inflow (c.f.s.)	114,500	-		114,850		114,850		
Outlet Works				Spillway	Deepavaal Brook			
Type	Conduits	Conduits		Conduits		Conduits	-	
Number	20	4		12	6	4	-	
Size (feet)	5 x 5	5 x 5		5 x 5		5 x 5	-	
Length (feet, each)	41	235		45	385	235	-	
Elevation at intake (ft., m.s.l.)	154.5	160.0		156.0		160.0	-	
Valve control	Gates (2)	Gates (2)		Gates (2)		Gates (2)	-	
Capacity								
Channel flow (c.f.s.)	3460	840		2070	1010	840	-	
At spillway level (c.f.s.)	16900	2560		10500	3750	2770	-	
Diversion Channel Improvement	Pompton River			Pompton River			Deepavaal Brook	
Bottom width (feet)	200 to 300			200 to 300			80	
Length (feet)	21,500			21,500			20,000	
Reservoir Dikes	Pompton Levee	Troy Hills (Lake Hiawatha) Levee	Levees to Protect Utilities	Pompton Levee		Troy Hills (Lake Hiawatha) Levee	Levees to Protect Utilities	
Average height (feet)	13	7	5-16	13		7	5-18	
Length (feet)	19,500	11,700	44,000	19,500		11,700	44,000	
Top width (feet)	8	8	8	8		8	8	
Top elevation (ft., m.s.l.)	185.0-192.0	186.5-191.0	185.0	187.5-192.0		188.5-191.0	188.5	
Relocations								
Highways								
Route No. 6	27,300 ft. raised to elev. 185.0			27,500 ft. raised to elev. 187.5				
Route No. 23	--			15,750 ft. raised for dam				
Local roads	--			4,300 ft., varying elev.				
Pompton Section	8,800 ft., varying elev.			8,800 ft., varying elev.				
Passaic Section	8,000 ft., varying elev.			10,500 ft., varying elev.				
Railroads								
Erie R. R. (M. & G.L. Branch)	8,200 ft. raised to elev. 200.0			8,200 ft. raised to elev. 200.0				
Delaware Lackawanna & Western R. R.	6,400 ft. raised to elev. 200.0			6,400 ft. raised to elev. 200.0				
Bridges								
To be raised	--			1				
To be replaced	3			3				
New bridges	6			6				
Interior Drainage								
Pumping plants required	1			1				
Range of capacity of pumping plants (g.p.m.)	135,000			135,000				
Lands, Easements and Rights-of-Way (acres)	21,400			22,600				

(1) Includes conservation storage.

(2) Hydraulically operated.

TABLE XXIV

PERTINENT DATA FOR CHANNEL IMPROVEMENT (16,000 C.F.S. AT PATERSON)

PLAN II
TWO BRIDGES MULTIPLE-PURPOSE RESERVOIR WITH CHANNEL IMPROVEMENT

PASSAIC RIVER WATERSHED

(See Table XXIII for pertinent data for reservoir)

Item	Mouth to Dundee Dam		Dundee Dam to S.U.M. Dam		S.U.M. Dam to Beatties Dam		Beatties Dam to Two Bridges		Two Bridges to Reservoir		Total
	Left Bank	Right Bank	Left Bank	Right Bank	Left Bank	Right Bank	Left Bank	Right Bank	Left Bank	Right Bank	
Channel Excavation											
Length (feet)	46,200		800 (Island)				17,500		1,500		66,000
Bottom width (feet)	150		(Removed)				200		250 to 600		-
Bottom slope (feet per foot)	0.0-0.00243						0.00009		0.00267		-
Earth Levees (1)											
Length (feet)	-	1,000	-	-			-	-	1,600	800	3,400
Maximum height above ground, river side (feet)	-	6	-	-			-	-	20	10	-
Average height above ground, river side (feet)	-	4	-	-			-	-	12	6	-
Concrete Walls											
Length (feet)	600	3,900	5,300	8,700			-	-	100	-	18,600
Maximum height above ground, river side (feet)	5	6	6	4			-	-	7	-	-
Average height above ground, river side (feet)	4	4	4	3			-	-	7	-	-
Average height above channel bottom (feet)	26	26	17	17			-	-	17	-	-
Interior Drainage											
Number of pumping plants required	-	1	1	2			-	-	-	-	4
Range of capacity of pumping plants (g.p.m.)	-	40,000	147,000	144,000 to 196,000			-	-	-	-	-
Bridge Work											
Number of bridges to be raised	1		2				-	-	-		3
Number of new bridges	5 (2)		2				-		-		7 (2)
Number of bridges to be removed	1		3 (3)				-		-		4 (3)
Miscellaneous							(4)				
Lands, Easements and Rights of Way (acres)	48		20				85		20		173

(1) All levees would have a top width of 8 feet and side slopes of 1 on 3
(2) Includes one bridge with new side spans only
(3) Includes one bridge with old pier removal only
(4) Three 35-foot tainter gates to be installed in Beatties Dam

total storage provided would be 278,000 acre feet, equivalent to 7.09 inches over the controlled drainage area of 735.2 square miles. Of this total storage, an amount of 208,000 acre feet, equivalent to 5.3 inches depth over the watershed area would be for flood control. This represents a net storage of 3.0 inches depth over the amount stored on the meadows during the 1903 flood. The reservoir would extend upstream for a distance of 11 miles to Chatham, along the Rockaway River a distance of 6 miles to above Lake Hiawatha, and along the Whippany River a distance of 6 miles to Florham Park. It would also extend up the Pompton River and diversion channel a distance of seven miles to Pompton Lakes. Improvements on a total of 1,280 parcels of property within the reservoir would require removal. The improvements include 870 permanent residences, 135 summer cottages, 160 farms, 75 commercial and industrial properties, 10 public buildings, and 30 miscellaneous parcels. The conservation pool would be formed within the reservoir area by construction of an impounding dam (Conservation Section) along the route of State Highway No. 6 to impound the normal flow from the Pompton River. Conservation pool level would be at elevation 176.5 feet, m.s.l. with a corresponding flowage area of 6,280 acres and storage of 70,000 acre feet. Backwater at pool level would extend along the Pompton River to Pompton Lakes. The works would be arranged so that normal flow on the main stem of the Passaic River would by-pass the conservation pool in discharging to the lower river.

124. The dam site for the Passaic Section consists of flat rolling lands which extend over a valley approximately 13,000 feet wide. Along the axis of the dam the greater portion of the valley floor is composed of a layer of variable thickness of stratified fine alluvial sand and overlying plastic clay and glacial till. Except for one locality, no rock was encountered by exploration generally within 100 feet of the surface. In the valley wall above the north abutment of the dam rock outcrops at approximately elevation 200 feet, m.s.l., but dips sharply

toward the dam, so that at the north abutment it is deeply covered with a glacial deposit consisting of a compact mixture of clay, silt, sand, gravel and boulders. Similarly, the south abutment consists of a firm glacial moraine deposit. At the site of the spillway on the south bank of the Passaic River, the surface layer of fine sand with silt was found to be 8 to 25 feet deep, underlain with hardpan or glacial till, below which rock was encountered at a depth of 36 feet. Detailed data on foundation conditions are given in Appendix D.

125. The main section of the dam (Passaic Section) would be a rolled earth embankment 17,800 feet long with a maximum height of 46 feet, a top width of 20 feet, and a top elevation of 200.0 feet, m.s.l. (Figure 6). Embankment slopes in the higher sections of the dam, totaling 9,000 feet in length, would be 1 on 10 on both sides below elevation 189 feet, m.s.l. and 1 on 3 above this level. Elsewhere, in sections having adequate foundation bearing capacity, slopes would be 1 on 4 on the upstream side and 1 on 3 on the downstream side. An impervious core of compacted till would be provided for the full length and depth of the embankment.

126. The Pompton Section of the dam would extend 11,500 feet across the Pompton River Valley from high ground in the vicinity of the old Route 23 bridge in Wayne to the divide in Lincoln Park (Figure 7). This section would also form the left bank of the Pompton River diversion channel. Foundation conditions in this section are substantially similar to those existing at the abutments of the main dam. The dam would be a rolled earth embankment. It would have a maximum height of 45 feet, a top width of 20 feet, a top elevation of 200 feet, m.s.l., and side slopes of 1 on 4 on the upstream side and 1 on 3 on the downstream side. An impervious core of compacted till would extend for the full length and depth of the embankment.

127. The Conservation Section of the dam would extend a distance of about 16,000 feet along the alignment of Route 6 from the Passaic

Section of the dam at Fairfield to the divide at Pine Brook (Figures 5 and 6). The foundation conditions in this section are substantially similar to those for the Passaic Section. The dam would be a rolled earth embankment with a top width of 80 feet to accommodate a new six lane highway proposed by the State for Route 6. This section would have a maximum height of 25 feet, a top elevation of 187.5 feet, m.s.l., and variable side slopes to suit foundation conditions as used in the Passaic Section. An impervious core of compacted till would extend throughout the full length and depth of the embankment.

128. The spillway in the Passaic Section would be a concrete ogee type structure, 620 feet in length, constructed on a hardpan foundation on the south bank of the Passaic River about 5,300 feet from the left abutment. Crest elevation would be 184.5 feet, with a lower weir, 120 feet long, having a crest elevation 176.5 feet, m.s.l. The spillways in the Conservation Section of the dam would have an effective length of 1,200 feet and would consist of five ogee type structures, each 250 feet long, spaced along the length of the dam, with a crest elevation of 176.5 feet, m.s.l. Outlet works in the Passaic Section (Figure 8) would consist of twelve 5-foot by 5-foot conduits, located in the spillway section at the Passaic River, and six 5-foot by 5-foot conduits located at the intersection of Deepavaal Brook with the embankment. Each conduit would be equipped with gates. Intake elevation would be at 156.0 feet, m.s.l. The outlets in the Pompton Section, consisting of four 5-foot by 5-foot conduits equipped with slide gates, would be located at the upstream end of the diversion channel and would discharge into the original Pompton River channel. Integrated with the outlet would be two 5-foot by 5-foot siphon conduits equipped with slide gates to carry interior drainage from the landside of the Pompton levee into the original Pompton River channel. The intake elevation of the outlet and siphon conduits would be about 160.0 feet, m.s.l.

129. The Pompton River channel improvement would involve deepening and widening of the Pompton River downstream from the old Route 23 bridge for a distance of 6,300 feet to Lincoln Avenue in Lincoln Park (Figure 7). From this point a diversion channel would be excavated to carry the flow into the conservation pool through a low point in the divide of Hook Mountain at Lincoln Park. The channel would be 18,600 feet long and would have a 200- to 300-foot bottom width and side slopes of 1 on 4. From the upper end of the diversion channel, a dry weather flow of 60 c.f.s. would be released into the original Pompton River channel by the outlets and siphon outlets.

130. The Pompton levee, for protection of Lincoln Park, Pequannock and Pompton Plains against flooding from the Pompton River and the diversion channel, would extend for 21,500 feet along the right bank of the diversion channel and the Pompton River from Jackson Avenue in Pompton Plains to the divide at Lincoln Park (Figure 7). The levee would have an average height of 13 feet, a top width of 8 feet, a top elevation varying from 187.5 to 192.0 feet above mean sea level, and side slopes of 1 on 4 on the water side and 1 on 3 on the land side. Interior drainage would be carried to the Pompton River by two siphon conduits (paragraph 128).

131. Within the reservoir area, the levee for protection of the community of Lake Hiawatha in Troy Hills would extend for 11,700 feet along the right bank of the Rockaway River between Vail Road and Knoll Road (Figure 5). It would have an average height of seven feet, a top width of eight feet, a top elevation varying from 188.5 to 191.0 feet, m.s.l., and side slopes of 1 on 4 for the water side and 1 on 3 for the land side. One pumping plant would be provided behind the levee for interior drainage. In addition the following facilities would be excluded from the reservoir area by means of levees and flood walls constructed to a top elevation of 188.5 feet, m.s.l., and provided with necessary

pumping units for interior drainage (Figure 5). The water supply works of the Commonwealth Water Company and of East Orange near the Passaic River, Canoe Brook and Slough Brook in the vicinity of Chatham would be protected from backwater flooding from the impounded waters by the construction of 14,000 feet of levee around the Canoe Brook reservoir; 10,000 feet of levee around the Commonwealth reservoir; and 3,900 feet of levee and 2,000 feet of concrete flood walls around eleven water supply wells, three pumping stations and one transformer building. Existing sewage treatment plants in the reservoir area would be protected by the construction of 2,500 feet of levee around the Caldwell Plant, 1,200 feet of levee around the Livingston Plant and 3,000 feet of levee around the Chatham Plant. The power plants of the Public Service Electric Company at Beaufort and Hanover would be protected by 6,000 feet and 3,000 feet of levee, respectively.

132. Additional work involved in the construction of the reservoir and the Pompton diversion channel would include the following (Figure 5): The Jersey City water supply aqueduct, where it passes through the conservation pool, would be relocated to the south side of the pool. Sections of Pine Brook Road would be raised to elevation 185.0 feet, m.s.l. along the conservation pool and would be realigned to join Route 202 on the left bank of the diversion channel. U. S. Highway Route 202, the Delaware, Lackawanna and Western Railroad (Boonton Branch) and Paterson Road would be raised and bridged over the land cut of the diversion channel in Lincoln Park. The bridges of the Erie Railroad (M. & G. L. Branch), old State Route 23, and the Newark Aqueduct which cross the Pompton River would be replaced by new structures. Route 23 would be raised to elevation 179.5 feet m.s.l. for 4,300 feet through the Pompton Section of the reservoir and the bridge carrying it across the Pomptom River would be altered by replacement of two existing spans with three new spans to provide a low steel clearance elevation of 178.0 feet m.s.l.

Route 6, in addition to being raised to elevation 187.5 feet, m.s.l., by being placed on the Conservation Section east of Pine Brook, would also be raised to the same elevation for about 11,700 feet west of Pine Brook to upland in the vicinity of Troy Hills. One cemetery each in Wayne Township, in Caldwell Township and in East Hanover Township would be relocated.

133. The reservoir area to be utilized for flood control storage would be cleared of brush and fallen timber only below elevation 181.5 feet, m.s.l. The conservation pool would be cleared completely below the same elevation.

134. The channel improvement work on the main stream below the reservoir, to provide a safe discharge capacity of 16,000 c.f.s. at Paterson (design flood 20 percent greater than the 1903 flood as modified by the reservoir), would involve the following: In the reach between the mouth of the Passaic River and the Dundee Dam (Figures 9-11), a channel 150 feet wide with side slopes of 1 on 3 and bottom elevation at 17.0 feet below m.s.l. (14.7 feet below m.l.w.) would be excavated from the Erie Railroad bridge (mile 7.7) to the Eighth Street Bridge (mile 15.0). Thence the channel would extend upstream at a uniform gradient to elevation 0.0 feet, m.s.l. at a point 400 feet downstream from the New York, Susquehanna and Western Railroad bridge (mile 16.4). Local protection works would be limited to the right bank in the reach extending from the Eighth Street Bridge (mile 15.0) to the Wall Street Bridge (mile 15.7) where 1,000 feet of levee and 3,600 feet of concrete wall would be constructed to form a continuous structure with an average height of four feet (Figure 11). Top elevations of the structure would vary from 15.5 feet to 15.9 feet, m.s.l. One pumping unit would be installed behind the protective works. In addition, 600 feet of concrete training wall would be provided at three bridge abutments on the left bank and 300 feet at one bridge abutment on the right bank. In the reach

between Dundee Dam and S.U.M. Dam (Figures 12 and 13), the island at West Broadway Bridge (Island Park) would be excavated to the depth of the surrounding bottom. A 4,200-foot concrete wall would be constructed along the right bank from the Erie Railroad bridge (mile 22.9) to the Hillman Street Bridge (mile 23.8) and one 4,500 feet long from below the Straight Street Bridge (mile 24.1) to the West Broadway Bridge (mile 24.6). On the left bank a concrete wall 5,300 feet long would be constructed between Short Street (mile 23.6) and Island Park (mile 24.8). The walls on the right bank would have an average height of about 3 feet and on the left bank about 4 feet. Top elevations would vary between 41.1 feet and 47.5 feet, m.s.l. Two pumping units would be provided behind the wall on the right bank and one behind the wall on the left bank. In the reach between S.U.M. and Beatties Dam, the plan requires no changes in the existing channel. In the reach between Beatties Dam and Two Bridges (Figures 14 and 15), the channel for its full length of 3.3 miles would be excavated to provide a 200-foot bottom width with side slopes of 1 on 3. In addition three new tainter gates each 35 feet wide would be installed in Beatties Dam. In the reach between Two Bridges and the Two Bridges Dam spillway (Figure 15), a distance of 1,500 feet, a channel would be excavated to provide a 250- to 600-foot bottom width and side slopes of 1 on 3. A levee 1,600 feet in length and about 12 feet high would be constructed on the left bank and a similar structure 800 feet long about six feet high would be constructed on the right bank.

135. All levees in connection with the reservoir and channel improvement plans would be rolled earth embankments with a top width of eight feet and an impervious core and cutoff of compacted clay. Side slopes would be 1 on 3 throughout, with the exception that levees within the reservoir area would have 1 on 4 slopes on the water side. (Figures 7 and 9). Flood walls would be of reinforced concrete with an 18-inch top width and with a steel sheet piling cutoff extending on an average

17 feet below the wall foundation to an impervious soil strata (Figure 9). Top elevations of both levees and walls would be established to allow a freeboard of three feet above the design discharge except in the navigable portion of the river downstream from the Eighth Street Bridge where a freeboard of only two feet would be provided because of the conservative design criterion applied in this reach, that the extreme high tide of record would recur coincidentally with the peak of the design flood (Appendix B).

136. Additional work involved in the channel improvement portion of the plan would include the construction of new bridges to replace the Wall Street Bridge (mile 15.7), 6.9 feet higher; the Erie Railroad spur bridge (mile 16.0), 2.5 feet higher; the Monroe Street Bridge (mile 16.1), 1.5 feet higher; the N. Y. S. & W. R. R. bridge (mile 16.4) at its present elevation; the Main Street Bridge (mile 24.5), 1.8 feet higher and the West Broadway Bridge (mile 24.6) at its present elevation. In addition, the Eighth Street Bridge (mile 15.0), the Hillman Street Bridge (mile 23.8) and the Arch Street Bridge (mile 24.4) would be raised 6.4 feet, 2.1 feet and 4.1 feet, respectively. Two new side spans would be constructed in the Second Street Bridge (mile 14.4); and two old bridge piers adjacent to the N. Y. S. & W. R. R. bridge (mile 19.0); the footbridge (mile 22.9); and the Mulberry Street Bridge (mile 24.7) would be removed.

137. Several factors have controlled the size and balance of various features of this plan. The maximum reservoir stage and, therefore, the height of the Two Bridges Dam were limited by the high cost of land acquisition above elevation 190 feet, m.s.l., and by the correspondingly high cost of protecting certain developments in the upper reaches of the reservoirs against backwater flooding. In this band of high-value properties are the Morristown Airport and the borough of Chatham.

138. The reservoir plan herein proposed, involving construction of the Pompton River diversion channel and dikes, provides the most practicable means of excluding the lands and property in Lincoln Park, Pequannock, Pompton Plains and Wayne from the reservoir area. The cost of this plan is substantially the same as that of an alternate plan involving the construction of a dam across the Passaic River near the mouth of the Pompton which would require no diversion channel but which would include the Pompton Valley as a part of the reservoir area. The latter plan, however, would involve social adjustments of a high order in relocating the inhabitants of this populated area, and is, therefore, not considered to be in accord with the public welfare.

139. The conservation pool of the proposed plan was confined between Route 6 and the Passaic Section of the dam in order to avoid a large stagnant shallow pool in the reservoir area upstream from Route 6. A large shallow pool with less than 6-foot depth of flooding would have greatly increased the mosquito nuisance, and would also have had a deleterious effect on the quality of the stored water for use as a domestic water supply. In contrast, the proposed conservation pool would be deep enough to meet the requirements of both mosquito control and water supply interests.

140. Most of the highways, including Route 10, and all local roads in the reservoir area would be retained at existing elevations. Route 23, in the Pompton section of the reservoir, would be raised to an elevation only three feet above conservation pool level (elev. 176.5 feet, m.s.l.). This policy of minimizing highway relocations was adopted to reduce construction costs and because the possibility of rerouting traffic during major floods offset almost entirely any economic justification for such construction. In this connection it is noted that, under existing conditions, these highways are now subject to flooding, and in most cases the proposed reservoir would result only in increasing the

period rather than the depth of flooding. However, Route 6, the major east-west highway in the reservoir, would be raised for protection against inundation because of the importance of this main artery.

141. Deepening the 10-foot project section of the navigation channel to 14.7 feet below mean low water above the Erie Railroad bridge, (mile 7.7) is proposed due to the substantial flood control and navigation benefits which are directly obtainable from this work.

142. Plan III - Local Protection Plan. This plan (Plate 5 and Figure 16) provides for excavation of an eight and one-half mile reach of the navigation channel below Dundee Dam (Figures 17 through 19), and a four mile reach of the channel below the West Broadway Bridge (Figures 20 and 21), and for the construction of walls and levees on both sides of the stream at the two critical damage areas in Paterson and Passaic (Figures 18, 19 and 21). Pertinent data on the various features of this plan are given in Table XXV.

143. The improvement is designed to provide protection by walls and levees against flooding from a recurrence of the 1903 discharge (35,800 c.f.s. at Paterson), in those localized sections of the Lower Valley where damages are most severe. Where the channel is excavated, reduction in flood stages would be effected and for a recurrence of a 1903 flood, would amount to as much as three feet in parts of the channel. In addition to protecting portions of Paterson and Passaic, the project would provide complete protection against a 1903 flood flow in Wallington and East Rutherford. Levees and flood walls would be of the same design as those described under Plan II (paragraph 135). All works are planned so as to permit their future integration into a complete channel protection plan for the entire river should such a plan ultimately be desired.

TABLE XXV

PERTINENT DATA

PLAN III
LOCAL PROTECTION PLAN
DESIGN FLOOD - 35,800 C.F.S. AT DUNDEE DAM

PASSAIC RIVER WATERSHED

Item	Mouth to Dundee Dam		Dundee Dam to S.U.M. Dam		Total
	Left Bank	Right Bank	Left Bank	Right Bank	
Channel Excavation					
Length (feet)	46,200		21,800		68,000
Bottom width (feet)	150		250-280-210		-
Bottom gradient (feet per foot)	0.0-0.00243		0.00034-0.00455		-
Earth Levees(1)					
Length (feet)	4,900	800	-	-	5,700
Maximum height above ground, river side (feet)	8	12	-	-	-
Average height above ground, river side (feet)	7	10	-	-	-
Concrete Walls					
Length (feet)	5,900	10,700	8,200	11,600	36,400
Maximum height above ground, river side (feet)	9	12	9	9	-
Average height above ground, river side (feet)	5	8	6	6	-
Average height above channel bottom (feet)	36	35	20	21	-
Interior Drainage					
Number of pumping plants required	2	1	2	2	7
Range of capacity of pumping plants (G.P.M.)	162,000 to 300,000	75,000	85,000 to 167,000	196,000 to 209,000	-
Bridge Work					
Number of bridges to be raised	4(2)		4		8(2)
Number of new bridges	8(3)		7		15(3)
Number of bridges to be removed	1		3(4)		4(4)
Lands, Easements and Rights-of-Way (acres)	64		169		233

(1) All levees would have a top width of 8 feet and side slopes of 1 on 3
(2) Includes two bridges with new side spans
(3) Includes one bridge with new side span only
(4) One involves removal of abandoned bridge piers only

144. Plan III would involve, in the reach between the mouth and Dundee Dam, excavation of the navigation channel between the Erie Railroad bridge (mile 7.7) and the New York, Susquehanna and Western Railroad bridge (mile 16.4) identical to the excavation provided under Plans I and II (Figures 17-19). On the right bank between Weasel Brook (mile 14.2) and the Wall Street Bridge (mile 15.8) 800 feet of levee and 9,300 feet of concrete wall would be constructed to form a continuous structure with an average height of eight feet (Figure 19). An additional 900 feet of concrete wall would be provided on the right bank of Weasel Brook between Passaic and Jefferson Streets. On the left bank of the main stream between the Erie Railroad bridge (mile 13.3) and the Eighth Street Bridge (mile 15.0), 4,900 feet of levee and 5,100 feet of concrete wall would be constructed to form a continuous structure with an average height of six feet (Figures 18 and 19). Top elevations would vary from 18.1 to 22.5 feet, m.s.l. One pumping unit would be provided behind the wall on the right bank and two behind the wall on the left bank. In addition, 500 feet of concrete training wall would be provided at bridge abutments on the right bank and 800 feet at bridge abutments on the left bank.

145. In the reach between Dundee Dam and S.U.M. Dam, the channel would be excavated from a point 800 feet downstream from the East 33rd Street Bridge (mile 20.8) upstream to a point 800 feet above the West Broadway Bridge (mile 24.6) (Figures 20 and 21). The improved channel from its downstream end to the New York, Susquehanna and Western Railroad bridge (mile 22.7) would have a 250-foot bottom width; upstream therefrom to the Sixth Avenue Bridge (mile 23.4) it would have a 300-foot bottom width and thence to the upstream end of the improvement above the West Broadway Bridge (mile 24.6) it would have a 210-foot bottom width. Side slopes would be 1 on 3 throughout except where the channel is confined by walls. On the right bank a continuous concrete

wall, 10,400 feet long would be constructed between the Erie Railroad bridge (mile 22.9) and Prospect Street (mile 24.8), and on the left bank a wall 7,400 feet long would be constructed between the Sixth Avenue Bridge (mile 23.4) and Island Park (mile 24.8) (Figure 21). Both walls would have an average height of about six feet. Top elevation would vary from 46.8 to 51.7 feet, m.s.l. Two pumping units would be provided behind the wall on the right bank and two behind the wall on the left bank. In addition, 1,200 feet of concrete training wall would be provided at six bridge abutments on the right bank and 800 feet at four abutments on the left bank.

146. Additional work involved under Plan III would involve modification and reconstruction of many bridges. In the reach between the mouth and Dundee Dam, the following bridge work would be required. The Union Avenue Bridge (mile 12.9) would be raised 3.3 feet and new side spans would be constructed at a corresponding elevation. The approach span of the Erie Railroad bridge (mile 13.3) would be replaced with a new span at a 14.9-foot higher elevation. The Gregory Avenue Bridge (mile 13.8) would be raised 6.3 feet. The Second Street Bridge (mile 14.4) would be raised 9.3 feet and the two side spans would be replaced. The Eighth Street Bridge (mile 15.0) would be raised 12.3 feet. The Wall Street Bridge (mile 15.7) would be replaced by a new structure 13.1 feet higher, the Erie Railroad bridge (mile 16.0) by one 9.3 feet higher, the Monroe Street Bridge (mile 16.1) by one 8.8 feet higher, the New York, Susquehanna and Western Railroad bridge (mile 16.4) by one 0.6 foot higher and the Ackerman Avenue Bridge (mile 17.0) by one 6.3 feet higher. In addition, alterations would be made in bridges crossing two of the tributaries joining the main stem in this reach, namely on Weasel Brook where the wooden bridge at the mouth (mile 14.2) would be replaced by a new structure at a 12.4-foot higher elevation, and on Saddle River where the Midland Avenue Bridge (mile 15.6) would be replaced by a new structure

at a 14.4-foot higher elevation. In the reach between the Dundee Dam and the S.U.M. Dam the following bridges would be raised by the amounts indicated: Market Street Bridge (mile 18.9), 4.3 feet; East 33rd Street Bridge (mile 20.8), 5.3 feet; Erie Railroad bridge (mile 22.9), 5.7 feet, and the Straight Street Bridge (mile 24.1), 5.0 feet. The following bridges would be replaced by new structures raised above the existing clearance elevations the amount indicated: Maple Avenue (Wagaraw) Bridge (mile 22.1), 4.0 feet; East 19th Street Bridge (mile 22.3), 6.5 feet; Sixth Avenue Bridge (mile 23.4), 1.3 feet; Hillman Street Bridge (mile 23.8), 6.0 feet; Arch Street Bridge (mile 24.4), 7.8 feet; Main Street Bridge (mile 24.5), 5.7 feet; and West Broadway Bridge (mile 24.6), 0.9 foot. In addition, two old piers no longer in use at the New York, Susquehanna and Western Railroad bridge (mile 19.0), the existing suspension footbridge (mile 22.9), and the motor car entrance bridge to Island Park (mile 24.7) would be removed.

147. Local Protection, Weasel Brook. The plan for flood control on Weasel Brook provides protection for the highly developed industrial, commercial and residential areas located on both banks of the stream from Monroe Street (mile 0.7) in Passaic to Third Street (mile 2.4) in Clifton (Figures 23, 24, and 25). The total length of the improvement would be 8,700 feet, of which 3,000 feet would be in the city of Passaic and 5,700 feet in the city of Clifton.

148. The improvement would afford protection against a recurrence of the 1903 flood (design flood of 1,300 c.f.s. at Clifton) which is three times the discharge of the 1945 flood, the largest flood of recent occurrence.

149. The plan would involve the construction of a concrete flume for practically the entire length of the improvement including channel relocation at sharp bends in the existing stream, and provision of new or reconstructed bridges and culverts. Details of the plan are described in the following paragraphs, and pertinent data are given in Table XXVI.

TABLE XXVI

PERTINENT DATA, LOCAL PROTECTION FOR WEASEL BROOK,

PASSAIC RIVER WATERSHED, N. J.

(Design Flood 1,300 c.f.s. at Clifton)

Channel Excavation	
Length (feet)	220
Bottom width (feet)	20 - 30
Bottom gradient (feet per foot)	.016
Concrete Flume	
Type B - Reinforced concrete walls, length (feet)	2,080
Type C - Gravity walls, length (feet)	3,640
Total length (feet)	5,720
Average height of walls above paving (feet)	10
Width of paving (feet)	20 - 30
Concrete Culvert (Exclusive of Bridges) Type A	
Length (feet)	1,670
Average width (feet)	20
Average inside height (feet)	10
Bridge Work (Culverts)	
Number of new bridges	14 (a)
Number of bridges, strengthened	1
Length (feet)	1,100
Lands, Easements and Rights-of-Way (acres)	11

(a) Includes 12 highway bridges, one railroad bridge and one footbridge

150. The concrete flume, 5,720 feet in length, would consist in part, of gravity wall sections (3,640 feet) and in part of reinforced concrete wall sections (2,080 feet). The concrete flume including culverts (8,500 feet) would be aligned with the existing channel for 4,800 feet and realigned at various locations for 3,700 feet. Width of the flume would vary from 30 feet in the downstream to 20 feet in the upstream portions. New walls would in general, have a height of 10 feet above the paved channel bottom with top elevation corresponding to the general existing bank elevation. Existing walls between Sherman and Monroe Streets in Passaic would be raised two to three feet. Compared with the existing channel, the flume would have a channel bottom generally three to five feet lower and widths as much as 10 feet greater.

151. Twelve existing highway bridges, one railroad bridge and one footbridge would be replaced by new bridges or culverts. Culverts would also be constructed under some buildings and structures in the improved channel. These culverts would aggregate 2,770 feet in length. In addition, the abutments of one existing bridge would be strengthened.

152. Local Protection, Saddle River. The plan for flood control on the Saddle River provides protection for a concentrated industrial and commercial area located on the left bank of the river between Passaic Street and State Highway Route No. 6 in the borough of Lodi, for a total length of about 4,000 feet, and for a commercial and residential area along a tributary stream entering the Saddle River about midway between the limits of the proposed improvement (Figure 26). On the right bank, except for a power plant which would experience only minor flooding under the design flood, the area is undeveloped. The improvement would afford protection against a recurrence of the 1903 flood (design flood of 7,000 c.f.s. at Lodi) which is twice the discharge of the 1945 flood, the largest recent flood. It would involve channel relocation, levee and wall construction, and improvement of the tributary stream. Details of the plan are described in the following paragraphs, and pertinent data are given in Table XXVII.

153. A sharp reverse curve in the existing stream immediately above the Passaic Street Bridge would be eliminated by excavation of a new channel, with a bottom width of 30 feet and a length of about 600 feet through low wasteland. A levee along the left bank of the relocated channel would be provided in lieu of a more expensive flood wall along the existing channel. A sharp bend in the stream at the Arnot Street Bridge would be eliminated by relocation of the bridge and excavation of a new channel for a length of about 1,000 feet. The new channel alignment would permit construction of a levee in lieu of more expensive flood walls.

TABLE XXVII

PERTINENT DATA, LOCAL PROTECTION FOR SADDLE RIVER, PASSAIC RIVER WATERSHED, N. J.

(Design Flood 7,000 c.f.s. at Lodi)

Channel Excavation	
Length (feet)	1,800
Bottom width (feet)	30
Bottom gradient (feet per foot)	.002
Earth Levees (Left Bank)	
Length (feet)	2,200
Maximum height above ground, river side (feet)	20
Average height above ground, river side (feet)	10
Top width (feet)	8
Side slopes, both sides	1 on 3
Concrete Walls (Left Bank)	
Length (feet)	1,350
Maximum height above ground, river side (feet)	20
Average height above ground, river side (feet)	10
Average height above channel bottom (feet)	17
Interior Drainage	
Number of pumping plants required	1
Capacity of pumping plants (g.p.m.)	175,000
Bridge Work	
Number of bridges to be raised. (Highway)	1
Number of bridges to be raised. (Utility Crossings)	4
Number of bridges to be removed.	2
Lands, Easements and Rights-of-Way (acres)	8

154. Work would also involve construction along the left bank of 1,350 feet of concrete flood walls and 2,200 feet of levees, up to 20 feet in height, lining and capping existing building foundation walls at several locations, and construction of a retaining wall 250 feet long and up to eight feet high to prevent encroachment of the levee embankment on a railroad siding. Levee closures at limits of the proposed improvement would be effected by raising streets a maximum of six feet for an aggregate length of about 900 feet. A freeboard of three feet above the design flow line would be provided for levees and walls.

155. The Arnot Street Bridge would be relocated over the new channel about 130 feet to the right of the existing channel and would be placed at an elevation 9.5 feet higher than its present elevation. Two short approach spans would be added as approaches. Two abandoned private bridges would be removed, and four structures supporting pipes and a coal belt conveyor crossing the river would be raised.

156. At the mouth of a small tributary entering Saddle River from the east, work would include the construction of a box culvert 14 feet wide, 6.5 feet high and 450 feet long to replace an existing inadequate culvert now carrying the stream beneath a large building; additional work would involve the enlargement of the channel upstream and downstream of the culvert to a bottom width of 14 feet; extension of an existing culvert under a railroad siding through the new levee; installation of flood gates and construction of a 175,000 g.p.m. pumping plant.

157. Local Protection, Molly Ann's Brook. The plan for flood control on Molly Ann's Brook provides protection for residential, commercial and industrial developments between West Broadway and Church Street in the borough of Haledon for a total length of about 6,000 feet (Figure 27). The improvement would afford protection against recurrence of the 1903 flood (design flood of 1,950 c.f.s.) which is about twice the discharge of the 1945 flood, the largest recent flood. It would involve channel straightening and widening, levee and concrete flume construction, and bridge reconstruction. Details of the plan are described in the following paragraphs, and pertinent data are given in Table XXVIII.

158. The existing channel would be straightened and widened to 60 feet bottom width for a distance of about 1,700 feet from West Broadway upstream to a point below Belmont Avenue; and for a distance of about 1,400 feet from a point about 500 feet upstream of Haledon Avenue to Church Street. Riprap paving would be placed at the entrance and exit of the paved flume.

TABLE XXVIII

PERTINENT DATA, LOCAL PROTECTION FOR MOLLY ANN'S BROOK,

PASSAIC RIVER WATERSHED, N. J.

(Design Flood 1,950 c.f.s. at Haledon)

Item	Left Bank	Right Bank
Channel Excavation		
Length (feet)	3,100	
Bottom width (feet)	60	
Bottom gradient (feet per foot)	.005 to .010	
Earth Levees		
Length (feet)	500	2,400
Maximum height above ground, river side (feet)	7	11
Average height above ground, river side (feet)	4	7
Top width (feet)	8	8
Side slopes, both sides	1 on 3	1 on 3
Concrete Flume		
Length (feet)	2,800	
Height of walls above paving (feet)	7	
Width of paving (feet)	30	
Interior Drainage		
Number of pumping plants required	1	1
Capacity of pumping plants (g.p.m.)	17,000	50,000
Bridge Work		
Number of bridges to be raised (Highway)	1	
Number of new bridges (Highway)	5	
Number of bridges to be removed (Footbridge)	1	
Lands, Easements and Rights-of-Way (Acres)	15	

159. Levee work would involve construction of a levee along the right bank of the proposed channel in the reach between West Broadway and Lee Avenue, about 1,000 feet long with a maximum height of 11 feet; and a levee along the left bank between Lee Avenue and Belmont Avenue about 500 feet long with a maximum height of 7 feet. The existing dike along the right bank between Haledon Avenue and Church Street which forms one side of the Lakeside Bathing Beach would be reconstructed to form a levee for a length of about 1,400 feet and maximum height of 10 feet. A freeboard

of three feet above the design flow line would be provided for all levees. Pumping plants would be constructed behind the levees at the downstream portion of the improvement to provide for interior drainage. A 17,000 g.p.m. pumping plant would be located on the left bank above Lee Avenue and a plant of 50,000 g.p.m. capacity would be provided on the right bank upstream from West Broadway.

160. A concrete flume 30 feet wide and 7 feet high for a distance of about 2,800 feet would be required in the highly developed section between Belmont Avenue and Haledon Avenue. A concrete weir would be provided at the upper end of the flume and a stilling basin at the downstream end. A minimum freeboard of three feet above the design flow line would be provided for the walls of the flume.

161. The West Broadway Bridge would be raised 2.6 feet, and the footbridge downstream from Haledon Avenue would be removed. The five bridges at Belmont Avenue, Row Street, Ida Street, Haledon Avenue and Church Street, would be reconstructed to conform with the improved channel, with vertical clearances ranging from 0.3 feet to 4.1 feet greater than the existing structures. The raised bridge approaches at West Broadway and Church Street would form levee closures at the lower and upper limits of the project.

162. Reconstruction of Lake Denmark and Picatinny Lake Dams. The improvement would provide for replacement of the existing Lake Denmark and Picatinny Lake Dams by new structures with enlarged spillways to accommodate safely, but with minimum freeboard, the discharge of a maximum probable flood (Figures 28 through 30).

163. The existing Lake Denmark Dam would be replaced by a new concrete dam and spillway, about 575 feet long, founded on rock (Figure 29). The non-overflow section would have a top width of five feet, a maximum height of 18.5 feet, and a top elevation of 828.0 feet, m.s.l. A freeboard of 5.4 feet would be provided to the top of dam above an inflow

flood of 5,600 c.f.s. (standard project flood). The spillway would be an ogee section located near the north end of the dam. It would be 100 feet long, and would have a crest elevation of 818.0 feet, m.s.l., which is substantially the same as the elevation of the existing rock spillway. The discharge channel below the spillway would be about 95 feet long, with a width varying from 110 feet to 60 feet, and would terminate in a bucket for energy dissipation. The five existing 72-inch pipes through the railroad and highway embankment downstream from the dam would be replaced by a new railroad and highway bridge which would span the spillway channel. Two 18-inch outlets with manually operated gates would be provided through the non-overflow section at the ends of the spillway. A section of the Wharton and Northern Railroad which crosses the proposed dam near the south abutment would require raising a maximum height of about three feet.

164. The existing Picatinny Lake Dam would be replaced by a new earth dam and concrete spillway having a total length of about 1,200 feet (Figure 30). The earth section would have a top width of 20 feet, side slopes of 1 on 3, a maximum height of 22 feet, and a top elevation of 725 feet m.s.l. The maximum water surface elevation for the standard project inflow flood of 7,800 c.f.s. would be 718.6 feet, m.s.l., corresponding to a freeboard of 6.4 feet to the top of dam. The spillway would be an ogee section located near the north end of the dam, and would be 125 feet in length with a crest elevation of 712.4 feet, m.s.l. The new crest elevation is the same elevation as the top of existing flash boards. A chute 87.5 feet long, a drop section 110 feet long with a drop of 16 feet, and a stilling basin 95 feet long, would be constructed with a uniform width of 125 feet. Two 24-inch pipe outlets with manually operated gates would be provided through a short concrete non-overflow section at the south end of the spillway. A sheet piling cut-off 35 feet deep would be provided in the foundation under the dam and spillway, and 20 feet deep

under the stilling basin sill to prevent detrimental underseepage. An existing highway bridge immediately downstream from the proposed stilling basin would be replaced by a new bridge with two 62.5-foot spans raised about nine feet above the existing roadway. A single track railroad and adjacent highway which parallel the north wall of the new spillway channel would be relocated on higher ground toward the north for a distance of about 1,800 feet.

XVII.. MULTIPLE-PURPOSE FEATURES

165. The Two Bridges Multiple-Purpose Reservoir (Plan II) was designed to meet the desires of the State Conservation Department and other interests for an increased dependable dry-season flow to be used primarily for immediate water supply requirements, and also to accommodate reasonable future water supply needs of the Northern Metropolitan District (paragraphs 33 and 34). The topographic and cultural features of the reservoir area limit the volume of conservation storage which can be provided economically to a maximum of about 70,000 acre feet. The depth of the conservation pool would be sufficient to assure water of an acceptable quality for domestic use with some treatment. The proposed conservation storage would provide a regulated dry-season flow of 300 c.f.s. This supply would be available for use within an area comprising about 70 per cent of the Northern Metropolitan District, to the extent required to meet future demands in that area. The State Department of Conservation, after discussion with interested water supply agencies, stated that an immediate prospective increase in the safe yield of the Passaic River above Beatties Dam in an amount of 80 m.g.d. could be used for water supply by existing water supply agencies as follows: 25 m.g.d. for the North Jersey Water Supply Commission, 25 m.g.d. for the Passaic Valley Water Commission, 25 m.g.d. for the Hackensack Water Commission, and 5 m.g.d. for the State of New Jersey. In addition, it is reasonable to expect that Jersey City and Newark with aqueducts adjacent to the

conservation pool would also require a portion of this water. Therefore, the amount required to meet the prospective needs of the area that can be economically serviced in the Northern Metropolitan District by additional water supply developed at Two Bridges was established at 80 m.g.d. (124 c.f.s.) when the supply becomes available and at 120 m.g.d. or 186 c.f.s. at about the mid life of the structure in 1975. This amount confirms the estimates of future water supply requirements based upon population and per capita consumption (Appendix C) and corresponds to an average annual rate of increase of 4 m.g.d., within the area which can be serviced by the reservoir, over a period of 30 years. The surplus flow available from the Two Bridges Reservoir would ultimately be absorbed by future water supply requirements beyond 1975, and in the interim period would be available for other purposes such as increase in primary energy at downstream hydro plants and for pollution abatement. The extent of the benefits obtainable under these categories is discussed in Section XXI.

166. Control works of the multiple-purpose reservoir would be operated so as to maintain the conservation pool during normal periods as nearly as possible at its spillway level of 176.5 feet m.s.l. from the flow of the Pompton River. The Passaic River during these periods would bypass the conservation pool through an improved Deepavaal Brook, and would discharge through the six outlet conduits in the Passaic Section of the dam into Deepavaal Brook which discharges into the Passaic River below Two Bridges. Flood stages above spillway elevation of 176.5 feet, m.s.l. would cause discharge through the five spillways in the conservation section of the dam leading from the conservation pool to the flood detention storage area. Lowlands in the flood detention storage area up to elevation 169 feet, m.s.l. comprising about 43 per cent of the area would be flooded on an average of once a year, 54 per cent of the area would be flooded every two years, 65 per cent once in ten years, and

66 per cent once in 100 years. Under natural conditions without the reservoir, 28 per cent of the area is flooded about once a year, 38 per cent every two years, 48 per cent once in ten years and 75 per cent once in 100 years. If adopted as a project, the reservoir would be constructed with Federal funds augmented by local contributions or their equivalent as determined by allocation of costs in proportion to the reservoir capacity utilized for water resources conservation and flood control. The project would be operated by the United States, with releases made from conservation storage in accordance with the desires of water supply and power interests.

XVIII. RECREATIONAL DEVELOPMENT

167. Two Bridges Flood Detention Reservoir (Plan I). A definite need exists for recreational development in the Two Bridges area, in view of its proximity to large centers of population and the lack of adequate existing recreational developments. New Jersey communities with an aggregate population of about 1,000,000 persons are located from 6 to 17 miles from the area, while the vast population of New York City is distant an average of only 20 miles from the dam site. The economic level of the population of this area is well above the national average. Types of recreation which were considered, included picnic grounds, playfields, and hiking and riding trails. Consideration was given to the possible development of small permanent lakes around the periphery of the reservoir at elevation 184.5 feet m.s.l. by construction of small dams at the junction of several tributary streams with the Passaic and Rockaway Rivers in order to provide swimming, boating and fishing facilities for an estimated day-use design load of about 15,000 persons. However, a preliminary survey indicates that the lakes which might be formed near the periphery of the reservoir would not be of adequate size to meet the anticipated needs, and the low-water runoff of the tributaries would be insufficient to insure

against stagnation. Moreover, the prevalence of the mosquito nuisance under existing conditions in this general locality would ordinarily preclude provision of overnight recreational facilities. However, lowering of the outlet of the Two Bridges Dam, installation of gates in Beatties Dam and construction of drains in the reservoir area leading to the outlet would considerably alleviate the local mosquito nuisance. Under these conditions extension of the recreational facilities to overnight use might ultimately prove practicable. It is concluded that the detention reservoir affords little opportunity for recreational development of these types.

168. However, there is opportunity through Federal or state ownership of the lands to preserve a wild life refuge in the area, particularly in the Troy Meadows. This locality is by far the most important wild life habitat of its kind within 150 miles of the New York metropolitan area.

169. Two Bridges Multiple-Purpose Reservoir (Plan II). Introduction in the Two Bridges Reservoir of a conservation pool having a water-surface area of about 6,200 acres would afford considerable incidental recreational value. Evaluation of these benefits in monetary terms is difficult because of intangible values. A feasible site for recreational development would be provided along the west side of the conservation pool for a distance of about three miles along Pine Brook Road between Passaic Avenue and Hook Mountain Road. The site would be about a half mile wide and would involve relocation of Pine Brook Road west of its present location. This site could accommodate a day-use load of 8,000 to 10,000 people. Since the area would be adjacent to the part of the project to be used for water supply, the use and development of the perimeter should be controlled directly by the State or County.

170. A report on the recreational resources of the Two Bridges Reservoir compiled by the National Park Service is included in Appendix J.

XIX. ESTIMATES OF FIRST COST

171. General. The estimated first costs of the Two Bridges Detention Reservoir Project (Plan I), the Two Bridges Multiple-Purpose Reservoir Project (Plan II) and the local protection project on the main stream (Plan III) are summarized in Tables XXIX, XXX, and XXXI. Summaries of the estimated first costs of channel improvement projects for Weasel Brook, Saddle River, and Molly Ann's Brook are given in Table XXXII, and the estimated costs for reconstruction of Lake Denmark and Picatinny Lake Dams are given in Table XXXIII. All estimates of cost are based on May 1948 price levels. Detailed cost estimates for these plans are contained in Appendix F.

XX. ESTIMATES OF ANNUAL CHARGES

172. Estimates of annual charges are based on interest charges of 3 percent for Federal expenditures and $3\frac{1}{2}$ percent for non-Federal expenditures. Charges for amortization of the various structures are based on a life expectancy of 50 years. All estimates are based on May 1948 price levels. The estimated annual charges including operation and maintenance, and annual operation and maintenance costs for the Two Bridges Detention Reservoir Project (Plan I), the Two Bridges Multiple-Purpose Reservoir Project (Plan II), and the Local Protection Project (Plan III), are contained in Table XXXIV. Summaries of the estimated annual charges including operation and maintenance and annual costs of operation and maintenance of the channel improvement projects for Weasel Brook, Saddle River and Molly Ann's Brook are given in Table XXXV. Estimated annual charges including operation and maintenance and annual cost of operation and maintenance for reconstruction of Lake Denmark and Picatinny Lake Dams are given in Table XXXVI. Details of the estimated annual charges are given in Appendix F.

TABLE XXIX

ESTIMATE OF FIRST COST

PLAN I - TWO BRIDGES DETENTION RESERVOIR

WITH MAIN STREAM CHANNEL IMPROVEMENT

PASSAIC RIVER WATERSHED, N. J.

(May 1948 Price Level)

Item	Estimated Cost in Dollars		
	Federal	Non-Federal	Total
DAM AND RESERVOIR			
Passaic Dam and Reservoir			
Construction	23,267,000	-	23,267,000
Relocations	5,200,000	-	5,200,000
Lands, Easements and Rights-of-Way	14,400,000	-	14,400,000
Sub-Total	42,867,000	-	42,867,000
Rounded to	42,900,000	-	42,900,000
Pompton Diversion Channel Dam and Dikes			
Construction	22,832,000	-	22,832,000
Relocations	4,582,000	-	4,582,000
Lands, Easements and Rights-of-Way	420,000	-	420,000
Sub-Total	27,834,000	-	27,834,000
Rounded to	27,800,000	-	27,800,000
Total - Dam and Reservoir	70,701,000	-	70,701,000
Rounded to	70,700,000	-	70,700,000
CHANNEL IMPROVEMENT			
Channel Excavation	3,975,000	-	3,975,000
Levee and Wall Construction	4,848,600	-	4,848,600
Alteration of Beatties Dam	91,500	-	91,500
Utilities & Interior Drainage	2,550,000	232,000	2,782,000
Bridges and Approaches	1,576,100	1,164,700	2,740,800
Lands, Easements and Rights-of-Way	-	853,100	853,100
Total - Channel Improvement	13,041,200	2,249,800	15,291,000
Rounded to	13,000,000	2,300,000	15,300,000
GRAND TOTAL - PLAN I	83,742,200	2,249,800	85,992,000
Rounded to	83,700,000	2,300,000	86,000,000

TABLE XXX

ESTIMATE OF FIRST COST

PLAN II - TWO BRIDGES MULTIPLE PURPOSE RESERVOIR

WITH MAIN STREAM CHANNEL IMPROVEMENT

PASSAIC RIVER WATERSHED, N. J.

(May 1948 Price Level)

Item	Estimated Cost in Dollars		
	Federal	Non-Federal	Total
DAM AND RESERVOIR			
Passaic Dam and Reservoir			
Construction	27,313,600	-	27,313,600
Relocations	8,780,400	-	8,780,400
Lands, Easements and Rights-of-Way	16,400,000	-	16,400,000
Sub-Total	52,494,000	-	52,494,000
Rounded to	52,500,000		52,500,000
Pompton Diversion Channel Dam and Dikes			
Construction	23,012,000	-	23,012,000
Relocations	5,115,200	-	5,115,200
Lands, Easements and Rights-of-way	419,800	-	419,800
Sub-Total	28,547,000	-	28,547,000
Rounded to	28,500,000	-	28,500,000
Total - Dam and Reservoir	81,041,000	-	81,041,000
Rounded to	81,000,000[a]	-	81,000,000
CHANNEL IMPROVEMENT			
Channel Excavation	3,975,000	-	3,975,000
Levee and Wall Construction	4,848,600	-	4,848,600
Alteration of Beatties Dam	91,500	-	91,500
Utilities & Interior Drainage	2,550,000	232,000	2,782,000
Bridges and Approaches	1,576,100	1,164,700	2,740,800
Lands, Easements and Rights-of-way	-	853,100	853,100
Total - Channel Improvement	13,041,200	2,249,800	15,291,000
Rounded to	13,000,000	2,300,000	15,300,000
GRAND TOTAL - PLAN II	94,082,200	2,249,800	96,332,000
Rounded to	94,000,000[a]	2,300,000	96,300,000

a Includes $26,300,000 allocated to conservation use, a non-Federal charge (Table XLII).

TABLE XXXI

ESTIMATE OF FIRST COST

PLAN III - MAIN STREAM CHANNEL IMPROVEMENT

PASSAIC RIVER WATERSHED, N. J.

(May 1948 Price Level)

Item	Estimated Cost in Dollars		
	Federal	Non-Federal	Total
MOUTH TO DUNDEE DAM			
Channel Excavation	2,792,500	-	2,792,500
Levee and Wall Construction	5,259,700	-	5,259,700
Utilities & Interior Drainage	1,764,700	144,300	1,909,000
Bridges and Approaches	2,383,000	1,701,000	4,084,000
Lands, Easements and Rights-of-Way	-	1,362,800	1,362,800
Total - Mouth to Dundee Dam	12,199,900	3,208,100	15,408,000
Rounded to	12,200,000	3,200,000	15,400,000
DUNDEE DAM TO S.U.M. DAM			
Channel Excavation	1,680,700	-	1,680,700
Levee and Wall Construction	7,212,000	-	7,212,000
Utilities & Interior Drainage	2,855,100	335,500	3,190,600
Bridges and Approaches	620,700	2,177,600	2,798,300
Lands, Easements and Rights-of-Way	-	1,988,400	1,988,400
Total - Dundee Dam to S.U.M. Dam	12,368,500	4,501,500	16,870,000
Rounded to	12,400,000	4,500,000	16,900,000
GRAND TOTAL - PLAN III	24,568,400	7,709,600	32,278,000
Rounded to	24,600,000	7,700,000	32,300,000

TABLE XXXII

ESTIMATE OF FIRST COST

LOCAL PROTECTION PLANS - MINOR TRIBUTARIES

PASSAIC RIVER WATERSHED, N. J.

(May 1948 Price Level)

Item	Estimated Cost in Dollars		
	Federal	Non-Federal	Total
Weasel Brook	2,650,000	1,100,000	3,750,000
Saddle River	1,235,000	240,000	1,475,000
Molly Ann's Brook	1,450,000	490,000	1,940,000

TABLE XXXIII

ESTIMATE OF FIRST COST

RECONSTRUCTION OF LAKE DENMARK AND PICATINNY LAKE DAMS

PASSAIC RIVER WATERSHED, N. J.

(May 1948 Price Level)

Item	Estimated Cost in Dollars (Federal)
Lake Denmark Dam	
Construction	353,200
Relocations and Bridge Reconstruction	78,800
TOTAL	432,000
Rounded to	450,000
Picatinny Lake Dam	
Construction	1,146,400
Relocations and Bridge Reconstruction	181,600
TOTAL	1,328,000
Rounded to	1,350,000
GRAND TOTAL - Lake Denmark and Picatinny Lake Dams	1,760,000
Rounded to	1,800,000

TABLE XXXIV

ANNUAL CHARGES (INCLUDING OPERATION AND MAINTENANCE)

PLANS I, II, & III

PASSAIC RIVER WATERSHED, N. J.

(May 1948 Price Level)

Item	Annual Charges in Dollars (Including Operation and Maintenance)		
	Federal	Non-Federal	Total
PLAN I - TWO BRIDGES DETENTION RESERVOIR WITH CHANNEL IMPROVEMENT			
Dam & Reservoir	2,749,100	46,000	2,795,100
Channel Improvement	537,700	148,900	686,600
Total - Plan I	3,286,800	194,900	3,481,700
PLAN II - TWO BRIDGES MULTIPLE-PURPOSE RESERVOIR WITH CHANNEL IMPROVEMENT			
Dam & Reservoir	3,088,200[a]	114,000	3,202,200
Channel Improvement	537,700	148,900	686,600
Total - Plan II	3,625,900[a]	262,900	3,888,800
PLAN III - LOCAL PROTECTION PLAN			
Channel Improvement			
Mouth to Dundee Dam	502,400	161,900	664,300
Dundee Dam to S.U.M. Dam	476,800	247,200	724,000
Total - Plan III	979,200	409,100	1,388,300

a Includes annual charges of $1,044,000 on 26,300,000 allocated to conservation use, a non-Federal charge (Table XLI).

ANNUAL COSTS OF OPERATION AND MAINTENANCE

(May 1948 Price Level)

Item	Operation and Maintenance		
	Federal	Non-Federal	Total
PLAN I - TWO BRIDGES DETENTION RESERVOIR WITH CHANNEL IMPROVEMENT			
Dam & Reservoir	119,000	0	119,000
Channel Improvement	33,000	50,000	83,000
Total - Plan I	152,000	50,000	202,000
PLAN II - TWO BRIDGES MULTIPLE-PURPOSE RESERVOIR WITH CHANNEL IMPROVEMENT			
Dam & Reservoir	72,500	61,500	134,000
Channel Improvement	33,000	50,000	83,000
Total - Plan II	105,500	111,500	217,000
PLAN III - LOCAL PROTECTION PLAN			
Channel Improvement			
Mouth to Dundee Dam	30,000	21,000	51,000
Dundee Dam to S.U.M. Dam	0	45,000	45,000
Total - Plan III	30,000	66,000	96,000

TABLE XXXV

ANNUAL CHARGES

LOCAL PROTECTION PLANS - MINOR TRIBUTARIES

PASSAIC RIVER, N. J.

(May 1948 Price Level)

Item	Annual Charges (Including Operation and Maintenance)		
	Federal	Non-Federal	Total
Weasel Brook	102,800	60,100	162,900
Saddle River	48,000	22,700	70,700
Molly Ann's Brook	56,000	36,000	92,000

ANNUAL COSTS OF OPERATION AND MAINTENANCE

(May 1948 Price Level)

Item	Federal	Non-Federal	Total
Weasel Brook	0	12,000	12,000
Saddle River	0	11,000	11,000
Molly Ann's Brook	0	12,000	12,000

TABLE XXXVI

ANNUAL CHARGES (INCLUDING OPERATION AND MAINTENANCE) AND

ANNUAL COST OF OPERATION AND MAINTENANCE

RECONSTRUCTION OF LAKE DENMARK AND PICATINNY LAKE DAMS

PASSAIC RIVER, N. J.

(May 1948 Price Level)

Item	Annual Changes Federal	Annual Cost of Operation and Maint. Federal
Reconstruction of Lake Denmark Dam	25,400	8,600
Reconstruction of Picatinny Lake Dam	63,100	11,500
Total	88,500	20,100

XXI ESTIMATES OF AVERAGE ANNUAL BENEFITS

173. Basis of Average Annual Benefits. Benefits which would accrue to the various plans of improvements are summarized in Tables XXXIX and XL. Details are given in Appendix G. These benefits include in varying degree:

a. Benefits directly attributable to prevention of flood damage;

b. Collateral benefits attributable to additional water supply, abatement of stream pollution, increased firm power generating capacity and energy, improvement to navigation, reduction of the mosquito nuisance and enhancement of land values; and

c. Intangible benefits.

Although the Passaic watershed is interstate in character, all direct benefits under the plans discussed in this report will accrue exclusively to areas in the State of New Jersey. The basis for determining the average annual benefits is outlined in the following paragraphs. In order that the flood benefits, which are based on July 1946 valuations of flood damages, might be made directly comparable with the estimated costs which are based on May 1948 prices, a conversion factor based on the Bureau of Labor Statistics consumers price index was used for the adjustment of the benefit values.

174. Flood Control Benefits from Reservoirs. Annual flood benefits derived from operation of the reservoirs in Plans I and II were obtained by evaluating the total annual preventable, recurring flood damages up to standard project flood magnitude under present conditions, and subtracting from this value the residual annual damages which would prevail after completion of the improvement. The flood benefits in the reservoir area due to elimination of losses because of dike protection and removal of property through acquisition were included, and an adjustment credit representing

the annual benefit from advance replacement of existing improvements was also added to the flood benefits. A summary of the average annual flood benefits for Reservoir Plans I and II, including channel improvements is given in Table XXXVII.

TABLE XXXVII

AVERAGE ANNUAL FLOOD BENEFITS, PLANS I AND II

RESERVOIR PLANS, MAIN STREAM

PASSAIC RIVER, NEW JERSEY

(May 1948 Price Level)

	Average Annual Flood Benefits in Dollars			
	Reservoir	Channel Improvement	Adjustment for Advance Replacement of Structures	Total
PLAN I				
Downstream from Reservoir	1,700,100	112,900	105,000	1,918,000
Within Reservoir	575,400	0	10,800	586,200
Total Area	2,275,500	112,900	115,800	2,504,200
			Rounded	2,504,000
PLAN II				
Downstream from Reservoir	1,700,100	112,900	105,000	1,918,000
Within Reservoir	575,400	0	30,500	605,900
Total Area	2,275,500	112,900	135,500	2,523,900
			Rounded	2,524,000

175. Flood Control Benefits from Local Protection. Annual flood benefits at localities along the main stream which would be protected by walls and levees in Paterson and Passaic (Plan III), were evaluated in terms of annual preventable damages only up to floods of design magnitude. Where channel excavation only would be provided under this plan, annual flood benefits were

evaluated as the difference between the total annual preventable damage up to the standard project flood without the channel improvement and the residual annual damages after such improvement. Annual flood benefits along tributary streams were evaluated by the same methods as for the main stream. In the case of channel improvements supplementing reservoir projects, (Plans I and II), the annual flood benefits were evaluated in a similar manner, but in the case of the channel improvement, analysis was based upon flows after modification by the reservoir. In all estimates of annual flood benefits the assumption was made that the design flood would occur once during a fifty-year economic life of the protective structures. A summary of average annual flood benefits for Local Protection Plan III is given in Table XXXVIII.

TABLE XXXVIII

AVERAGE ANNUAL FLOOD BENEFITS, PLAN III,

LOCAL PROTECTION PLAN, MAIN STREAM

PASSAIC RIVER, NEW JERSEY

(May 1948 Price Level)

Item	Average Annual Flood Benefits in Dollars		
	Mouth (Newark) to Dundee Dam (Clifton)	Dundee Dam (Clifton) to S.U.M. Dam (Paterson)	Mouth (Newark) to S.U.M. Dam (Paterson)
Walls and Levees	398,310	430,640	828,950
Channel Excavation	93,170	27,010	120,180
Adjustment for Advance replacement of structures	105,800	132,600	238,400
Total	597,280	590,250	1,187,530
		Rounded	1,188,000

176. Benefits from Reconstruction of Lake Denmark and Picatinny Lake Dams. The benefits which would accrue to the reconstruction of the spillways and dams at Picatinny Arsenal are reducible to an annual basis only on an assumption as to when these structures will fail. Inasmuch as failure of the dams will occur only once, the total flood losses which would be inflicted upon downstream properties as a result of a single failure can be directly compared with the capitalized cost of corrective works, including maintenance and operation, in determining the justification for the project. Investigations by this office indicate that the dams and spillways could not safely accommodate a major flood. Based on the data furnished by the Commanding Officer, Picatinny Arsenal, direct damages from failure of the Lake Denmark and Picatinny Dams would total about $1,600,000 within the limits of the Arsenal. About 30 buildings housing complex technological ordnance equipment and supplies, laboratories, and records would be inundated as a result of such a failure. Of even greater significance is the indirect damage which would occur through the loss of the water supply afforded by the two lakes. Loss of this supply, and the time required to replenish the lakes after emergency repairs to the dams, would entail a complete shut-down of operations of the entire Arsenal for a period of not less than six months and possibly longer. Under normal peace-time schedules the corresponding loss in production is estimated at $3,500,000 or a total direct and indirect loss of $5,100,000. If this loss were to be distributed over a 50-year period, the annual loss would be $102,000. Similarly, should failure occur during a National emergency, the annual losses would be many times this value. These damages do not include additional indirect damages to other units of the Army and Air Forces relying on the technological research activities of this Arsenal to keep abreast of the rapidly changing pattern of war.

In addition, should the Boonton water supply dam be destroyed in consequence of the upstream dam failures, not only would the direct costs of replacement be very great, but the indirect costs of depriving Jersey City and Hoboken of their water supplies would be catastrophic and incalculable. The foregoing annual damages would accrue as annual benefits to be compared to annual charges for reconstruction of the dams and spillways to assure them against failure.

177. Water Supply Benefits. Benefits for water supply would accrue only to the Two Bridges Multiple-Purpose Reservoir (Plan II). Based upon the past trend in water consumption in the area which can be served from the conservation pool in the Two Bridges Reservoir (paragraph 165), an additional supply of 80 m.g.d. will be required to satisfy immediate prospective demands when the supply becomes available, and a total of 120 m.g.d. at the midlife of the reservoir in 1975 which is also the average demand over the 50-year life of the project. Even though it is anticipated that all of the available supply in the conservation pool will ultimately be absorbed in water supply use, for the purpose of computing water supply benefits for this report only, the prospective 1975 requirements of 120 m.g.d. were used. The principal beneficiaries of this supply would be the municipalities in the northern metropolitan district now served by the following systems: Wanaque, Hackensack Water Company, Passaic Valley, Jersey City and Newark.

178. The value of water supply benefits was estimated from a comparison of the costs for comparable supplies at other sites in New Jersey, New York and New England. An immediate comparison is available locally in the Wanaque development within the Passaic watershed, which was constructed during the period 1920-1930 to provide a safe yield of 82 m.g.d. at a cost of $26,500,000, of which $14,800,000 represented the cost of the dam and reservoir, and $11,700,000 the cost of the delivery aqueduct. Adjustment of these values to May 1948 price levels (Index 2.1) indicates

that the present-day total cost of this water supply would be $685,000 per m.g.d. of which $382,000 per m.g.d. would be attributable to the dam and reservoir. A further comparison is provided by the Bunnvale project, in the Raritan River watershed which was proposed in 1930 by the North Jersey District Water Supply Commission. The estimated cost of this project, designed to provide a safe yield of 155 m.g.d. was $43,170,000 of which $24,210,000 represented the cost of the dams and reservoirs and $18,960,000 the cost of the delivery aqueduct and appurtenant works. Adjusting these costs to May 1948 price levels, provides a present-day value for the water supply from this project of $601,000 m.g.d., of which $337,000 per m.g.d. represents the value of the storage. The New Jersey State Water Policy Commission in a 1945, "Report on The Development of Adequate Water Supplies for North and South Jersey," estimated the cost of the Dock Watch Hollow project in the Raritan River watershed at about $30,000,000 for a yield of 75 m.g.d. The value of water supply under this project, adjusted to May 1948 price levels, would be $584,000 per m.g.d. including aqueduct. A summary of the costs of other water developments is given in Appendix G, Table G17. Based on the foregoing costs, it is apparent that a capital value of the additional water supply from the Two Bridges Reservoir project, taken as $300,000 per m.g.d., is reasonably conservative. The corresponding annual water supply benefits attributable to the project from an immediate yield of 80 m.g.d. at an annual charge of four percent on this capitalized unit value would be $960,000, on a yield of 120 m.g.d. would be $1,440,000, and on a yield of 160 m.g.d. would be $1,920,000.

179. Pollution Abatement Benefits. The benefits which would accrue to the reservoir plan through pollution abatement by increase in low water flow are based upon an evaluation by the United States Public Health Service of $3.00 per c.f.s.-day increase over the unregulated minimum dry season flow of 68 c.f.s. (Appendix J, Part II).

This is an average seasonal value applicable to the period from June through September. After diversion for water supply of 186 c.f.s. (120 m.g.d.) there would be available for pollution abatement a dependable summer flow of 114 c.f.s. or 46 c.f.s. above the existing unregulated minimum flow. On this basis the annual benefit through pollution abatement would be $17,000. The cost of providing the increment storage in the Two Bridges Reservoir to provide 114 c.f.s. dependable low-water flow for pollution abatement would be considerably less than the cost of providing the necessary storage by a separate conservation dam and reservoir and the cost of providing an alternate method of pollution abatement.

180. Power Benefits. The benefits which would accrue to the reservoir plan through increased hydro power generating capacity in downstream plants are based on an evaluation by the Federal Power Commission of $20.00 per Kw of increased firm capacity and 3.5 mills per Kwh of increased energy, (Appendix J, Part V, Fig. 2). The Federal Power Commission also determined that development of power at the dam site would afford a very low degree of economic justification. However, based on the total storage available for conservation use, less the storage required to firm-up stream flow for water supply and pollution abatement use, and based on the most critical dry periods of stream flow on the Passaic and Pompton Rivers, it was computed that a dependable stream flow of 220 c.f.s. in the fall and winter seasons would be available for use in increasing the power now being developed at downstream plants. On this seasonal dependable flow, the Commission has evaluated the power benefits of Plan II at $82,000 annually. Preliminary estimates indicate the cost of a separate equivalent power dam and reservoir would be greater than the cost of providing the incremental storage for power use in the Two Bridges Reservoir. The value of the power, capitalized at the rates used in this report would be $1,975,400, or in round figures, $2,000,000. Benefits to this extent would accrue to the city of

Paterson and the Passaic Valley Water Commission, the owners of the two power dams in the Passaic River, as a direct result of the construction of the storage reservoir by the United States. The two power projects are not now under license, but it is understood that under the provisions of Section 10f of the Federal Power Act, approved June 10, 1920, as amended, the Commission could determine and fix an equitable annual charge to be paid to the United States. In lieu of this procedure, however, for purposes of this report, the value of $2,000,000 is covered by the $26,300,000 allocation of costs to conservation of water resources, (Table XLII).

181. Navigation Benefits. Deepening the existing 10-foot navigation channel in conjunction with the deepening of the waterway below Dundee Dam to 14.7 feet below mean low water, (17.0 feet below m.s.l.), as proposed under all three plans considered constitutes a material benefit to navigation. This benefit would result in the more economical transportation of petroleum products (which constitute more than 97 per cent of the existing commerce of the 10-foot section of the waterway) by reducing the number of vessel trips required through full draft loading of existing vessels, and by permitting the use of larger deeper draft vessels. Based on present operating costs it is found that a saving of $0.16 per ton may be expected. This saving applied to the prospective petroleum commerce in 1975 (obtained by extension of 1929-1940 trend) in the 10-foot section of the waterway would result in an annual saving of $262,000. Detailed analysis of the foregoing is contained in Appendix G.

182. Mosquito Control Benefits. The Two Bridges Detention Reservoir (Plan I) would have, to some extent, a deterrent effect on present mosquito breeding in the Great Meadow area because of improved drainage conditions following the lowering by about two feet of the hydraulic control at the proposed dam site. This condition would result in an annual reduction in maintenance of mosquito drainage ditches in the area of $15,000 which amount was

considered as a benefit accruing to the project. In a similar manner the Two Bridges Multiple-Purpose Reservoir (Plan II) would alleviate mosquito breeding conditions in the flat areas above the conservation pool by facilitating drainage through Deepavaal Brook which would be deepened under the proposed plan. In addition, the deep conservation pool would eliminate the shallow mosquito breeding pools which now form in this area. These conditions would result in an annual reduction in maintenance of mosquito drainage ditches in the area of $20,000, which amount was considered as a benefit accruing to the project. However, it would still be necessary for local interests to expend $20,000 annually for larviciding, shore line maintenance, and other mosquito control measures.

183. Increased Utilization of Property. The effect of the "dry" portion of the Two Bridges Multiple-Purpose Reservoir plan on the land use for agricultural production was considered negligible on the basis of a study of the affected area by the Soil Conservation Service of the Department of Agriculture (Appendix J). However, the conservation pool provided under this plan would tend to increase property values in the region. It would eliminate so much of the existing undesirable swamp as would be submerged by it, and replace it with a desirable and scenic lake. This would tend to increase values, attract developers and buyers, and raise the type of future improvements to a higher standard. North of the lake near Lincoln Park and Towaco, it is estimated that land would be converted within a 15-year period after construction, from acreage to residential use, and west of the lake, certain unused lands would be converted to acreage suitable for subdivision. In addition, the existing improvements in the region would increase in value and numerous new buildings would be located in the area during the 15-year period. The total enhancement in property values is estimated to aggregate $2,600,000 over a 15-year period. Annual benefits from this enhancement would be $90,000 on the basis of the annual return at five percent of the present worth of the enhanced value at a gradual increase over a 15-year period. The present worth of the $2,600,000 enhancement on this basis would be $1,800,000, which at five percent would give a return of $90,000 annually. The Pompton

diversion channel flood levee would also permit higher use of lands in Lincoln Park and Wayne because of the flood protection afforded by the levee. The higher use of these lands would involve the conversion of swamps to crop land, and waste land to acreage suitable for subdivision. The total increase in value is estimated at $206,000 over a 15-year period. The annual benefits on the basis of a gradual increase during this period would be $8,000, and the total annual benefits to the project from increased and higher utilization of all property would aggregate $98,000.

184. Intangible Benefits. An intangible benefit accruing to the reservoir Plans I and II would be the preservation in public ownership, of the wild life feeding and breeding grounds now provided in nature by those marshy lowlands of the Central Basin within the limits of the detention reservoir and the detention area of the multiple-purpose reservoir. These lands are considered by the United States Fish and Wilflife Service to be one of the most important fresh water marsh habitats for wild life on the Atlantic Coast. This agency has been interested in the Passaic marshes as a National waterfowl refuge site, and during the late thirties its land evaluation engineers surveyed the Troy and Great Piece Meadows with a view to purchase. In 1941, the project was temporarily abandoned because of high acquisition costs. Under present uncontrolled conditions, the value of this area as a wild life sanctuary is being jeopardized by the inroads of marginal communal development. An additional intangible benefit accruing to both reservoir plans is the removal of the present hazard of possible heavy loss of life. The recent extensive encroachment of summer cottages on the banks of the Central Basin within the proposed reservoir area, creates the possibility of catastrophic loss of life in the event of a major flood during the summer season when occupancy of this area is high.

185. A summary of the benefits from the various plans of improvements is given in Tables XXXIX and Table XL.

TABLE XXXIX

ESTIMATED AVERAGE ANNUAL BENEFITS FOR PLANS I, II AND III

MAIN STREAM, PASSAIC RIVER, N. J.

(May 1948 Price Level)

Type of Benefit	Annual Benefits in Dollars		
	Plan I Two Bridges Detention Reservoir	Plan II Two Bridges Multiple-Purpose Reservoir	Plan III Local Protection (channel improvement)
Flood Control(a)	2,504,000	2,524,000	1,188,000
Navigation	262,000	262,000	262,000
Water Supply	-	1,440,000	-
Power	-	82,000	-
Pollution Abatement	-	17,000	-
Mosquito Control	15,000	20,000	-
Higher Utilization of Property	-	98,000	-
Total Benefits	2,781,000	4,443,000	1,450,000

(a) Includes adjustment for advance replacement of existing structures.

TABLE XL

ESTIMATED AVERAGE ANNUAL BENEFITS FOR MINOR TRIBUTARIES

PASSAIC RIVER, N. J.

(May 1948 Price Level)

Plan of Improvement	Average Annual Flood Control Benefits (a)
Local Protection, Weasel Brook	173,200
Saddle River	70,400
Molly Ann's Brook	160,400
Reconstruction of Lake Denmark and Picatinny Lake Dams	102,000(b)

(a) Includes adjustment for advance replacement of existing structures.

(b) Represents annual damages based on total damages of $5,100,000 from failure of the dams assumed to occur once in 50 years.

XXII. COMPARISON OF BENEFITS AND COSTS

186. A summary of the annual charges, annual benefits and benefit-cost ratios for the projects discussed in this report is given in Table XLI. The benefit-cost ratios do not include the value of intangible benefits and the value of safeguarding human life which might derive from the various projects.

TABLE XLI

BENEFIT-COST RATIOS

PASSAIC RIVER, N. J.

(May 1948 Price Level)

Plans of Improvement	Annual Charges (Dollars)	Annual Benefits (Dollars)	Benefit-Cost Ratio
Plan I - Two Bridges Detention Reservoir	3,481,700	2,781,000	0.80
Plan II - Two Bridges Multiple-Purpose Reservoir with Channel Improvement			
Flood Control and Incidental Functions	2,844,800	2,884,000	1.01
Conservation Use	1,044,000	1,559,000	1.49
Total - Plan II	3,888,800	4,443,000	1.14
Plan III - Local Protection			
Passaic River Mouth to S.U.M. Dam	1,388,300	1,450,000	1.04
Local Protection on Minor Tributaries			
Weasel Brook	162,900	173,200	1.06
Saddle River	70,700	70,400	1.00
Molly Ann's Brook	92,000	160,400	1.74
Reconstruction of Lake Denmark and Picatinny Lake Dams	88,500	102,000	1.15[a]

a. If consequential failure to the Boonton water-supply dam is assumed the benefit-cost ratio would be increased many fold.

XXIII. ALLOCATION OF COSTS

187. Plan I - Two Bridges Detention Reservoir with Channel Improvement. For purposes of this report, the initial Federal construction cost of the Two Bridges Detention Reservoir Project, in an estimated amount of about $83,700,000 (Table XXIX) would be allocated to the Corps of Engineers in accordance with its function, assigned by the Congress, to construct flood control and navigation projects. The initial non-Federal cost of about $2,300,000 would be allocated to the State of New Jersey. The estimated cost of operation and maintenance in an amount of about $202,000 (Table XXXIV) would be allocated in an amount of $152,000 to the Corps of Engineers and in an amount of $50,000 to local interests.

188. Plan II - Two Bridges Multiple-Purpose Reservoir with Channel Improvement. The Two Bridges Multiple-Purpose Reservoir would serve two major functions, namely: flood control, including navigation and increased utilization of property; and water resources conservation including water supply, increase in energy at downstream power plants, pollution abatement and mosquito control. The allocation of the cost of this plan among the Federal Government and state and local interests involved for these functions, is discussed in the following paragraphs and summarized in Table XLII.

189. Method of Allocation of Cost. The cost of the multiple-purpose reservoir is allocated to flood control and conservation as defined in the preceding paragraph on the following basis. All costs incurred for items specifically necessary for flood control and for the conservation reservoir are assigned to those purposes. For items which are primarily necessary for flood control but are modified due to conservation storage, the primary cost is allocated to flood control and the incremental cost due to modification because of conservation storage is allocated to conservation. For items which are primarily necessary for conservation purposes, but are modified for flood control, the

primary cost is allocated to conservation and the incremental cost due to modification for flood control is allocated to flood control. Joint costs not readily divisible to either function are allocated both to flood control and conservation in proportion to the reservoir capacity utilized for each purpose. Items allocated to flood control include the outlet gates for flood control purposes; the incremental portion of the conservation dam attributable to raising of Route 6; and the basic portion of the levees, protection of existing facilities and raising of Route 6 in the detention portion of the reservoir to the elevation of the spillway required for flood control only. Items allocated to conservation include the outlet gates for conservation purposes; Deepavaal channel improvement; relocation of the Jersey City aqueduct; raising of Route 23; the basic portion of the conservation dam required solely for conservation storage; and the incremental portion of levees, protection of existing facilities, and raising of Route 6 made necessary by the higher elevation of the spillway because of the inclusion of the conservation storage. Items allocated jointly to flood control and conservation include the dam embankment, spillway structure, Pompton diversion channel and outlet works, relocation of cemeteries and reservoir lands. The costs of the reservoir items allocated to flood control, conservation, and joint use are $13,760,000, $12,500,000 and $54,740,000, respectively. The allocation of the various items in further detail is given in Appendix F. The item of $54,740,000 for joint use is allocated to flood control on the basis of $54,740,000 x 208,000/278,000 or $40,940,000, and the conservation on the basis of $54,740,000 x 70,000/278,000 or $13,790,000. The total reservoir costs allocable to flood control and conservation are $54,700,000 and $26,300,000, respectively.

190. In the case of the channel improvement portion of Plan II, the initial Federal cost in an amount of about $13,000,000 is allocated entirely to the Corps of Engineers for construction of flood control

and navigation projects. The initial non-Federal cost of about $2,300,000 is allocated to local interests.

191. Allocation of Operation and Maintenance Costs. The allocation of the operation and maintenance costs for the dam and reservoir estimated at $134,000 (Table XXXIV) should be made in the light of the plan for the acquisition and ownership of lands which is developed in succeeding paragraphs. The Federal Government would operate and maintain the dam and reservoir and would make releases from the conservation pool for water supply, and for increase in low water flow, as would be requested by the State of New Jersey or its authorized agency. The State would police the conservation pool and control the uses and development of the lake and its shores, subject to the provisions of flood control easements resting in the United States. The State would perform all work necessary for maintaining the quality of the water in the conservation pool, such as algae control, aeration, and sanitary policing. It would assume the annual cost of operation and maintenance of the conservation pool by reimbursing the Federal Government for the annual cost of operation and maintenance of the portions of the structures made necessary by inclusion of the pool and all other structures required for water supply purposes. It would retain all revenue derived from the sale of water, from the operation of any recreational facilities, and from leasing, subject to Federal restrictions, of lands for agriculture. The State would also be responsible for all mosquito control measures. The operation and maintenance costs for the channel improvement portion of the plan estimated to total $83,000 (Table XXXIV) would be allocated to the Corps of Engineers in the amount necessary to cover the cost of additional maintenance required in the navigation channel and to local interests in the amount necessary for operation and maintenance of the flood control works.

192. The distribution among Federal and non-Federal interests of the items of operation and maintenance for both the reservoir and channel

improvement portions of the plan would be as follows:

Federal:

Maintenance and operation of Passaic Dam excluding the conservation section (Route 6) but including the Pompton Section of the dam and the Pompton dike.

Maintenance and operation of the detention portion of the reservoir for flood control.

Maintenance and operation of the navigable section of the flood control channel below 8th Street, Passaic.

Non-Federal:

Maintenance and operation of the conservation pool including the conservation section of the dam (Route 6).

Maintenance and operation of levees at Troy Hill, Canoe Brook and nearby reservoirs, and all other levees, dikes, and local protective works located around both reservoir areas with the exception of the Pompton dike.

Maintenance and operation of the entire flood control channel improvements from the dam to the head of the navigable section of the river at 8th Street, Passaic, including the relocated channel of Deepavaal Brook.

Maintenance and operation of highways and bridges.

Mosquito control.

193. The total annual cost of operation and maintenance of the Two Bridges Multiple-Purpose Reservoir with Channel Improvement Project (Plan II) distributed in accordance with the foregoing principles is as follows:

	Federal	Non-Federal	Total
Dam and Reservoir			
Dam and Levees	40,700	18,800	59,500
Diversion Channels	10,300	1,600	11,900
Reservoir, including cleanup after floods	8,000	4,000	12,000
Highways and Bridges	3,000	4,000	7,000
Mosquito Control		20,000	20,000
Operation of Reservoir	10,500	13,100	23,600
Total Dam and Reservoir	72,500	61,500	134,000
Channel Improvement - Total	33,000	50,000	83,000
Grand Total - Plan II	105,500	111,500	217,000

Not included in the foregoing non-Federal costs are the annual costs for policing the conservation pool for maintaining the quality of the water, and for the operation of any recreational facilities that might be provided.

TABLE XLII

ALLOCATION OF COSTS - PLAN II

TWO BRIDGES MULTIPLE-PURPOSE RESERVOIR WITH CHANNEL IMPROVEMENT

PASSAIC RIVER, N. J.

(May 1948 Price Level)

Purpose	Corps of Engineers	State of New Jersey and Local Interests	Total
Allocated Initial Cost (Dollars)			
Flood Control	67,700,000	2,300,000	70,000,000
Conservation of Water Resources	-	26,300,000	26,300,000
Total	67,700,000	28,600,000	96,300,000
Allocated Cost of Operation and Maintenance (Dollars)			
Flood Control	93,000	60,000	153,000
Conservation of Water Resources	12,500	51,500	64,000
Total	105,500	111,500	217,000

194. Plan III - Passaic River Channel Improvement Project. The initial Federal cost for Plan III in an amount of about $24,600,000 is allocated entirely to the Corps of Engineers for construction of flood control and navigation projects. The initial non-Federal cost of about $7,700,000 is allocated to local interests at Paterson, Passaic, and Wallington. The cost of operation and maintenance in an amount of about $96,000 is allocated to the Corps of Engineers in an amount of $30,000 for the additional maintenance of the

navigation channel, and to local interests at Paterson, Passaic, and Wallington in an amount of $66,000 for operation and maintenance of the flood control works.

195. Minor Tributaries. The initial Federal costs of local flood protection projects on Weasel Brook, Saddle River and Molly Ann's Brook are allocated to the Corps of Engineers; and the initial non-Federal costs and costs of operation and maintenance are allocated to local interests.

196. Picatinny Arsenal Dams. All initial construction costs for dam reconstruction at Picatinny Arsenal are allocated to the Corps of Engineers. The operation and maintenance costs are allocated to the military authorities at the Arsenal.

XXIV. PROPOSED LOCAL COOPERATION

197. Local Cooperation, Plan I, Detention Reservoir. Since this plan is found in preceding paragraphs to be not justified, there appears to be no necessity for a discussion of the specific provisions of local cooperation.

198. Local Cooperation, Plan II, Two Bridges Multiple-Purpose Reservoir with Channel Improvement. For projects of this character, the general provisions of existing flood control laws require that local interests furnish all lands, easements and rights-of-way necessary for channel improvements, hold and save the United States free from damages due to the works, and maintain and operate them upon completion, and that the United States acquire all lands necessary for the reservoir and dam site, construct the dam and reservoir, and operate it at Federal expense. In the present instance, the reservoir would be designed and operated so as to provide

not only flood storage but a much needed expansion of the water supply of Northern New Jersey. It would in effect take the place of a water supply reservoir which must otherwise be built somewhere in the State in the near future. The allocation of the portion of the project cost to conservation of water resources has been estimated in the preceding paragraphs to be $26,300,000. Accordingly, the State or local interests should be required to contribute not only the lands, easements, and rights-of-way necessary for the channel improvement, but $26,300,000 in cash for the conservation of water resources.

199. In lieu of the contribution of this sum in cash, there are advantages to a plan whereby the State would acquire and convey to the United States, without reimbursement, all of the lands, easements and rights-of-way not only for the channel improvement, but for the reservoir as well. The multiple-purpose reservoir to be created by the project would, for the greater portion of the time, consist in effect of two reservoirs. One, with a water surface area of approximately 6,300 acres and with a fairly constant water level, would be the basic water supply reservoir; and the other, with an area of approximately 15,000 acres, would remain empty for most of the time and would be filled or partially filled only during short periods of large runoff from the watershed. If the State were to acquire fee title to all of the lands needed for the reservoir and convey to the United States only a perpetual flowage easement, the State would retain technical ownership of the lands. It would control not only the water in the conservation pool for water supply and other purposes, but also the uses of lands in the detention portion of the reservoir as well, subject of course to the provisions of the flowage easements granted to the United States. It could rent the lands in the detention portion of the reservoir for useful purposes, such as

grazing and agriculture subject to the flowage easements, and all rentals therefrom would accrue to the State.

200. The reservoir site lies on the outskirts of metropolitan New Jersey. The dam site is only 20 miles measured on a straight course from the tip of Manhattan, New York City. The reservoir, when full, would cover approximately 35 square miles with its longest arm, also measured in a straight line, about 11 miles in length. Portions of the reservoir area are even now under development, and as the residents of the metropolitan regions of New Jersey and Greater New York continue to move from the cities and develop suburban areas, the locality marked for the reservoir will become increasingly valuable. In the event of adoption by Congress of this plan, it is quite probable that a considerable period of years will elapse before local cooperation is consummated, and several more years might pass before construction could be started. If the responsibility for the acquisition of the reservoir lands is placed in the State, it would have a definite interest in discouraging, and perhaps controlling, further development of this area for other purposes. Regardless of such control, however, it is possible that real estate values may increase above the costs estimated in this report. It is considered not unreasonable that this risk be assumed by the State, in the same manner in which the United States must assume the risk of increased construction costs. Accordingly, under this plan, the State should acquire all lands, easements, and rights-of-way estimated at $16,800,000 and contribute a cash balance in the amount of $9,500,000, with the realization that this cash contribution is not to be reduced to compensate for any increase in the cost of lands, nor is it to be increased in the event the lands may be acquired for an amount less than that estimated herein.

201. In lieu of making the cash contribution, or any part of it, the State of New Jersey, or any responsible local interests should be permitted to contribute in kind by the performance of some integral portion of the

construction work, to be agreed upon by the Chief of Engineers. In evaluating any such work, deduction should be made for any Federal-aid funds which might be utilized by the State.

202. The present flood problem in the lower Passaic River has been aggravated by encroachments along the river channels. The head of navigation is at Passaic, and in the application of the laws administered by the Department of the Army for the protection of navigable waters, there is no positive control by the Federal Government of structures in or over the river above the head of navigation. On the other hand, most of the proposed flood walls, levees and channel improvements would be in the reach above Passaic. The provisions of local cooperation under this plan, therefore, should require the enactment of appropriate legislation by the State to assure an adequate control over the river to prevent any further encroachments.

203. For the channel improvement portion of Plan II, below the dam site, it is estimated that approximately $2,300,000 would be expended for the customary provisions of local cooperation. Such provision would include the acquisition of lands, easements, and rights-of-way, the acquisition or modification of buildings or improvements on properties needed for construction or access, the relocation of all buildings or improvements which local interests desire to save, the modification and relocation of sewer, water, power, telephone and gas facilities, except such parts as may be integral to the protective structures, and the removal or alteration of bridges and their approaches. The details of the alterations required by local interests are contained in Appendix E. In connection with the construction of new bridges or new spans for bridges, the division of responsibilities and of costs should be on the basis that wherever the abutments are in line with flood walls and they are approximately comparable to the proposed adjacent wall sections, the Federal Government would construct the abutments as part of the flood

walls, subject to the further provision that if the cost of the abutments exceeds materially that of an equivalent wall section, the Federal Government would construct them and local interests would contribute that part of the cost in excess of the equivalent wall section.

204. Local Cooperation, Plan III, Local Protection Plan. Under this plan, local interests would acquire all lands, easements and rights-of-way at their expense in accordance with the provisions of existing law applicable to similar projects. The same principles should be applied in determining the division of responsibilities and of costs in connection with the alteration of bridges and relocation of utilities as described in the preceding paragraph for Plan II. The cost to local interests under Plan III is estimated to be $7,700,000. The details of the items of local cooperation are contained in Appendix E.

205. Local Cooperation, Local Protection Plans, Minor Tributaries. The general conditions of local cooperation would be those described in Paragraph 203. The cost to local interests under the plans for local protection on Weasel Brook, Saddle River, and Molly Ann's Brook are estimated at $1,100,000; $240,000; and $490,000, respectively. The details of the items of local cooperation required under each of these plans are contained in Appendix E.

206. Reconstruction of Picatinny Arsenal Dams. In connection with any Federal flood control project which might be adopted for reconstruction of the Picatinny Arsenal Dams, no conditions of local cooperation would be prescribed.

XXV. COORDINATION WITH OTHER AGENCIES

207. The following Federal agencies were consulted in connection with problems pertinent to flood control on Passaic River. Reports of the agencies are included in Appendix J.

U. S. Public Health Service; on malaria control at the proposed reservoirs, and pollution abatement on Passaic River.

U. S. Department of Agriculture, Soil Conservation Service; on the effects of the proposed reservoirs on land use practices.

U. S. Department of the Interior, National Park Service; on the recreational resources incident to the proposed Two Bridges Reservoir.

Federal Power Commission; on the power potentialities of the Passaic River basin.

U. S. Department of the Interior, Fish and Wildlife Service; on the effects of the proposed Two Bridges Reservoir on the existing fish and wild life resources.

208. The U. S. Public Health Service concluded that an increase in mosquito intensity could occur under improper conditions of reservoir operation, but that adequately controlled drainage works and careful water level regulation would result in material benefits. It recommended that no clearing be performed in the detention basin and that drainage and some larvicioding operations alone should be sufficient for complete malaria control after the reservoir is put into operation.

209. With respect to pollution abatement of the Passaic River downstream from Little Falls, the U. S. Public Health Service concluded that residual deposits in this section of the river, including sewage and industrial wastes not collected by the Passaic Valley Sewerage Commission and urban storm drainage, are sufficient to cause gross pollution of the tidal portion of the river; that the cost of abating this pollution by collection

and treatment would be high; that low flow regulation by the proposed Two Bridges Reservoir would permit considerable savings in the cost of pollution abatement; and that the value of such flow regulation would be at least $3.00 per c.f.s. day of reliable increased flow during the season from June through September.

210. In connection with the preliminary study of land use in the Two Bridges detention reservoir (Plan I) before and after construction, the Soil Conservation Service, U. S. Department of Agriculture, estimated an increase in annual production from $766,000 to $785,000 for crops and a decrease from $4,800 to $4,720 for pasture. Annual production of livestock housed in the area but supported mainly by imported feed, estimated at $99,800, would be removed from the area and established elsewhere (Appendix J). The foregoing analyses were based upon a preliminary plan for the detention reservoir furnished the Soil Conservation Service in November 1946. This preliminary plan differs from the present plan (Plan II) in several respects, but principally in the introduction of a conservation pool. Since the conservation pool occupies the least productive land in the area, and since the frequency of flooding in the detention portion of the reservoir is substantially unchanged from the preliminary plan, the conclusions of the Soil Conservation Service that reservoir construction will only negligibly affect agricultural production in the area, are considered applicable to the multiple-purpose project (Plan II).

211. In discussing the recreational resources of the proposed Two Bridges Reservoir, the U. S. Department of the Interior, National Park Service concluded that consideration should be given to the development of picnic areas with playfields on the periphery of the reservoir, hiking and bridle trails through the flood detention area and facilities for wild life protection and preservation. The conservation pool of the Two Bridges Reservoir would have a particular recreational value in providing

a potential recreation site which could accommodate a day-use load of 8,000 to 10,000 people if such use did not interfere with the water supply function of the pool. Recreational development around this reservoir, however, was not considered of national significance and it was concluded that the facilities should be maintained by the State of New Jersey or the counties of Essex, Passaic and Morris. However, no recreation benefits have been included in connection with the economic analysis of the plan, since the State of New Jersey might consider that the pool cannot be used safely for both recreation and water supply.

212. With reference to the power potentialities of the Passaic River and tributaries, the New York Regional Office of the Federal Power Commission concluded that the construction of new power plants could not be justified economically; that the addition of conservation storage at potential reservoirs for the sole benefit of existing and future downstream power plants also could not be justified, but if other benefits such as flood control, water supply and recreation could be combined with power benefits, a multiple-purpose project involving some power storage might be justified in terms of increased generation at existing plants.

213. In connection with the effects of the proposed Two Bridges Reservoir on fish and wild life resources, the U. S. Department of the Interior, Fish and Wildlife Service, stated that the fishery resources of the streams within the reservoir area are of little importance, but the possibility of developing the conservation pool for sport and food fishing for the citizenry of this thickly populated area should receive consideration. If a reservoir project were authorized, the Fish and Wildlife Service would request that final plans provide for the development and operation of a wild life management area by the Fish and Wildlife Service in cooperation with the New Jersey Board of Fish and Game Commissioners.

214. Officials of the Public Roads Administration and the New Jersey State Highway Department were consulted in connection with the planning of that portion of the Two Bridges Reservoir project involving the raising of Highway No. 6 (U. S. Highway 46) to form part of the conservation dam, and in connection with the reconstruction of the highway bridges thereon. The plans were generally approved by these agencies subject to possible modification in detail on preparation of construction drawings.

215. Coordination with the State of New Jersey is discussed in the succeeding section.

XXVI. DISCUSSION

216. The principal areas within the Passaic River watershed which are subject to extensive flood damage and against which flood protection is of paramount importance comprise the highly industrial and urban territory along the Passaic River at and in the vicinity of the cities of Paterson and Passaic. Additional losses occur in the other residential, commercial and industrial areas along the main stream from its mouth to Two Bridges, and along certain reaches of a number of its tributaries.

217. The plan which directs itself specifically to the protection of the most highly industrial and urban areas is Plan III. Under this plan, channel dredging and the construction of flood walls, levees and pumping plants would be constructed through the cities so as to pass safely a flood of 1903 magnitude (35,800 c.f.s.). This capacity is on the basis that the natural valley storage in the Great Meadows area will not be materially diminished by future encroachments. The plan would cost the United States approximately $24,600,000 and local interests $7,700,000. Such a project shows a favorable benefit-cost ratio, although it is only slightly above unity. There would be no benefits other than flood control and navigation. It would require the reconstruction and the raising of

many bridges in the Passaic and Paterson areas to an extent which is perhaps not desired by local interests. None the less, the alteration of the bridges would be to no greater degree than that which other cities have found necessary in order to make possible the passage of great floods through confined channels, and to remedy conditions which have been brought about by their own encroachments into the flood plains of rivers. The plan has no insurmountable obstacles. Subject to the availability of funds, the project could be completed after adoption within a period of approximately three years.

218. Plan II is the general comprehensive plan for the control of floods, and for the provision of water supply and other benefits. This plan calls for the construction of a large dam and reservoir in the vicinity of Two Bridges which when full would cover over 33 square miles in area, supplemented by channel improvement and local protective works downstream. It is estimated that the cost of the project to the Federal Government would be approximately $67,700,000 and to local interests $28,600,000. The project would protect the cities of Passaic and Paterson against a repetition of the 1903 discharge increased by twenty per cent. It would provide a water supply reservoir which could furnish an additional water supply of 120 million gallons per day. The project would protect not only the cities of Paterson and Passaic, but would provide a considerable degree of protection along the entire Passaic River from Two Bridges to its mouth and along the Pompton River from Pompton Plains to its mouth. It would assure that the meadows above Two Bridges would remain dedicated to flood control purposes.

219. Under date of 19 May 1948, the Commissioner of Conservation of the State of New Jersey advised the District Engineer that the Water Policy and Supply Council of the New Jersey Department of Conservation had given consideration to this plan, (Plan II), and to the other plan discussed above (Plan III), and that the Council favored the Multiple-Purpose Reservoir with the partial channel improvement plan,

(Plan II), then estimated to cost $85,000,000. It advised that informal conferences had been held with State and local interests and that a plan was proposed whereby local costs of $30,400,000 would be assumed by the State, counties and municipalities concerned. The Commissioner stated his willingness to recommend the project to the State Legislature, and to the interested municipalities.

220. Under date of 9 September 1948, the State of New Jersey enacted a law authorizing the State to participate in a Federal program of flood control, and authorizing the Commissioner of Conservation to carry out the State's participation in a Federal program of flood control. The provisions of the legislation are in a large measure similar to those contained in the laws of the State of New York on the subject, and establish the procedure whereby the State may participate in a Federal flood control program. The act provides, however, that the Commissioner may not exercise any of the powers granted under the said act until the project or projects shall have been approved by an act of the State Legislature.

221. The studies and investigations made by this office of plans for flood control for the Passaic Valley have disclosed that there is a marked difference in the interests of the inhabitants of the upper and of the lower valley. It is evident that there is in certain localities strong opposition to the Two Bridges Multiple-Purpose Reservoir Plan, in spite of the fact that the majority of interests contacted seem to prefer this plan for the welfare of the State as a whole.

222. The Multiple-Purpose Reservoir with Channel Improvement (Plan II) provides the best overall plan for the protection of the residents of the Passaic River from floods. Obviously, however, a project of this magnitude which would call for the expenditure of approximately $100,000,000, of which about $30,000,000 would be State, county or municipal funds, could not be adopted and carried to completion without the full support of all interests concerned. Rather than have such

a plan the subject of local debate for years before its authorization, or continue for years after its authorization before funds could be raised for construction, it would be preferable in the interest of progress in the protection of the principal damage centers from floods to proceed with Plan III. On the other hand, Plan III would call for the construction of flood walls and levees designed to pass a greater discharge (and hence of greater height) than those which would be necessary if a reservoir were constructed to moderate the flood discharges. This plan would require also that continuing attention be given to the Great Meadows area to assure that the natural valley storage now available be not encroached upon. For these reasons, this plan should not be initiated unless it becomes apparent that Plan II cannot become a reality.

223. In preceding paragraphs are presented the basic reasons why it is considered that the State's contribution to the cost of Plan II should consist in large part of the acquisition and conveyance to the United States, without reimbursement, of all lands, easements, and rights-of-way necessary for that project. It is realized that this procedure would be a departure from the normal one in the case of reservoir projects authorized by Congress and constructed by this Department, but in this instance it is believed that the circumstances are so unusual as to warrant the departure. There is reason to predict that if current economic conditions continue, and there is no restraint on the development and exploitation of real estate, the reservoir area might become so valuable that the project, if restudied and reevaluated at some later date, would show an unfavorable benefit-cost ratio, due solely to an increase in the cost of the reservoir. If the State's participation in the project is established so as to include the acquisition of real estate as described above, there is a real likelihood that in the interim

between approval of the project by the State, and authorization by the National Congress, the lands will remain dedicated, in substantial measure at least, to reservoir purposes.

224. With respect to flood protection along Weasel Brook, a local protection project appears justifiable from Monroe Street in Passaic upstream to Third Avenue in Clifton. The cost of such a project, based on current prices, is estimated to be $2,650,000 Federal, and $1,100,000 non-Federal. The plan would provide protection against a recurrence of the 1903 flood. It would include an enlarged and realigned concrete flume for a distance of about 1.6 miles, and necessary bridge alterations. The State of New Jersey and local interests appear to be in favor of this plan, but it is pointed out that the participation which must be expected of local interests would be a considerable one.

225. A flood control project along the Saddle River to protect the industrial and commercial sections of Lodi is justifiable. Flood protection at other localities along this stream either by a flood detention reservoir or channel improvement would not be warranted. The plan, which would provide complete protection against a recurrence of the 1903 flood, would involve a local protection project from a point above Passaic Street upstream to State Highway No. 6. The cost of the project based on current prices is estimated to be $1,235,000 Federal, and $240,000 non-Federal cost. The State of New Jersey and local interests support this plan, although the latter would prefer a more extensive project.

226. Along Molly Ann's Brook, a flood control project is justified in the residential, commercial and industrial section of Haledon between West Broadway and Church Street. The plan would provide for channel enlargement and straightening, levee construction and a concrete flume

for a total distance of slightly over one mile. The project would afford complete protection against a recurrence of the 1903 flood. The cost of the project based on current prices would be $1,450,000 Federal and $490,000 non-Federal. The State of New Jersey and local agencies favor this plan.

227. The most feasible plan for the elimination of the menace to the Picatinny Arsenal from failure of the Federally-owned Picatinny Lake and Lake Denmark water supply dams would involve their reconstruction. The project on the Lake Denmark Dam would include provision of a new spillway, and a concrete non-overflow section. Reconstruction of the Picatinny Lake Dam would call for a new enlarged concrete spillway and a new non-overflow earth section.

228. The cost of the project based on current prices is estimated to be $1,800,000, all of which would be Federal cost. The direct and indirect losses to Picatinny Arsenal in the event of failure of existing structures might aggregate in normal peace time over $5,000,000 and during a period of National emergency, this loss might be increased many times. The plan meets the desires of the New Jersey State Department of Conservation. Although the construction of this project might be carried out under a separate appropriation from other than flood control funds, it is included herewith as part of the comprehensive flood control plan of the Passaic River.

XXVII. CONCLUSIONS

229. The Passaic River watershed, with an area of 935 square miles, has been subjected to three disastrous floods within the past half century. The lower reaches of the river are highly developed, and industrially are of paramount importance to the State of New Jersey, and to the eastern portion of the United States. No Federal flood control

project is authorized anywhere throughout the length of the river. The average annual damages are estimated to be about $2,700,000 and under future conditions of developments, it is believed that these damages will average nearly $4,000,000 annually. A repetition of the 1903 flood would cause damages approximating $50,000,000.

230. A local protection project consisting of channel enlargement, flood walls, levees, and pumping plants for the protection of the highly industrialized cities of Passaic and Paterson and their immediate surroundings is justifiable. Although not comprehensive in scope, and lacking the factor of safety for the passage of flood discharges in excess of the 1903 flood, which is the maximum of record, such a project would none-the-less protect Passaic and Paterson against discharges experienced during that flood, provided the natural valley storage now available in the Great Meadows area is preserved.

231. A comprehensive solution to the flood problem on the main stream, however, will involve the construction of a dam and reservoir in the vicinity of Two Bridges at the outlet of the natural flood storage area which is presently available there, together with channel improvement and local protective works downstream. The reservoir should be multiple-purpose in scope, since a flood detention reservoir only would not be economically justified. Such a project, which would provide, among other things both water supply and flood control, is justified.

The project would have collateral benefits including power, pollution abatement, and navigation. Minor benefits are anticipated from recreation and wild life interests, and from the elimination of mosquito breeding areas.

232. The overall development of the Passaic Valley will best be served by the adoption and prosecution of the multiple-purpose reservoir and related works (Plan II) described in preceding sections, but in respect thereto all interests should bear in mind the urgent need for flood control measures primarily to protect Paterson and Passaic and the remarks made in paragraph 222 above.

233. For the minor tributaries downstream from Two Bridges, local protection projects are found feasible at Weasel Brook, Saddle River and Molly Ann's Brook consisting of channel enlargements, concrete flumes and levee and wall construction. In addition, the reconstruction of the Federal dams at Picatinny Lake and Lake Denmark are warranted in order to remove a serious hazard to the Picatinny Arsenal. Any of these projects on the minor tributaries can be separately authorized and separately constructed, and each would provide its full estimated benefits irrespective of whether or not the main flood control works on the Passaic River are constructed.

XXVIII. RECOMMENDATIONS

234. The District Engineer recommends the construction of the following projects for flood control and other purposes within the Passaic River watershed, New Jersey:

a. A multiple-purpose reservoir on the Passaic and Pompton Rivers in the vicinity of Two Bridges, New Jersey, together with channel improvements substantially as described herein and as shown on the attached drawings, subject to such modifications as in the discretion of the Secretary of the Army and the Chief of Engineers may be advisable, at an estimated cost to the United States of $67,700,000 for construction and $105,500 annually for maintenance and operation, subject to the conditions that the State of New Jersey shall:

(1) Acquire fee-simple title to lands comprising the dam site and reservoir areas, together with any rights-of-way which may be necessary for the multiple-purpose reservor, including the Pompton Dike and other dike sections, at an estimated cost of $16,800,000, and convey without consideration to the United States, such right, title and interest as the Secretary of the Army may determine to be necessary to the purposes of the project, the acquisition and conveyance to be in such order and at such times as is determined by the Chief of Engineers.

(2) Contribute to the cost of the project, the sum of $9,500,000 in cash, at such times and in such amounts as are determined by the Chief of Engineers, subject to the provision that work in kind may be performed in lieu of cash, upon approval of the Chief of Engineers.

(3) Provide all lands, easements and rights-of-way necessary for channel improvement of the Passaic River below the Two Bridges Dam, including the alteration of bridges and provision for utilities, all at an estimated cost of $2,300,000.

(4) Hold and save the United States free from damages due to the construction and operation of the channel improvement works.

(5) Maintain and operate all channels and channel improvement works from Two Bridges downstream to the upper end of the navigation channel at the Eighth Street Bridge, Passaic; together with the operation and maintenance of such other features of the multiple-purpose project as contemplated herein, all in accordance with regulations prescribed by the Secretary of the Army.

(6) Assure by the enactment of appropriate legislation that the construction of bridges or other works and encroachments which might adversely affect the flood capacity of the Passaic River channel below the Two Bridges dam site will not be permitted.

b. Local protection works on Weasel Brook in Passaic and Clifton, New Jersey, as described herein and as shown on the attached drawings, subject to such modifications as in the discretion of the Secretary of the Army and the Chief of Engineers may be advisable, at an estimated first cost to the United States of $2,650,000, subject to the conditions that local interests shall, at an estimated first cost of $1,100,000 and $12,000 annually for operation and maintenance, provide all lands, easements and rights-of-way necessary for the improvement and including the alteration of bridges and provision for utilities, hold and save the United States free from damages due to the construction and operation of the works, and maintain and operate the completed works in accordance with regulations prescribed by the Secretary of the Army.

c. Local protection works on Saddle River in Lodi, New Jersey, as described herein and as shown on the attached drawings, subject to such modifications as in the discretion of the Secretary of the Army and the Chief of Engineers may be advisable at an estimated first cost to the United States of $1,235,000, subject to the conditions that local interests shall, at an estimated first cost of $240,000 and $11,000 annually for operation and maintenance, provide all lands, easements and rights-of-way

necessary for the improvement and including the alteration of bridges and provision for utilities, hold and save the United States free from damages due to the construction and operation of the works, and maintain and operate the completed works in accordance with regulations prescribed by the Secretary of the Army.

d. Local protection works on Molly Ann's Brook in Haledon, New Jersey, as described herein and as shown on the attached drawings, subject to such modifications as in the discretion of the Secretary of the Army and the Chief of Engineers may be advisable at an estimated first cost to the United States of $1,450,000, subject to the conditions that local interests shall, at an estimated first cost of $490,000 and $12,000 annually for operation and maintenance, provide all lands, easements and rights-of-way necessary for the improvement and including the alteration of bridges and provision for utilities, hold and save the United States free from damages due to the construction and operation of such works, and maintain and operate the completed works in accordance with regulations prescribed by the Secretary of the Army.

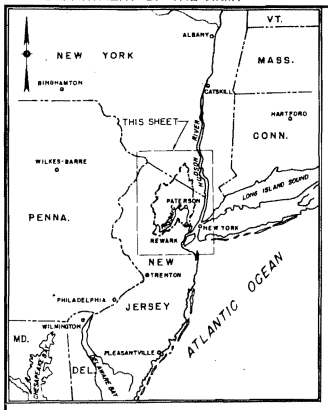
e. The reconstruction of the Federally-owned dams at Lake Denmark and Picatinny Lake at Picatinny Arsenal, New Jersey, as described herein and as shown on the attached drawings, subject to such modifications as in the discretion of the Secretary of the Army and the Chief of Engineers may be advisable, at an estimated first cost to the United States of $1,800,000; with maintenance by military authorities.

235. The total estimated cost of the works recommended above is $74,835,000 Federal, and $30,430,000 non-Federal; and the annual operation and maintenance costs are estimated to be $125,600 Federal, including $20,100 for operation and maintenance of Picatinny Arsenal dams by military authorities, and $146,500 non-Federal.

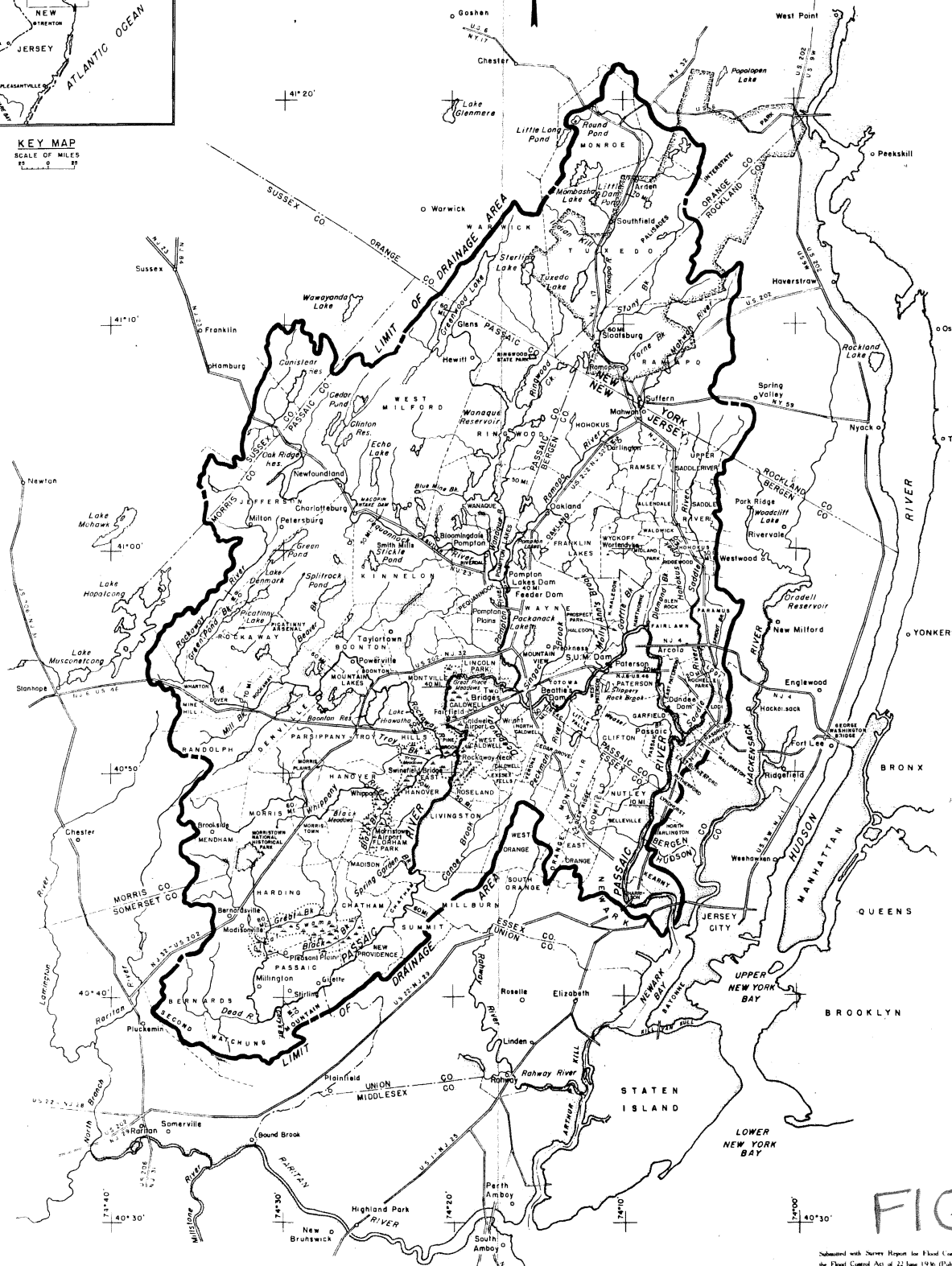
W. W. WANAMAKER
Colonel, Corps of Engineers
District Engineer

DEPARTMENT OF THE ARMY

CORPS OF ENGINEERS



KEY MAP
SCALE OF MILES



SCALE OF MILES
1" 0 5 10

FIG. 1

Submitted with Survey Report for Flood Control in compliance with Section 6 of the Flood Control Act of 22 June 1936 (Public Law No. 738, 74th Congress.)

PASSAIC RIVER, NEW JERSEY

INDEX MAP

SHEET 1 SCALES AS SHOWN IN 1 SHEET

DEPT OF THE ARMY, CORPS OF ENGINEERS, OFFICE OF THE DISTRICT ENGINEER
NEW YORK DISTRICT, NEW YORK, N.Y. MAY 1940

SUBMITTED	RECOMMENDED	APPROVED
CHIEF, DESIGN BRANCH	CHIEF, ENGINEERING DIVISION	DISTRICT ENGINEER

Designed	Drawn by	DRAWING NUMBER
	Checked by	CR-PCR-1

FIGURE 1